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Characteristics of noise complaints and the associations with urban morphology: A comparison across densities

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Abstract: This study aimed to characterise spatial-temporal distribution of noise complaints across urban areas with different densities and to analyse the associations between urban morphology and noise complaints. Taking New York City as the study area, crowdsourced noise complaints and urban morphology datasets from the city government's open data source were statistically analysed. The results suggest that between boroughs the characteristics of noise complaints are different, in terms of their spatial-temporal distribution, their relation to road transport network, land use, and building morphology. Noise complaints were clustered around the highest density area (Manhattan). The rate of noise complaints showed a year-on-year increase, peaking in autumn and spring. The rate of noise complaints is higher in areas with higher densities and roads that are 20-40m wide, closer to road crossings, and in enclosed blocks. The relationships between noise complaints and urban morphology are weaker in high-density boroughs than in other boroughs.

Keywords: noise complaints; urban density; urban morphology; noise pollution

1. Introduction

Exposure to noise is an increasingly common and serious problem globally because of rapid urbanisation. Noise complaints top the list of environment-related complaints and along with the influence of urban planning on the sound environment, have received increased research attention across a number of disciplines (Kang, 2006). Current estimates predict that two-thirds of the world's population will be living in urban areas by 2050 (United Nations, 2014), and urban density as a factor of urban planning is an important consideration from a psychological and sociological point of view (Hui, 2001). It has been shown that the environmental issues impact people differently at different levels of density; high-density, crowded, and stressful urban environments might negatively impact residents' health because of factors such as air pollution and noise problems (World Health Organization, 2019).

Numerous studies have been conducted on urban environment and urban morphology, with the comparison across densities. For instance, Naeher et al. (2000) found that PM2.5 and CO were significantly higher in high-density villages. Yuan et al. (2014) showed that low urban permeability in high-density areas could reverse air flow near the ground, allowing air pollutants to disperse into the windward area of the pollutant sources. Guo et al. (2016) presented a regression model for land surface temperature based on building height, where the model performance varies depending on whether the building density is above or below 0.16.

A number of studies have examined the associations between urban morphology and environmental noise issues in different density areas. Wang and Kang (2011) examined the relationships between noise level distribution and urban morphology based on two representative cities, suggesting that there are significant differences in spatial noise-level distribution between high and low-density cities. Zhou et al. (2016) investigated traffic noise distribution and street morphology in urban residential blocks. They found that the floor space index showed a significant positive correlation with the standard deviation of ground and building façade noise only in small low-rise blocks. Hupeng et al. (2017) analysed the relationships between urban street spatial parameters and sound propagation in the high-density city, demonstrating that when the cross-sectional enclosure degree and the plan enclosure degree increased, or vehicle lane width decreased, sound attenuations decreased. Hao and Kang (2014) studied the associations between urban morphology and the spatial noise level attenuation of flyover aircraft in low-density areas, finding it to be mainly correlated to the building frontal area index and the horizontal distance of the first-row building to the flight path.

In terms of noise perception, Meng et al. (2017) investigated acoustic perception based on crowd density characteristics in high-density urban open spaces. Hao et al. (2015)

examined the relationship between traffic noise resistance and urban morphology in low-density residential areas. Consideration has also been given to soundscape, defined as the acoustic environment perceived or experienced and/or understood by a person or people, in context (ISO, 2014). Hong and Jeon (2017) examined the effect of urban morphology on the spatiotemporal variability of soundscape in Seoul, Korea. They found that high-density commercial areas have lower sharpness values compared with low-density commercial areas. However, in terms of noise complaints which are strongly related to noise annoyance, indicative of the areas where residents are highly annoyed with noise, there is still a lack of research taking into account the associations with urban morphology. A direct comparison between areas of different densities in terms of noise complaints would be of great interest. Meanwhile, with the arrival of the big data era, such data from multiple sources has been applied on environmental research, such as air quality and the thermal environment (Cao et al.,2020; Zheng et al., 2019). Especially, nowadays the big data enable the large scale research on environment. However, little research has occurred on open multi-sourced big data to study the associations between urban morphology and sound environment.

Therefore, the aim of this study was to examine the distribution characteristics of noise complaints in different urban densities, and how they are influenced by urban morphology. New York City (NYC) was selected as the study area, as its five boroughs have a considerable range of density. A statistical analysis was performed on crowdsourced noise complaints and urban morphology datasets from the NYC government's open data source. More specifically, the research questions were: (1) What are the characteristics of spatial and temporal distribution of noise complaints in different urban densities? (2) What are the associations between noise complaints and urban morphology, including transport network, land use, and building morphology in different urban densities?

2. Methods

2.1. Case study area

With the aim of identifying characteristics of noise complaints and the associations with urban morphology across high- and low-density areas, NYC was selected for analysis, including five boroughs: Manhattan, Brooklyn, Bronx, Queens, and Staten Island (Figure 1). Manhattan is a highly developed borough with an extremely high population density of 27,560 people/km^2. The urban environment is also highly developed in terms of buildings and roads. Brooklyn and Bronx have a population density of 14,350 people/km^2 and 13,000 people/km^2, approximately half that of Manhattan. The population density in Queens is 8,140 people/km^2. Staten Island has the lowest density, with 3,130 people/km^2. Manhattan has a relatively high prevalence of office and commercial areas, and the proportion of residential areas is about 20% lower than in other boroughs (NYC planning, 2019a).

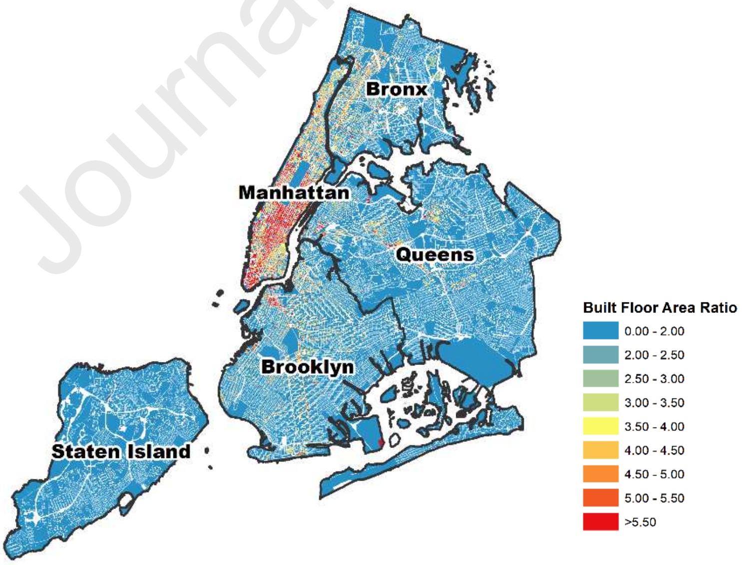

Figure 1. The distribution of built floor area ratios in New York City.

2.2. Crowdsourced noise complaints dataset

Noise complaint data can be understood as a crowdsourced dataset which is collected via a participatory method of building a dataset with the help of a large group of people. NYC

311 is NYC's governmental non-emergency service number. The 311 system records data on each report, including time, case type, and reporter's location. The service handles complaints related to noise, air pollution, health, public safety, and 15 other problem categories (NYC 311, 2019b; NYC 311, 2019c).

According to 311 data from 2010 to 2018, there were 2.92 million noise complaints in total. There were 10 types of noise complaints in the original dataset: "Collection Truck Noise", "Noise", "Noise – Commercial", "Noise – Helicopter", "Noise – House of Worship", "Noise – Park", "Noise – Residential", "Noise – Street/Sidewalk", "Noise – Vehicle", and "Noise Survey". The noise complaint types are classified based on where the noise comes from or is generated by. For instance, Noise-Residential refers to noise that comes from inside a residential building, such as TV shows. Noise-Streets/Sidewalk is noise coming from the street or sidewalk, such as loud talking. In this study, "Noise – unclassified" is used to refer to "Noise" above. "Noise Survey" was eliminated since there was no "Noise Survey" data in 2018.

Apart from year-changing analysis, noise complaints for the whole of 2018 were selected for this study (for year changing, 2010-2018 data was used). There were 436,692 complaints in 2018, of which 2,287 were eliminated due to missing information. Finally, 434,395 complaints were retained for analysis. Subsequently, these were imported into ArcGIS 10.3 for spatial analysis and visualisation, based on the longitude and latitude information of each noise complaint. In this study, noise complaint rate (the number of complaints per 1,000 people) was calculated for analysis.

2.3. Urban morphology dataset and indicators

There are considerable urban morphology indicators related to the sound environment (Margaritis and Kang, 2016; Gozalo, 2016; Souza & Giunta, 2011; Tong & Kang, 2020;

Zhou et al., 2016). Based on literature review and datasets from the Department of City Planning in NYC, urban morphology indicators were mainly categorised into three groups: road transport network, land use, and building morphology. In this study, transport network features were extracted from a LION geographic base file, which is maintained by the Department of City Planning. In this dataset, the single-line was used to represent the city's streets. The lines/streets contain geographic spatial information, which can be reflected on the NYC map, as well as the unique ID, width, and name (NYC Planning, 2019b). Land use and building morphology data were extracted from the Primary Land Use Tax Lot Output (PLUTO) data file, which contains extensive land use and geographic data (NYC Planning, 2019c).

In terms of the road transport network, there are two aspects considered in this study: the average distance between noise complaints and the nearest road crossing, and the road density (the length of road per spatial unit). To calculate these indicators, a fishnet was created in ArcGIS 10.3 by dividing the study area into smaller rectangular cells (namely, spatial analysis units), each with a unique code. A large cell size will hardly capture spatial variability or yield an adequate sample size, where a small cell size will result in too many noise complaints projected onto cells without any roads, and will increase the computational cost. Therefore, in this study, 500m×500m rectangular cells were selected as spatial analysis units by considering the space type, building density, road distribution pattern, road type, and land use (Guo et al., 2016; Wang & Jian, 2011).This method allowed us to calculate the transport network indicators in each cell, as well as land use and building morphology indicators. Meanwhile, noise complaint rate (the number of complaints per 1,000 people) was also calculated in each cell for further statistical analysis.

In term of land use, it included building floor area for each type of land use (including commercial, residential, office, retail, garage, storage, factory, park, and others), land value (including assessed land value and assessed total value), and residential units (including residential units and total units). These indicators were originally derived from PLUTO. Total units was the sum of residential units and non-residential units; assessed land value was calculated by multiplying the estimated full market land value, determined as if vacant and unimproved, by a uniform percentage for the property's tax class; and assessed total value was calculated by multiplying the estimated full market land value by a uniform percentage for the property's tax class (NYC planning, 2019c). Indicators such as residential area density were calculated using PLUTO. Building morphology included lot area, building area, number of building floors, frontage ratio (building frontage/block frontage), depth ratio (building depth/block depth), and floor area ratio. These indicators, originally from PLUTO, were also calculated by creating the fishnet as mentioned above.

2.4. Data analysis

In terms of the characteristics of spatial and temporal distribution of noise complaints, apart from the basic descriptive statistics, the inferential statistics including Chi-square test and Kruskal-Wallis test were also used. The Chi-square test is a non-parametric tool designed to analyse differences when the dependent variable is measured (McHugh, 2013). In this study, the Chi-square test is applied to identify the difference in noise complaints among boroughs and types. Kruskal-Wallis test assess for significant differences on a continuous dependent variable by a categorical independent variable (Kruskal & Wallis,1952; McKight & Najab, 2010). It was used to determine if there are statistically significant differences between different periods on noise complaints in this study.

To explore the associations with the urban morphology, including transport network, land use, and building morphology on noise complaints, Spearman's Rho were used. In this study, the rate of noise complaints was not normally distributed, according to the Shapiro-Wilk test (Ghasemi and Zahediasl, 2012; Yap and Sim, 2011). Therefore, Spearman's Rho, as a nonparametric test, was applied to measure the relationships between urban morphology and noise complaint rate, since it does not make any assumption about the distribution of the variables (Hauke & Kossowski, 2011). The process was conducted using the IBM Statistical Package for Social Sciences 26 (Landau & Everitt, 2003).

3. Results

3.1. Temporal and spatial distribution characteristics of noise complaints

3.1.1. Spatial distribution

The distribution of the locations of reported noise complaints is shown in Figure 2 and the rate of noise complaints by type is displayed in Table 1. Overall, the difference in noise complaint rate across boroughs was significant ($p<0.01$) via the Chi-square test. It is clear that the distribution of the various types of noise complaints is not even (Figure 2). Table 1 clearly shows that the highest noise complaint rate was observed in Manhattan; the value of noise complaint rate was 93.19 per thousand people. It can be explained by that the rate of top four noise complaint types, including residential, street/sidewalk, unclassified, and commercial noise complaints, were significantly higher than that in other boroughs. Then, in Brooklyn the noise complaint rate was 76.25. Subsequently, the noise complaint rate was similar in Bronx and Queen, with the value of 33.22 and 34.88, respectively. The lowest noise complaint rate was observed in Staten Island, at 24.08 per thousand people. Especially, residential, commercial, and park noise complaint rates were significantly lower than those in other boroughs. It can be inferred that higher noise complaint rate occurred in higher density areas. Also, the similar patterns were found in noise complaint rate for each type.

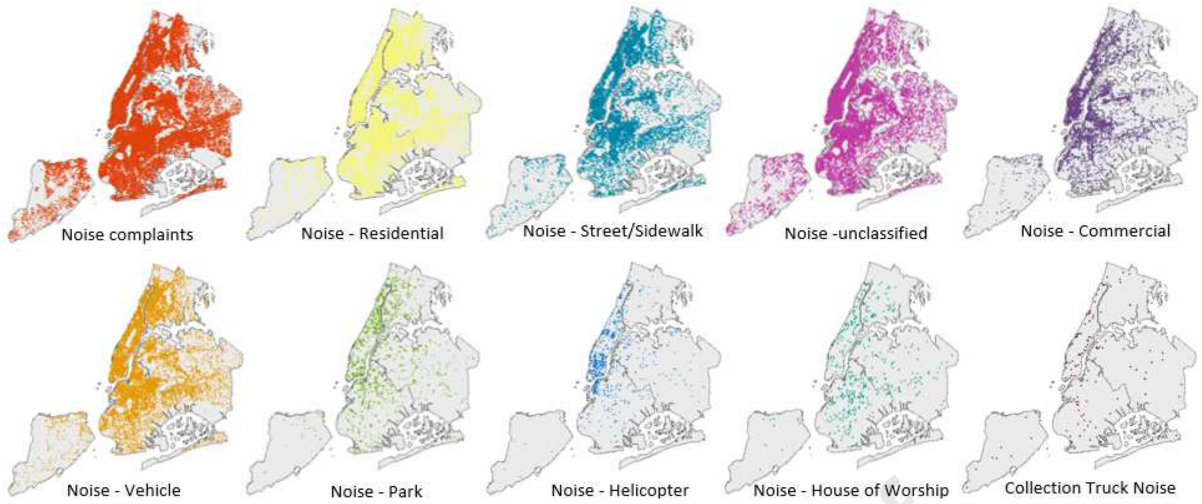

Figure 2. The distribution of noise complaints by type (each point represents a noise complaint).

Table 1. Noise Complaint Rate (the number of complaints per 1,000 people) by Type

	New York City overall	Manhattan	Brooklyn	Bronx	Queens	Staten Island
All type of noise complaints	51.72	93.19	76.25	33.22	34.88	24.08
Noise – Residential	25.81	33.43	38.14	21.66	19.16	15.05
Noise – Street/Sidewalk	8.78	20.68	12.70	6.12	2.94	1.87
Noise – Unclassified	7.09	19.46	9.71	1.21	4.88	3.46
Noise – Commercial	5.31	11.99	9.11	1.59	3.39	1.67
Noise – Vehicle	4.01	6.35	5.22	2.31	4.05	1.87
Noise – Park	0.49	0.79	0.97	0.27	0.30	0.10
Noise – Helicopter	0.12	0.39	0.16	0.02	0.07	0.02
Noise – House of worship	0.09	0.08	0.22	0.04	0.07	0.03
Collection Truck Noise	0.02	0.03	0.02	0.00	0.01	0.02

The proportion of noise complaint by type, in terms of complaint rate, is displayed in Table 2. In overall NYC, the noise complaints with higher percentages were residential (49.90%), unclassified (13.72%), commercial (10.27%), street/sidewalk (16.97%), and vehicle noise (7.75%). The remainder of noise complaints represent less than 2% of the total. Overall, there was a significant difference in noise complaint type composition between boroughs via Chi-square test. In Manhattan, the proportion of street/sidewalk, unclassified, commercial, and helicopter noise, was higher than in other boroughs. Vehicle, house of worship, and residential noise complaints in Manhattan had lower values. The highest proportion of vehicle noise complaints was observed in Queens, with a value of 11.61% which was significantly higher than other boroughs. Meanwhile, the highest percentage of residential noise complaints was seen in Bronx, at 65.20%, which was significantly higher than that in Manhattan (approximately twice the value for Manhattan). Bronx has the smallest number of commercial and helicopter noise complaint rate. The highest proportion of noise complaint rate about houses of worship and parks occurred in Brooklyn. Staten Island had three extreme values: highest collection truck noise complaints at 0.09%, lowest park noise complaints at 0.41%, and lowest street/sidewalk noise complaints at 7.75%.

Table 2. Proportions of Noise Complaint Rate by Type (highest proportion for each type of noise complaint is highlighted in orange, the lowest in blue.)

	New York City overall	Manhattan	Brooklyn	Bronx	Queens	Staten Island
Noise – Residential (%)	49.9	35.87	50.02	65.20	54.94	62.49
Noise – Street/Sidewalk (%)	16.97	22.19	16.66	18.43	8.43	7.75
Noise – Unclassified (%)	13.72	20.88	12.74	3.64	13.99	14.38
Noise – Commercial (%)	10.27	12.86	11.94	4.78	9.72	6.91
Noise – Vehicle (%)	7.75	6.81	6.84	6.96	11.61	7.76
Noise – Park (%)	0.95	0.84	1.27	0.81	0.87	0.41
Noise – Helicopter (%)	0.24	0.42	0.21	0.05	0.19	0.10
Noise – House of worship (%)	0.17	0.08	0.29	0.11	0.21	0.11
Collection Truck Noise (%)	0.03	0.04	0.03	0.01	0.04	0.09
Total (%)	100	100	100	100	100	100

Overall, in the high-density borough of Manhattan, there were four types of highest noise complaints and three types of lowest noise complaints. In other boroughs, the proportions of most types of noise complaints were around the average level. It is remarkable that in Manhattan, with the highest population and building density, residential noise complaints accounted for the highest percentage of complaints among all types, although it was at least 15% lower than in any other borough. This could be the result of the difference in land use: Manhattan has the lower proportion of residential areas. Another notable result is that the proportion of street/sidewalk noise complaints in Manhattan (22.19%) was three times higher than that of Staten Island (7.75%). It is possible that, in a typical high-population and high-building density area like Manhattan, pedestrian traffic would be more crowded than in Staten Island, a sparsely populated area. It means that residents in Manhattan would perceive more noise than Staten Island's residents.

3.1.2. Temporal distribution

The rate of noise complaints increased from 2010 to 2018 (Figure 3). Correspondingly, the rate of noise complaint increased approximately 2.10 times from 24.66 per thousand people to 51.72 per thousand people. The tendency of noise complaints by season within every year was similar. For noise complaint types, the tendency was more dramatic for streets/sidewalks, followed by vehicle, unclassified, park, and commercial noise complaints, while it was relatively less dramatic for residential noise complaints.

In terms of park and street noise complaints, in all boroughs, the lowest noise complaint rate was always in winter, while in the other three seasons the rate of noise complaints were significantly higher, with the quantity in summer being slightly lower. The tendency of vehicle noise complaint rate was similar to that of park and street noise complaints, while the difference between seasons was less obvious. Unclassified and commercial noise complaints had two significant peaks, autumn and spring, whereas the rate of unclassified and commercial noise complaints was lowest in winter and summer, in all five boroughs.

Two factors could contribute to the difference between seasons. The first plausible reason is the temperature, causing fewer outdoor activities, such as walking in the street and attending outdoor retail markets. This could partly explain the change in park, street, unclassified, and commercial noise complaints, as these obviously change with the seasons. The second possible explanation is open windows during summer. Residents are likely to close their windows when it is cold outside, consequently reducing the noise, which could partly explain the change in vehicle noise complaints.

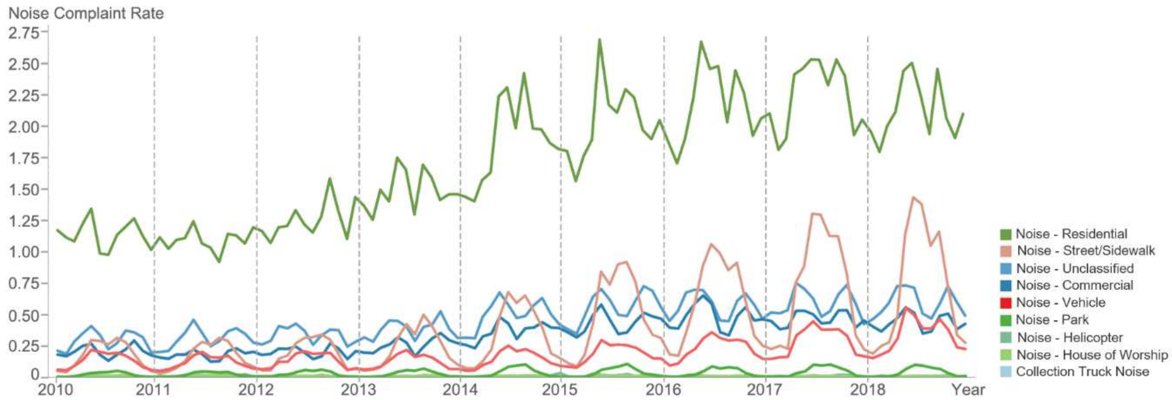

Figure 3. Changes in the rate of noise complaints by type from 2010 to 2018.

With respect to weekly changes, the highest rate of noise complaints was found during weekends, with the values of 11.55 for Saturday, and 10.88 for Sunday. From Sunday to Monday, the noise complaint rate decreased to 5.80 by 47%. Among weekdays, the noise complaint rate was higher on Friday at a value of 6.90, followed by Monday. This tendency was the same for every borough.

From hourly changes perspective, in all five boroughs, the highest rate of noise complaints appeared at 23:00 with a value of 4.88, followed by 22:00 with a value of 4.49. WHO (2018) provides recommendations for noise levels for protecting human health from exposure to environmental noise originating from various sources. Hence, the different types of noise complaints were further discussed. During the daytime, the noise complaint rates per hour for residential, commercial, street/sidewalk, and vehicle noise complaints were 0.72, 0.12, 0.24, and 0.15, respectively, compared with the value of 1.78, 0.41, 0.61, 0.21 during the night. It can be seen that all these noise complaint types increased, perhaps due to the impacts of noise on sleep disturbance, which suggest that the differences in noise complaints among different time periods were not mainly caused by the differences in noise types.. Significant difference was found between different hours in noise complaints via Kruskal-Wallis Test with $p<0.01$. All types of noise complaints (except unclassified noise complaints) started to plummet from around 8:00 with a value of 1.23 (approximately half the value for

7:00), except for Manhattan, where the decrease was more gradual. A second small peak of complaints appeared in the afternoon at 15:00 with a value of 1.78. Among the five boroughs, the trend of complaint rate about vehicles was similar to most types of noise complaints; however, in Queens, vehicle complaints increased from 9.00.

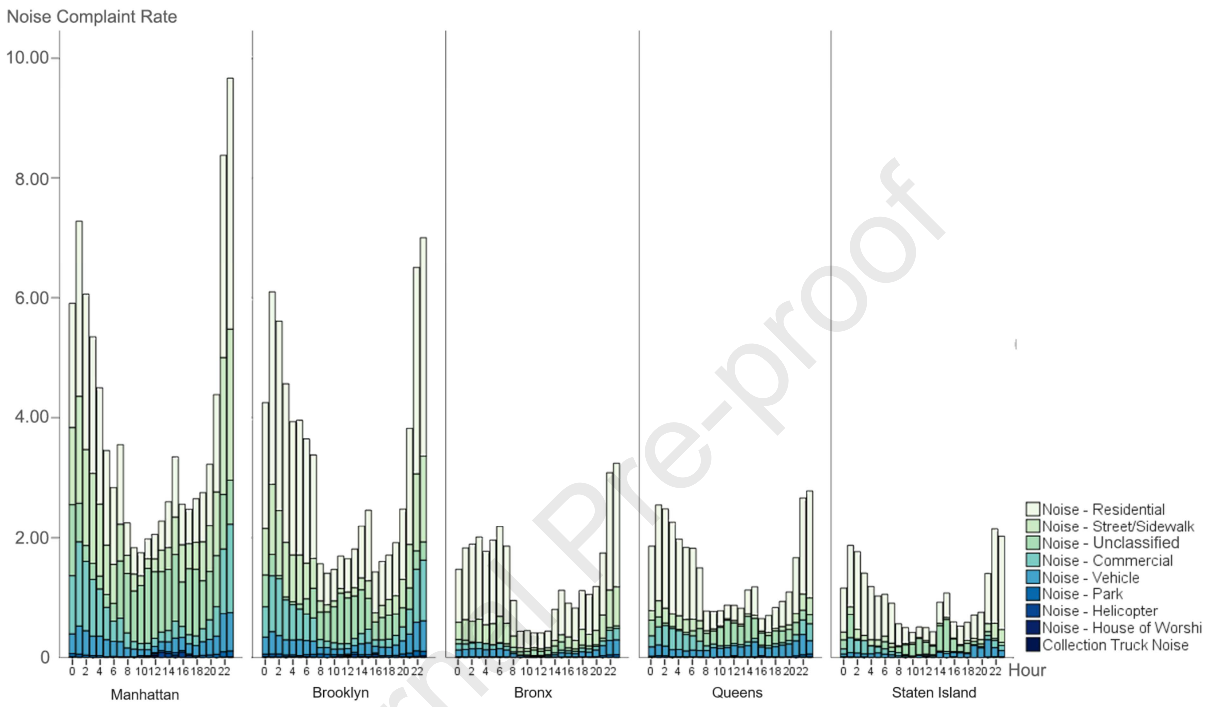

Figure 4. Changes in the rate of noise complaints by hours of the day.

3.2. The associations with urban morphology

3.2.1. Transport network

Table 3 shows the relationships between noise complaint rate and transport network by borough. It can be seen that in Brooklyn, Bronx, and Queens, distance to the nearest road crossing was significantly negatively related to the rate of noise complaints. No significant relationship is found in Manhattan and Staten Island. This finding is in line with the research of Gozalo et.al. (2016), who found that the number of crossings was positively related to noise level. This could be due to traffic volumes: closer proximity to road crossings means experiencing the effects of more than one road.

For noise complaint rates, all boroughs except Manhattan, were positively related to road density, as shown in Table 3. Specifically, in Manhattan, noise complaint rate was negatively related to only 0-20m-wide road density with the magnitudes being -0.152. In Brooklyn, among all widths of road, only 20-40m road density was positively related to the rate of noise complaints, with a coefficient value of 0.413. Noise complaint rate was negatively related to other classifications of road, with lower values around -0.1. In Bronx, noise complaints had negative relationships with 0-20m width, and positive relationships with 20-40m, 40-60m, and 60-80m roads. In Queens, there were positive relationships in 20-40m, 40-60m, and 60-80m road densities, whereas no significant correlation was found in 0-20m and greater than 80m road widths. In Staten Island, a negative relationship also appears for 0-20m road density and positive relationships in 20-40m and 40-60m road densities.

Generally, noise complaints occurred in areas with a high density of 20-60m roads, especially in areas with 20-40m roads, which had higher coefficient values. Generally speaking, this finding is broadly consistent with that of Margaritis and Kang (2016), who found that primary road length has an impact on noise levels. Across all five boroughs, the least significant relationships were found in Manhattan, where even the significant relationships were weaker than in other boroughs. The results could be explained by the fact that the high and dense buildings in Manhattan limit the effect strength of road density, hence the correlation coefficient is near zero.

Table 3. Correlation Coefficients Between Noise Complaint Rate and Transport Network

	New York City overall	Manhattan	Brooklyn	Bronx	Queens	Staten Island
Distance to road crossing	.073**	-.006	-.179**	-.109*	-.109**	-.061
Total road density	370**	.015	.203**	.352**	.192**	.465**
0-20m road density	-.118**	-.152**	-.139**	-.133**	-.001	-.144**
20-40m road density	.345**	.121	.413**	.317**	.212**	.509**
40-60m road density	.289**	.035	-.099*	.271**	.114**	.257**
60-80m road density	.167**	-.080	-.154**	.283**	.064*	-.004
>80m road density	-.062**	-.030	-.179**	-.045	-.016	-.016

* Correlation is significant at the 0.05 level.

** Correlation is significant at the 0.01 level (Following notes are same).

3.2.2. Land use

Table 4 shows the relationships between noise complaints and land use, including land function, residential unit, and land value. In terms of land function, the rate of noise complaints in NYC overall was positively related to all functions of land, except for parks. Among these functions, the relationship between residential floor area and noise complaint rate was higher than for other functions of land, followed by retail floor area. However, in Manhattan, noise complaints were only related to residential, retail, and storage floor area at 0.01 significance level, with lower coefficient values than in other boroughs. For park, the significant negative relationship is only observed in Staten Island. To some extent, this result is in line with studies that found that the impact of sound and visual interaction on perception, e.g. greenery, could reduce noise annoyance (Echevarria Sanchez et al., 2017; Van Renterghem et al., 2015). However, the negative association is only found in the Staten Island, lowest density area in NYC.

Regarding assessed land value and assessed total value, significant positive relationships between these and noise complaint rate were found in NYC overall, Brooklyn, Bronx, Queens, and Staten Island. However, in Manhattan, no significant relationship was found between the rate of noise complaints and assessed land value.

In terms of residential units, noise complaint rate had a positive relationship with residential units and total units, with coefficient values of 0. 619 and 0.631 in NYC overall. These relatively strong relationships also appeared at borough level, except for Manhattan, where the relationship was not significant. The difference could be explained by the fact that, because of the high building density in Manhattan, with the addition of each residential unit, the increase of noise complaints would be limited.

Table 4. Correlation Coefficients Between Noise Complaint Rate and Land Use

	New York City overall	Manhattan	Brooklyn	Bronx	Queens	Staten Island
Commercial floor area	.481**	.085	.398**	.351**	.288**	.278**
Residential floor area	588**	-.174*	.457**	.534**	.448**	.621**
Office floor area	.456**	.134*	.268**	.421**	.314**	.311**
Retail floor area	.537**	.225**	.392**	.470**	.426**	.430**
Garage floor area	.412**	-.068	.297**	.298**	.224**	.213**
Storage floor area	.386**	.233**	.295**	.290**	.316**	.201**
Factory floor area	.268**	.132	.249**	.193**	.250**	.129**
Other floor area	.456**	.134*	.268**	.421**	.314**	.311**
Park area	.010	-.130	.059	-.039	-.015	-.136**
Assessed land value	.347**	-.109	.265**	.352**	.105**	.124**
Assessed total value	.520**	-.059	.440**	.458**	.252**	.366**
Residential units	.619**	-.086	.506**	.560**	.498**	.660**
Total units	.631**	-.025	.519**	.564**	.509**	.674**

3.2.3. Building morphology

The relationships between noise complaints and building morphology are shown in Table 5. In terms of lot area and building area, in NYC overall, as well as Bronx**,** Queens, and Staten Island, negative relationships were found between noise complaint rate and lot area, while there was a positive relationship with building area, with higher values around 0.5. The results indicate that the lower the built area/lot area ratio, the lower the noise complaint rate. This is partly because a lower ratio of built area indicates there is a garden or yard in the lot, which could impact residents' perception and noise absorption (Echevarria Sanchez et al., 2017; Liu & Kang, 2018). In Manhattan, no significant relationship was observed for lot area or building area; in Brooklyn the relationship was significant only for building area. Noise complaint rate had positive relationships with the number of building floors in NYC overall, and in every borough except for Manhattan. This means that, as the number of floors increases, the rate of noise complaints are likely to increase.

In terms of front ratio and depth ratio, the front ratio is equal to the building's frontage (along the street) divided by the lot frontage, while depth ratio is equal to the building's depth (which is the effective perpendicular distance) divided by lot depth. The rate of noise complaints was positively related to front ratio and depth ratio in each borough. However, in Manhattan, the significant level was only at 0.05 which was lower than in others.

The associations between front ratio and depth ratio and noise complaint rate could probably be explained by the fact that traffic noise is one of dominant noise sources on daily life and attracts more attention. People in street-facing buildings are exposed to more traffic noise and can probably see more vehicles, which increases the possibility that they will report noise issues (Van Renterghem et al., 2015).

The last indicator was floor area ratio, which is a typical measure of area density. It was positively related to the rate of noise complaints in NYC overall and in all boroughs, except for Manhattan.

Overall, the more enclosed and denser the blocks are, the higher noise complaint rate are likely to be . The relationships between building morphology and noise complaints vary from different density areas; they were weaker in Manhattan than in other boroughs. To some extent, the results confirm Wang and Kang's research (2011), which also showed different relationships between building coverage and noise level in different density cities, where the relationship was significantly negative in high density areas while the correlation tended to be positive in low density area.

Table 5. Correlation Coefficients Between Noise Complaint Rate and Building Morphology

	New York City overall	Manhattan	Brooklyn	Bronx	Queens	Staten Island
Lot area	-.221**	-.091	-.003	-.189**	-.090**	-.184**
Building area	.608**	-.009	.500**	.532**	.457**	.623**
Number of floors in building	.613**	-.106	.494**	.593**	.481**	.614**
Frontage ratio	.507**	.149*	.321**	.498**	.383**	.509**
Depth ratio	.554**	.167*	.300**	.600**	.408**	.403**
Floor area ratio	.605**	.007	.486**	.527**	.459**	.606**

4. Discussions

This study used multi-sourced big data rather than questionnaire or interview which are widely applied in sound environment research. The usage of such spatial data enables us to analyse urban built environment issues at a larger scale, longer term and broader spatial coverage. In the field of urban sound environment, previous research has mainly focused on the noise level. Recently, noise perception has received more attention. By considering the perception of sound, the influence of urban sound environment on human well-being could be studied better. However, the study of noise perception is insufficient in the urban scale due to limited sample size. Hence, spatial-temporal multi-sourced big data, GIS technique, and statistical method were utilized and combined in this study which filled the gap. The present results are broadly significant in environment issues. First, from the noise pollution perspective, noise is a primary contributor to certain risk factors related to physical and mental health, such as loss of hearing, sleep disorder, and stress (Schreckenberg, Griefahn, & Meis, 2010). Noise complaints can give a useful indication for the area where residents who are highly annoyed by environmental noise. This study depicted characteristics of the spatial and temporal distribution of noise complaints and clarified its relation to urban morphology parameters. These results could be helpful for reducing environmental noise pollution by urban planning. For instance, policymakers could set up the noise level criteria during different time periods in twenty-four hours or different seasons in a year. Planners could focus on layout on 0-60 metres roads where noise complaints occur more. Second, with urban sprawl, divisive urban issue of density has a critical importance for sustainability (Newman, 2014). This study analysed the difference of noise complaints in various urban densities. Due to the environment pollution and conflicting interests, it would be important for policymakers to make the policy efficient and effective considering various urban densities. While in literature it is shown greenery could reduce noise annoyance (Echevarria Sanchez et al., 2017), based on the results from this study, an increase on park density did not have a significant effect on decreasing noise complaints in high density areas, while in a low-density area, reducing noise pollution would benefit more from using and protecting parks. Third, neighbour complaints appear to be a growing phenomenon and are a key feature of contemporary urban living. They have significant effects on the quality of life for residents, as well as on the level of health and neighbourhood cohesion (Ellaway, Macintyre, & Kearns, 2001; Mouratidis, 2019). Noise complaints, as a type of neighbourhood complaints, are more serious in high-density areas. In addressing urban conflicts, high density cities should therefore be emphasised.

Overall, these findings could be used to identify areas that have more serious noise complaint issues and to identify factors that should receive more attention when addressing such issues in areas of varying density. It is expected that this research can, to some extent, inform urban planners and policymakers from the perspective of acoustic impacts, leading to more effective noise-management strategies and planning progress across areas of various densities. The results of this study can therefore be useful for reducing the negative impact of environmental noise and improve the quality of life.

Future studies on the current topic are recommended. First, while this study considered only the transport network, land use, and building morphology, future studies could involve more socio-economic indicators such as social class or the willingness of residents to use the platform, since the relationships between noise complaints and socio-economic spatial inequalities are significant (Xie & Kang, 2010). From this perspective, it would also be useful to consider other cities where the socio-economic conditions are different. Second, although the characteristics of spatial and temporal distribution of noise complaints and their relations to urban morphologies have been identified, the causality and motivation for complaints remains undiscussed. With more data on complainants' characteristics, such as occupation, qualification, and other demographic factors, the causality and motivation for complaints could be better understood from psychology and social behaviour perspective. Third, this study primarily focuses on noise complaints; to develop an integrated understanding of environmental complaints, research on other types of complaints is needed, such as air pollution, wastewater, and odour.

5. Conclusions

Using NYC boroughs with different urban densities as case study sites, this study examined the characteristics of noise complaints and examined the relationships between noise complaints and urban morphology. This research indicates that urban-planning parameters could be applied to achieve better sound environments. Such study could be useful to develop more effective noise-management strategies. The findings are as follows:

(1) In NYC, the noise complaints are not evenly distributed spatially across the whole city; rather, they are clustered around the highest density area (i.e. Manhattan). The rate of noise complaints increases every year, with an annual peak in autumn and another in spring.

(2) Noise complaint rate is generally negatively related to the distance to the nearest road crossing. Meanwhile, it is higher in areas with a high density of 20-40 metres roads.

(3) Noise complaint rate is positively related to all types of land use, except for parks. In terms of parks, the significant relationship between noise complaints and the proximity of a park is only observed in Staten Island.

(4) The more enclosed and denser blocks are, the higher the noise complaint rate is. The relationships between noise complaints and building morphology are weaker in high-density boroughs than in other boroughs.

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Highlights

- Noise complaints are unevenly distributed and clustered around high-density areas
- Patterns of noise complaint rate seasonally and weekly are revealed
- Noise complaint rate is higher in areas with a high density of 20-40 metres roads
- The more enclosed and denser blocks are, the higher the noise complaint rate is
- Urban morphology influences noise complaint rate less in high-density areas

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: