A STUDY OF DOSE-RESPONSE RELATIONSHIPS FOR DIFFERENT URBAN SITE TYPOLOGIES

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ABSTRACT

The paper intends to analyse the different attitudes of the residents in the urban areas towards the annoyance induced by traffic noise, taking into account the effects of the street configuration and of the presence of specific public transport modes on the definition of the dose-response curve.

The annoyance was investigated through a campaign of noise and traffic measurements and an epidemiological survey to understand the people annoyance, administered via web and e-mail to a sample of 830 people, residents in the buildings close to the measurement points.

The analysis of the dose response relationship shows that the correlation between annoyance and noise is low. At the same value of day equivalent level, people living in the L sections (large streets) are more annoyed than people living in U sections (narrow streets) of about 4 dB(A) with 10% of more people annoyed.

The use of on ordinal regression model and the calculation of the cumulative probabilities allowed to define two cut points on the dose-response curves (60 and 75 dB(A)) thus dividing the people people in three categories and making the representation of the dose-response relationships different from that defined by Miedema.

The results show different people attitudes when they express their annoyance in the urban sites, highlighting that the noise levels are useful, but not enough to define the discomfort of the residents, while the site characteristics could shed light on the annoyance's variance.

Keywords: Noise, Annoyance, Dose-response, Transport Impact, Indicators, Sustainability

INTRODUCTION

Noise pollution from transport activities is an endemic problem in modern societies. For this reason, several projects (SILENCE, Qcity, Harmonoise) have been conducted to define mitigation techniques and a common European approach to reduce the noise emitted in the residential areas (*1*,*2*).

Studying noise emissions is important from different points of view because noise affects the quality of the environment, the residential satisfaction (*3*) and the people wellbeing and health (*4,5*).

In fact, noise induces social and behavioural effects, notably annoyance and sleep disturbance. From a medical point of view, the effects of noise on human health are also well known: hearing impairment, speech intelligibility, physiological dis-functions, mental illness, performance reduction, cardiovascular diseases (*6,7,8,9,10,11*). Many of these effects are assumed to result from the interaction of a number of auditory and non-auditory variables.

The need to safeguard the quality of life and the health of the population calls for more efforts for transport noise abatement as regards to the increasing demand of mobility. To reconcile these conflicting needs, the EU 6th Action Programme “Environment 2010: Our Future, Our Choice” stipulated that the number of people regularly effected by long-term high levels of noise, estimated as 100 million people in the year 2000, should reduce by around 10% by 2010 and by 20% by 2020. The difficulty to attain those targets is that 80% of people live in the urban areas, where transport infrastructures represent the most important source of noise. In fact, today 115 million people are exposed to noise levels L_{den} higher than 55 dB(A), and, at night time, 80 million people are exposed to L_{night} higher than 50 dB(A) (*12*). All over the world, a total of 2 billion citizens are subject to road traffic L_{den} of over 55 dB (*13*).

Thence, lawmakers are increasingly requiring the use of reliable and homogeneous instruments for monitoring and evaluating transport noise emissions. In some cases, the national norms establish rules to preserve the sound quality of specific areas (e.g. parks, hospitals, schools, etc.) and to reduce people noise exposure, recommending the adoption of noise indicators and setting thresholds to comply with.

To this extent, in the literature different noise indicators are proposed (*14,15*) according to the type of transport system and to the purpose of the evaluation.

In Europe, the need to define guidelines to set common noise legislation led to the Environmental Noise Directive 2002/49/EC, also known as the “END” (*16*). This Directive urges the monitoring of the main European cities and the biggest transport infrastructures, assessing the number of people exposed and mapping sound levels, using L_{den} and L_{night} and asks to the member states to define dose-response relationships.

This task is quite challenging because the relationship between annoyance and noise exposure does not depends only on the sources but also on the environmental context in which people live. Furthermore, the effect on annoyance of the different transport modes is dissimilar and suggests the definition of different dose-response relationships (*17,18,19*). While the evaluation of the noise impact by single transport mode is well established, more difficult is the evaluation of the annoyance when there are current of noise emissions coming from different sources (*20,21,22,23,24,25*).

However, to better explain the annoyance, some researchers suggest to take into account other characteristics of noise such, as the noise events (*26,27,*26) or the awaking percentage and rattle (*28*).

Some variables which influenced noise and annoyance are physical, in general easy to measure, while others are psycho-physical, more subjective, depending on the context and the characteristics of the residents, and they are not easy to interpret (*29,30*).

For example, in urban areas, noise is influenced by pavement typologies and traffic typologies, (*31*), street dimension (*32,33*), urban shape (*34*), the presence of public transport (*35*). Some studies showed that the access to a quiet area or a green area could decrease the annoyance on the residents (*36,37,38,39*). Moreover, the same noise source could have a different impacts in terms of annoyance, depending also on the area: an urban or rural area (*40*) togheter with to a high noise sensitivity are mainly associated to high noise annoyance (*41,30,42*).

The dose-response curves are based on average values and do not take into account the effect of the different territorial contexts on annoyance.

The paper analizes the different attitudes of the residents in the urban areas towards the annoyance induced by traffic noise, taking into account the effect of the street configuration and of the presence of specific public transport modes both on the noise propagation and on the definition of the dose-response curve.

The next sections explain the methodology for the survey and the data analysis design. The results are then described and conclusions are finally presented.

METHODOLOGY: THE SURVEY AND DATA ANALYSIS DESIGN

The paper aims at analysing the annoyance induced by the transport infrastructures on the residents in urban areas using a holistic approach. Physical and psycho-physical issues were considered together when choosing the measurements locations in order to obtain a database well suited to understand the cause-effect relationship.

The urban environment was characterized a selection of variables that are easily measurable in a city: notably the number of road lanes – used like a proxy for traffic volumes (*32*) – the site configuration and the presence of tramlines. The variables were combined with the Design of Experiment (DOE) (*43*) to better understand the influence of the variables on noise. The DOE allowed to set up an experimentation plan identifying a set of locations – the standard sites – where to carry out the noise measurements (*44,45*) and the epidemiological surveys in the city of Torino (nort-west of Italy).

The campaign of measurements has been made using the integrating phonometer Larson Davis 824 and the 01dB Symphonie system. Both the instruments comply with the Italian technical specifications (*46*) and the European Directive (*16*). Noise data are collected using "Fast" constant sampling, measuring L_{eq}, L_{min}, L_{max}, statistical levels L_{xx} and the spectrum in third octave bands. At the same time the traffic measurements were carried out, recording the number and typologies of vehicles as well as their speed using the traffic counter HI-STAR NC-97 and a video-camera. Beside the in situ measurements, a questionnaire for to the people living in the defined standard sites was designed to understand theirannoyance but also what are all the important data for the description of the respondents' profile. The questionnaire, administered via web and e-mail, covered the following points:

- the socio-economic characteristics of the respondents: age, gender, occupation, income, etc.;
- the characteristics of the dwelling;
- the floor at which the flat is located, the number of rooms, the typology of the windows, the layout of the different rooms specifying, for each room, whether they have a view on the street;
- the perception of annoyance;
- the attitude and sensitivity to noise;
- the information about health conditions.

The questionnaire was designed according to our previous experience in similar studies (*47,48*) and to the indications of the literature *(17, 49*). We decided to evaluate the annoyance during specific time slots to find out potential changes along the day; the respondents had to express the annoyance using a a seven and five points Likert scale (*50*) considering both the annoyance related to the whole day (street score) and that in the following time slots:

- night: from midnight to 06.00;
- day: from 06.00 to 08.00;
  from 08.00 to 09.00;
  from 09.00 to 13.00;
  from 13.00 to 17.00;
  from 17.00 to 18.00;
  from 18.00 to 19.00;
- evening: from 19.00 to 22.00;
- night: from 22.00 to 24.00.

The measurements and the surveys were carried out in four different waves carrying out the noise and traffic measurements and administering the survey to a sample of 830 people, residents in the buildings close to the measurement points.

The data analysis design

The data recorded at the standard sites were:

- qualitative: they come from the questionnaire and are classified in:
  - categorical data, as gender, occupation, etc., and dichotomous variables (“yes-no” answers);
  - ordinal data: level of education, level of annoyance and, in general, all the data that can be ordered;
- quantitative: socio-economic characteristics, noise and traffic data; they are numeric values expressed on “ratio scales”, like age, income, speed, number of vehicles, L_{eq}, etc.

The data analysis aimed at:

- describing the sample;
- analysing the relationships among the variables through an inferential analysis.

The analysis of variance (ANOVA) was used for the traffic and noise data to compare the sites’ characteristics and check the classification made at the DOE stage.

The ANOVA is a statistical method needing normally distributed and homoskedastic quantitative data, but it is a robust technique also if that hypothesis is violated (*51*).

When the analyses were carried out among qualitative data or among qualitative and ordinal or quantitative data, we used contingency tables to evaluate their relationships, notably the ANOVA, the Spearman rho correlation coefficient for ordinal data and the ordinal regression.

The evaluation of the dose-response relationship was carried out using the ordinal logistic model; it allowed to define the probability to select a degree of the dependent ordinal variable as a function of independent continuous and discrete variables (*52*).

Having adopted scales with different lengths, the scores were normalized using the same methodology adopted by Miedema and Vos (*54*), where all the scores are referred to a 0-100 scale. This normalization implied to scale down to “0” our scores that started from “1” according to the Likert scales.

RESULTS

This section presents the results of the analysis carried out in the standard sites according to three levels of analysis.

Firstly, the results of the traffic and noise measurements in relation to of the street shape are given, to check the accuracy of the site selection made through the DOE.

Secondly, the results of the correlation between the annoyance for each of the three periods – day, evening and night – and the corresponding noise value expressed by different noise indicators are presented.

Finally, the dose-response relationships built on the epidemiological survey are reported.

The segmentation of the sites according to the foad characteristics

The use of the variable “number of lanes” in the standard site definition was very useful to obtain, during the ex-post analysis, a different site segmentation according to the traffic volumes. The traffic measurements allowed buildinga new variable, named “traffic”, divided in three classes:

- Class 1: volume ≤ 500veh/h;
- Class 2: 500 < volume ≤ 1500veh/h;
- Class 3: > 1500veh/h;

that was used in the ANOVA to evaluate the effect on some noise indicators ($L_{eq,h}$, L_{min}, L_{max}) of the:

- traffic volume (called TRAFFIC);
- site configuration with L or U profile depending on the presence of the building on one or both side of the street (called TYPE_COD);
- presence of tramway (called TRA_COD).

The results presented in

FIGURE 1 show the statistical significance of the traffic-related variables ($p<0.05$) while the factor “presence of tramway” and the interaction “presence tramway-type of geometry” are not significant (respectively $p=0.281>0.05$ and $p=0.226>0.05$). Furthermore, it is possible to observe that the U profile sections are noisier than those with L profile.

Dep Var: LEQ_T_IN N: 126 Multiple R: 0,903 Squared multiple R: 0,815					
Variables	**Sum-of-Squares**	**df**	**Mean-Square**	**F-ratio**	**P**
TRAM_COD$	**6,419**	**1**	**6,419**	**1,174**	**0,281**
TYPE_COD$	152,339	1	152,339	27,852	0,000
TRAFFIC	666,482	2	333,241	60,927	0,000
TRAM_COD$*TYPE_COD$	**8,116**	**1**	**8,116**	**1,484**	**0,226**
TRAM_COD$*TRAFFIC	811,847	2	405,924	74,216	0,000
TYPE_COD$*TRAFFIC	216,095	2	108,048	19,755	0,000
TRAM_COD$*TYPE_COD$*TRAFFIC	102,512	2	51,256	9,371	0,000
Error	623,524	114	5,470		
TRAM_COD$*TYPE_COD$*TRAFFIC					

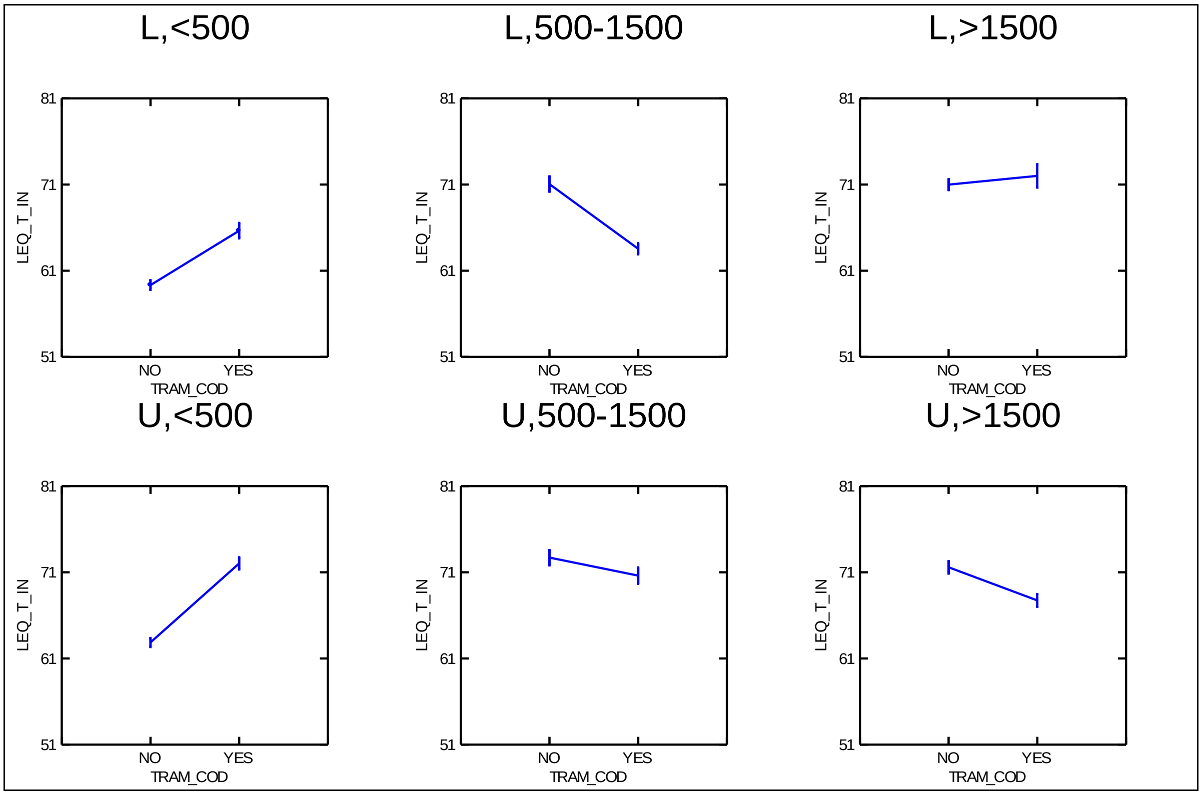


FIGURE 1 Anova results on variables interaction

The ANOVA was carried out also for the noise indicators L_{max} and L_{min}, that are important to understand the acoustical climate. The results (FIGURE 2, Part “a” and “b”) show that:

- the interaction “section typologies-traffic” does not effect the variable L_{min} ($p=0.445>0.05$). The U and L sections present the same L_{min} in both groups of narrow and large streets;
- the L_{max} is not affected by the “presence of tramway” and by the interaction of all three factors (tram, site typology and traffic), showing, respectively, $p=0.367>0.05$ and $p=0.062>0.05$.

The above analyses show that the only presence of the tramway and the interaction “presence tramway-typology” are not enough to define noisier sections without the traffic volumes.

An increase of traffic does generate a corresponding increase of L_{eq} and L_{min}, but this does not apply for L_{max} (Figure 2, Part “c”). The reason is that the L_{max} could be influenced from events like car acoustic systems, vehicles’ acceleration or other typical noise sources, difficult to recognize after the measurements and not directly related to the traffic flow.

Furthermore, when the traffic flow is low (in our case <500 veh/h), the sections with tramway are noisier than the sections without it, independently of the L or U shape of the site ; when the traffic flow increases this difference disappears and the presence of tramway is not useful to identify a noisy section (FIGURE 2, Part “d”).

The reason is the interaction of the two sources; when the traffic is higher it becomes the main noise source and masks the other sources (e.g. the tramway). The suggestion from this result is to provide tramlines in streets with high traffic volumes because they they do not induce any increase of Leq.

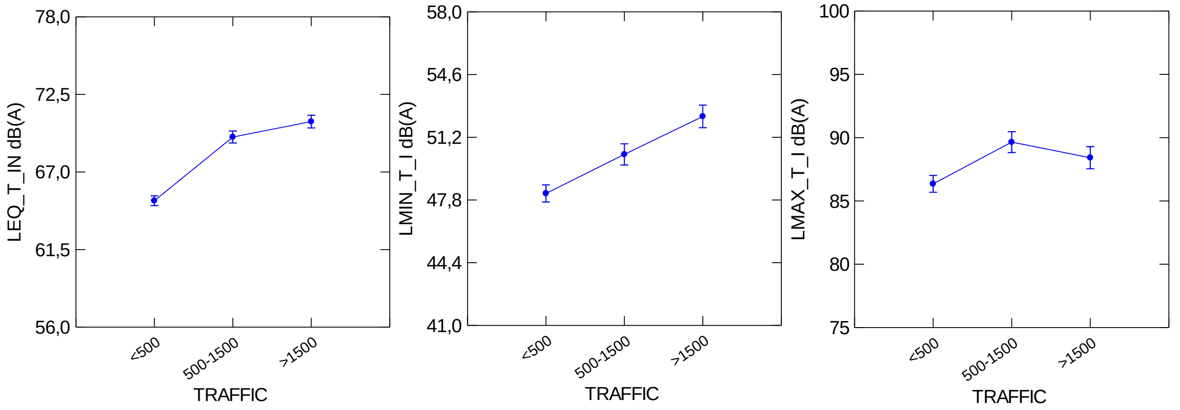
Part a) Dep Var: LMIN_T_IN N: 126 Multiple R: 0,808 Squared multiple R: 0,652

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
TRAM_COD$	453,881	1	453,881	45,261	0,000
TYPE_COD$	83,752	1	83,752	8,352	0,005
TRAFFIC	305,092	2	152,546	15,212	0,000
TRAM_COD$*TYPE_COD$	186,469	1	186,469	18,595	0,000
TRAM_COD$*TRAFFIC	227,884	2	113,942	11,362	0,000
TYPE_COD$*TRAFFIC	**16,347**	**2**	**8,174**	**0,815**	**0,445**
TRAM_COD$*TYPE_COD$*TRAFFIC	62,448	2	31,224	3,114	0,048
Error	1,143,210	114	10,028		

Part b) Dep Var: LMAX_T_IN N: 126 Multiple R: 0,667 Squared multiple R: 0,445

Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
TRAM_COD$	**16,885**	**1**	**16,885**	**0,820**	**0,367**
TYPE_COD$	80,031	1	80,031	3,887	0,051
TRAFFIC	210,878	2	105,439	5,122	0,007
TRAM_COD$*TYPE_COD$	228,009	1	228,009	11,075	0,001
TRAM_COD$*TRAFFIC	652,025	2	326,012	15,836	0,000
TYPE_COD$*TRAFFIC	268,417	2	134,208	6,519	0,002
TRAM_COD$*TYPE_COD$*TRAFFIC	**117,431**	**2**	**58,715**	**2,852**	**0,062**
Error	2,346,962	114	20,587		

Part c)



Part d)

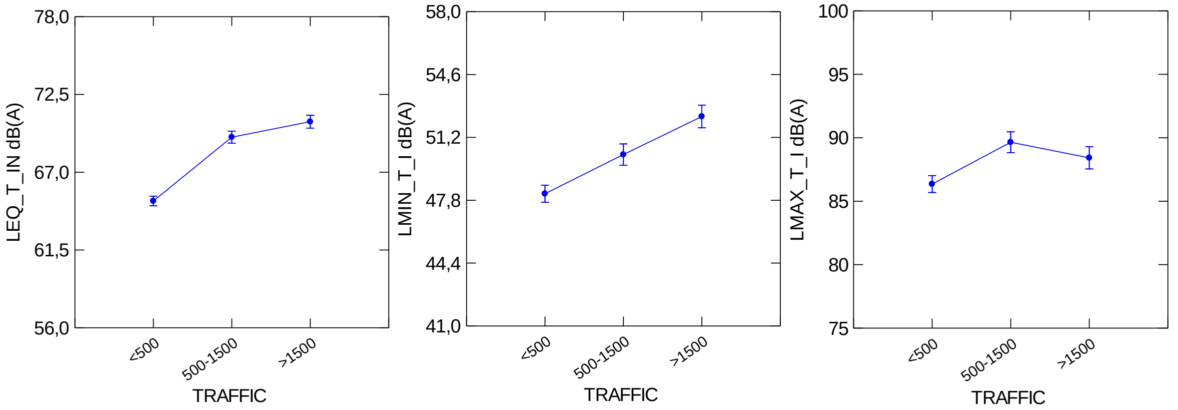


FIGURE 2 Anova result: effect of the single factor Traffic on noise indicators

The annoyance perception related to the noise indicators

To distinguish the possible difference of annoyance during the different periods of the day, we use the median of the scores given to annoyance in the different time intervals. The median was considered appropriate because, notwithstanding the normalization of the scores, the annoyance is expressed with ordinal values and, for this typology of categorical data, statisticians do not suggest to use the mean to measure the central tendency (*53*).

We obtained three values of annoyance:

- Day_Ann_All= median of the annoyance score during the day period;
- Night_Ann_All= median of the annoyance score during the night period;
- Eve_Ann_All= value of annoyance in the evening period. Since the evening period is a two hours interval, the score is a unique value not needing the calculation of the median.

When the measurement period does not cover all the 24 hours, (day, evening and night), the noise value is calculated using the energetic mean of the hourly noise values (L_{eq}, L_{min}, L_{max}, L_{90}, L_{95}), measured in the respective periods of the 24 hours. Some researchers showed that weekly noise may be evaluated by sample measurements during some hours of the day rather that with seven continuous days of measurements (*54*). For example, they state that a noise sample measured in the range from 1 p.m to 5 p.m could be used to represent the noise in the day period because its value is statistically representative of the same noise value measured on all the day period.

According to those indications, the variables used for the calculation are:

- $L_{eq\_6\_20}$ = equivalent level or energetic mean in the “day” period;
- L_{eq20_22} = equivalent level or energetic mean in the “evening” period;
- L_{eq22_6} = equivalent level or energetic mean in the “night” period;
- L_{min_DAY}= minimum level or energetic mean of minimum levels in the “day” period;
- L_{max_DAY}= maximum level or energetic mean of maximum levels in the “day” period;
- L_{bg_DAY} = background noise in the “day” period; for this index L90, L95 or their average values during the period, depending on the availability of the data are used;
- L_{min_NIGHT} = minimum level or energetic mean of minimum levels in the “night” period;
- L_{max_NIGHT} = maximum level or energetic mean of maximum levels in the “night” period;
- L_{bg_NIGHT} = background noise in the “night” period; for this index L90, L95 or their average value during the period, depending on the availability of the data are used.

To investigate possible correlation among the noise variables, the annoyance and the site configuration, we made an explorative analysis on the whole sample, using the Spearman “rho” coefficient (*53*).

The results show that the scores given to the annoyance during the day period are correlated with the scores assigned to the night period (Spearman ρ=0.64) and with the global street score (Spearman ρ=0.67); the annoyance during the day periods are similar to those during the night ones. There are, instead, low correlations among the annoyance levels and the corresponding noise levels: the equivalent level could be not sufficient to describe the perceived annoyance.

To understand if the respondents attitude towards annoyance is due to the site typology, the same analyses were conducted on the data grouped according to the geometrics characteristics already used for the site classification.

FIGURE 3 reports the synthesis of the correlation analysis.

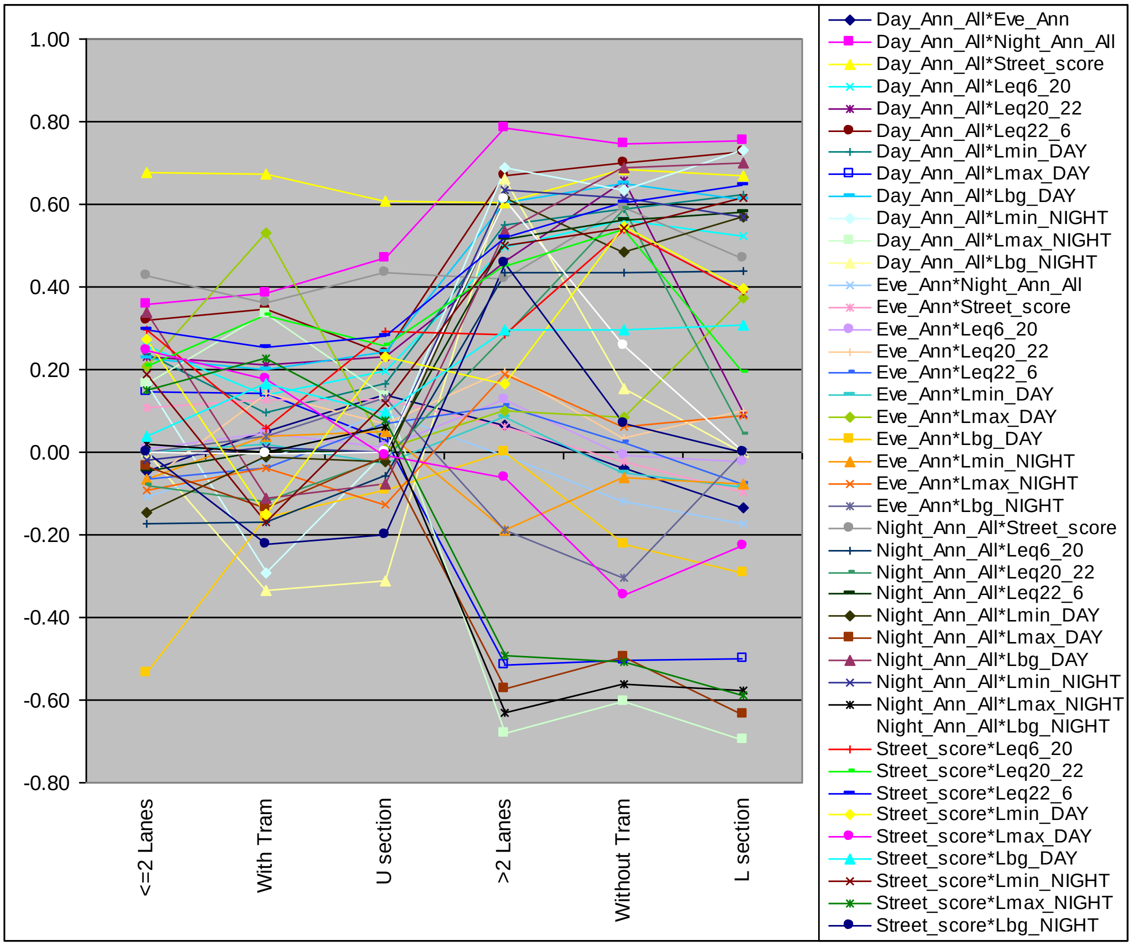


FIGURE 3 Spearman correlation coefficient in function of the grouped sites characteristics

The synthesis reported in FIGURE 3 shows a different behaviour of the large streets compared to the narrow streets. The streets with less than two lanes, the tramway and a U shape are typically narrow streets; for them the correlation coefficient is very low for all the combinations of the variables. The streets with more than two lanes, no tramway and L shape are typically large urban streets; for them the correlation coefficients show a large dispersion, from low to high values.

The results show that, in general, it is possible to observe a low correlation between annoyance and noise levels in all the groups, showing values coherent with those obtained by other authors (*55,56,57*). The correlation among the annoyance levels in the day period and the street score is constant throughout the groups (ρ≈0.6). In large streets the day annoyance is correlated with the night annoyance.

Then, we evaluated the effect of the different sites' typology on the dose response relationship, focusing on:

- the narrow sections: streets having less than two lanes and U shape;
- the large sections: streets having more than two lanes and L shape.

We selected the narrow streets with U geometry because they showed the highest sensitivity to the traffic changes and the traffic flows could mask the noise produced by a tramway. The evaluation of the relationship among annoyance and noise levels showed low correlation in both sections. The highest values are related to the correlation among annoyance during day period and L_{eq} from 6.00 to 20.00 (respectively ρ=0.25 for narrow section andρ=0.30 for large section).

The dose-response relationship

The ordinal regression model was used to predict the probability that a respondent belongs to the categories of the dependent ordinal variable, taking into account the explanatory variables (*58,52,59).* First of all we established the kind of variables to be included in the model: for the dependent variable we used the global level of annoyance, "street_score", grouped into three classes:

- Little Annoyed, LA (coded 0) if the "street_score"≤=30;
- Annoyed, A (coded 1) if 30<"street_score"≤60 ;
- Highly Annoyed, HA (coded 2) if "street_score">60.

We decided to keep the middle interval larger than the other ones, and use different cut points than Miedema and Oudshoorn (*19*), to evaluate the probability that a respondent belongs to one of the above classes. Miedema and Oudshoor (*19*) considered little annoyed (LA) those who expressed an annoyance level higher than 28, annoyed (A) those who gave a score higher than 50 and highly annoyed (HA) those who stated more than 72. Furthermore, according to this approach, the people giving a score lower than 28 were not considered while who gave a score higher than 72 were considered in the both two levels LA and A.

The other variables used in the model are:

- the equivalent level during the day period: "L_{eq6_20}". This noise indicator shows the highest correlation with the annoyance. Unfortunately, difficulties encountered during the measurements did not allow us to carry out weekly noise measurements, useful for the calculation of the L_{den}. For this reason we decided to investigate the relationship among annoyance and noise using complete measured data on day period without carrying out any noise simulation. The "L_{eq6_20}" is used as a continuous variable, covariate;
- the site typology, "Type". This factor allows taking into account the different behaviour of the narrow and large streets emerged in the previous analyses. This variable is used as a two-levels factor: Type1(section with L shape) and Type2 (section with U shape).

The model is built using the "complementary log-log" link function, that is the most appropriate for our data, (*60*), and it is run using all the respondents of the considered sites (350 cases) and only the variables without missing data.

The results show that all the explanatory variables used are significant (Wald test with p<0.05 for all the variables), even though the variance explained by the model is partial (Nagelkerke R2= 0.144).

Equations (1) and (2) give the cumulative probabilities for the two categories LA and A defined by the model.

$$\mathrm{Prob}_{\mathrm{LA}} = 1 - e^{-e^{[6{,}158-(0{,}103 Leq6\_20+0{,}306 Type1+0 Type2)]}} \qquad (1)$$

$$\mathrm{Prob}_{\mathrm{A}} = 1 - e^{-e^{[7{,}908-(0{,}103 Leq6\_20+0{,}306 Type1+0 Type2)]}} \qquad (2)$$

where:

L_{eq6_20} = equivalent level during day period;

Type1 = dummy variable for L shape; it is equal to "1" if the model is used for data in L section and to 0 otherwise;

Type2 = dummy variable for U shape; it is equal to "1" if the model is used for data in U section and to 0 otherwise.

The probability, that a respondent belongs to a category of the dependent variable, LA, A or HA, is given by the difference of the cumulative probabilities and is reported in the equations (3), (4), (5):

$$\%LA = \mathrm{Prob}_{LA} = 1 - e^{-e^{[6,158-(0,103 Leq6\_20+0,306 Type1+0 Type2)]}} \quad (3)$$

$$\%A = \mathrm{Prob}_{A} - \mathrm{Prob}_{LA} = e^{-e^{[6,158-(0,103 Leq6\_20+0,306 Type1+0 Type2)]}} - e^{-e^{[7,908-(0,103 Leq6\_20+0,306 Type1+0 Type2)]}} \quad (4)$$

$$\%HA = 1 - \mathrm{Prob}_{A} = e^{-e^{[7,908-(0,103 Leq6\_20+0,306 Type1+0 Type2)]}} \quad (5)$$

In FIGURE 4 the curves represented by the equations (3), (4) and (5) are depicted and show the influence of the variable "Type".

The curves, for the streets with L shape (Type1), are represented by continuous lines while, for the streets with U shape (Type2), by dashed lines.

The results show that the same value of day equivalent level (L_{eq6_20}) produces different reactions: the people who live in the L sections (large streets) are more annoyed than the people living in the U streets (narrow streets) of about 4 dB(A).

For the same level of noise, in the U streets there are 10% of more people annoyed than in L streets, at each level of annoyance (LA, A, HA). This difference is not constant along all the curve; notably, for LA and HA curves, the differences decrease at the ends (lower and higher value of noise level); for A curve the same pattern applies including also the mid part of the curve (around 67 dB(A)). Such result highlights that at very high and low noise level the annoyance perception is the same in each of the standard sites; instead, from 45 to 95 dB(A) the annoyance could be influenced by the site configuration.

In addition, it is possible to define two cut points in the Figure 4 forming three intervals: till to 60 dB(A) for the LA, from 60 dB(A) to 75 dB(A) for A and over 75 dB(A) for HA.

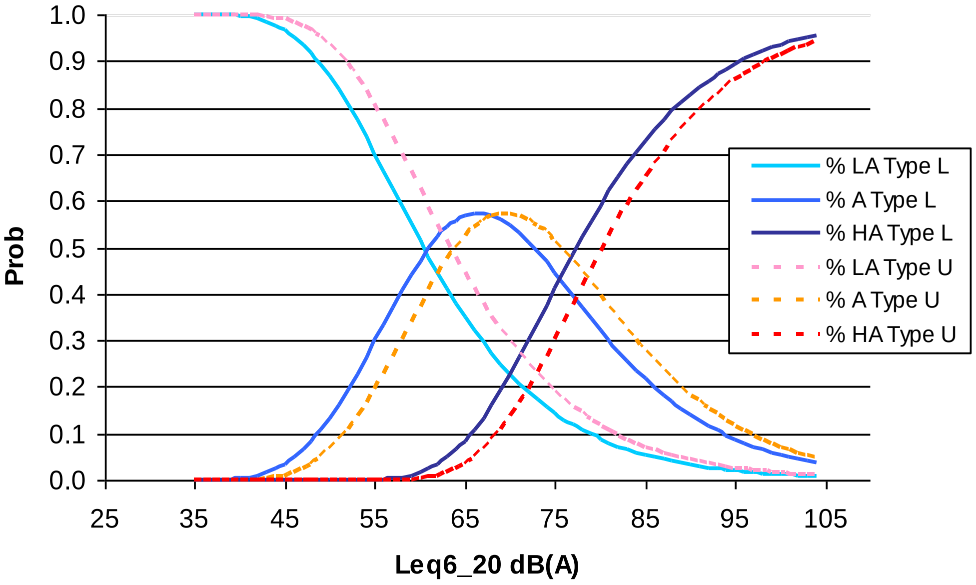


FIGURE 4 Dose-response relationship by equation (3), (4), (5)

DISCUSSION AND CONCLUSION

This research has tackled the issue of the noise impact produced by the transport infrastructures pointing out the factors influencing the annoyance of the residents in the urban areas.

The application of the Design of Experiment (DOE) to choose the measurements sites was a good way to design the data analysis and to find the factors influencing the noise through the definition of the "standard sites". Such approach allowed us to find out that, during the day period, the noise produced by road traffic (in specific "volume conditions") masks the noise produced by the tramway. An increase of traffic generates a corresponding increase of L_{eq} and $L_{min,}$ but with different magnitude while this does not apply for L_{max} (Figure 2, Part "c") as, in some cases, the L_{max} decreases. The reason is that the L_{max} could be influenced by some street events like use of car acoustic system, vehicles' acceleration or other typical road noises difficult to recognize after the measurements, like scooters passing by (*61*). When the traffic flow is low (in our case <500 veh/h) the sections containing a tramline are noisier than sections without it, whatever the site typology (L or U shape). Instead, when the traffic flow increases, this difference disappears (Figure 2, Part "d") due to the interaction of the two sources; when the traffic is higher it becomes the main noise source and masks the other ones (e.g. tramway).

Furthermore, the sections with U shape appear to be noisier than L shape sections, under the same traffic conditions. This fact suggests to select U sections like the critical ones during urban environmental monitoring.

The inferential analysis points out a different correlation between noise and annoyance levels in the measurement sites, allowing us to define two different sites' typologies: "narrow" streets and "large" streets.

The statistical analysis on the above two sections show that there is a significant but weak correlation among annoyance and noise levels (from ρ=0.25 to ρ=0.30).

The analysis of the dose response relationship shows that the correlation between annoyance and noise is low. Using the noise recorded in the day period and the site characteristics it is possible to state that, at the same value of day equivalent level (L_{eq6_20}), people living in the L sections (large streets) are more annoyed than people living in U sections (narrow streets); this difference can be measured as a shift of about 4 dB(A) of the dose-response curve and of 10% more people annoyed.

The two cut points identified on the dose-response curves (60 and 75 dB(A)) make the representation of our dose-response relationships different from that defined by Miedema where a third level polynomial approximation is used to fit the curves (*19*). The use of an ordinal regression model and the calculation of the cumulative probabilities allow us to evaluate, for each level of noise, the probable subdivision of annoyed people in the three categories. This representation could be more useful for explaining data to the public and differ from that of Miedema and Oudshoorn where each curve is calculated evaluating the probability to pass a specific annoyance boundary *(19*).

The results show different people attitudes when they express their annoyance at urban sites. The noise levels are useful, but not enough to define the discomfort of the residents, while the site characteristics could shed light on the annoyance variance.

The paper gives some suggestions and highlights the need to investigate in depth the relationships between noise level and annoyance not only to obtain a better evaluation of the perception of disturbance, but also to allow a global evaluation of the urban soundscape taking into account the city configuration together with the need of planners and urban developers. In addition, an interesting outcome is related to the approach used to measure the noise and traffic data, alternative to the current technical indications but overcoming the difficulty of the continuous seven days noise measurement.

A further development of the research could be the annoyance evaluation in the selected urban sites as a function of the long-term indicator L_{den}. Furthermore, more data are needed to analyse in depth the night period, using different noise indicators, like the number of events or other indicators proposed in the literature (*14*), that in the current research we could not take into account for noise recording limitations.

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