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Statistical Road Classification Applied to Stratified Spatial Sampling of Road Traffic Noise in Urban Areas

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ABSTRACT: Monitoring of road traffic noise is becoming an important issue in modern cities due to the spreading of noise pollution and the extension of monitored areas.Thus,the stratified spatial sampling is frequently applied to reduce the costs and provideadequate accuracy in order to obtain reliable noise maps. The definition of the strata in the sampling may refer to the legislative classification of roads: in Italy 8 classes of roads are defined. Generally, this classification often does not reflect the actual use of roadsin the mobility network, as it is mainly based on the geometrical characteristics of the roads.In order to improve the efficiency of stratification, an alternative criterion is proposed, based on clustering of 24 h patterns of road traffic noise. To explain thiscriterion,a preliminary analysis of 74patterns of 24h continuous monitoring of the hourly equivalent levels L_{Aeqh}taken in the city of Milan, Italy, in 35 different sites has been performed. The applied agglomerative algorithms provided two groups and the mean profile ofeach cluster was associated with the available traffic flow data, namely the rate at morning rush hour. By means of ROC curve, the first cluster was associated with traffic flow greater than 1500 vehicles/hour and the second with less than 1500 vehicles/hour. The proposed criterion of road stratification performed better than the one based on the legislative classification of roads as, for a given accuracy, it needs a lower number of sites to estimate the noise indicators.

Key words: Urban traffic monitoring,classification of roads, statistical analysis and spatial stratification

INTRODUCTION

Urban traffic noise has been the object of several studies dedicated to investigate the different aspects of its impact(EEA, 2014; Brown et al., 1987, Alberola et al., 2005; EU's Policy, 2002; Zou et al, 2014; Babish, 2006). For the measurement of such noise in large areassystematic samplingis frequently used, that is selecting measurements sites by the use of grids overlaid on a map(Brown et al., 1987). However, this approach, though interesting, has some drawbacks. For example, the validity of the conclusions is strongly dependent on the size of the grid(Barrigon Morrillas et al., 2002). The noise immission from a street generally depends on its activity, the use in the urban context,its width, the presence of reflecting surfaces and obstacles, the type of paving, etc..Such featuresoften suggest a different approach based on stratified sampling (Barrigon Morrillas et al., 2002; Romeu et al., 2006). By this strategy, roads sharing the same characteristicsfor some parameters (i.e. traffic flow,number of lanes, etc.)are grouped together in a stratum. Then, the road network is divided into different groups (strata) according to the road classification and each road can be assigned to one, and only one, stratum. Stratified sampling can provide greater precision than a simple random sample of the same size, but it may require more effort than the latter due to the need of a prior knowledge of the population characteristics in order to define the strata(Fuller, 2009).For instance, the mobility graph of the city of Milan is rather complex, with about 5 million daily people transfers and 650,000 daily vehiclesentering the municipal border. According to the general plan of urban traffic of the new Italian Road Code, the road network in Milan can be summarized in 8 classes of roads (from

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type "A" to "F" and sub-classes).

Here, class roads of type "A" are referred to as motorways, type "D" as main urban roads (4 lanes), type "E" as urban roads (2 lanes) and type "F" as local roads. Class "F"is the largest group,including76.5% of the wholeroad network.Unfortunately, the above legislative road classification often does not reflect the actual use of roadsin the mobility network, as it is mainly based on the geometrical characteristics of the roads. In order to improve the efficiency of stratification, an alternative criterion is proposed based on clustering of 24 h patterns of road traffic noise. To explain this criterion, a preliminary analysis of 74 patterns of 24 h continuous monitoring of the hourly equivalent levels L_{Aeqh} taken in the city of Milan, Italy, in 35 different sites has been performed. The applied agglomerative algorithms provided two groups and the mean profile of each cluster was associated with the available traffic flow data, namely the rate at morning rush hour, namely 7:30-8:30 a.m.. Considering this traffic flow, by means of the ROC curve the threshold between the two cluster can be fixed at 1500 vehicles/hour.The obtained two cluster mean profiles were used to estimate the mean values of $L_{Aeqd}$and L_{Aeqn} levels and to determine the minimum number of sites required to perform such estimate with a predetermined accuracy. The proposed criterion of road stratification proved to performbetter than the one based on the legislative classification of roads as, for a given accuracy, it needs a lower number of sites to estimate the noise indicators considered.

MATERIALS & METHODS

The dataset considered in the preliminary analysis aimed to set-up the methodology refers to the city of Milan, Italy, and is made of 74 patterns of 24h continuous monitoring of the hourly equivalent levels $L_{Aeqh}$of road traffic noise, measured in 35 different sites corresponding to 8 classes and sub-classes of the Italian legislative road classifications. Sub-groups belonging to classes "E" and "F"were gathered. Data were recorded on weekdays and in absence of rain as prescribed by the current Italian legislation (DME n° 76, 1998).Because of the non-homogeneity of LAeqh level dataset, due to various monitoring conditions such as different distances from the road but also to the characteristics of the street itself (its geometry, the presence of reflecting surfaces and obstacles in sound propagation and types of paving), each j-th value of thetemporal series was referred to the corresponding daytimeL_{Aeqdj}(06-22 h) taken as reference level, that is for each hour the following parameter ij was computed:

$$¢_{ij} = L_{Aeqh_{ij}} - L_{Aeqdj} \text{ [dB] (i= 1, ………., 24)} \quad (1)$$

For all the 35 sites only the morning rush-hour (time interval 7:30-8:30 a.m.) vehicle flow rate was available.For the 18 sites where the monitoring dataincluded more days at the same site, the median of ij hourly values was considered. The median was chosen as itisless influenced by the presence of outliers.Of course the data-set, due to its reduced sample size and the monitoring constraints (i.e. availability of sites having features appropriate for unattended 24 h noise monitoring),cannot be properly representative of the entire road network of Milan. However, this limitation, even though influencing the results, is not so crucial in setting-up the proposed procedure to classify the roads on the basis of their 24 h profiles ij. In addition, even though the present paper deals with road traffic noise, this is often the predominant noise source in urban areas and is also the most frequent cause of the variability of the sound levels in urban settings (Carmona del Rio et al., 2011).

As above addressed, the Italian legislative classification of roads is mainly based on the geometry of the road and, therefore,not alwayscorresponds to itsactual use by the urban traffic. In other words, roads of the same geometry and class can show quite different vehicle flow, depending on their actual function in the mobility road network. Thus, the 24h patterns of hourly L_{Aeqh}level profiles can be largely different for roadsin the same class, leading to the increase of hourly L_{Aeqh} variability within each class and possible overlap of hourly L_{Aeqh} variability among classes.This is a drawback for the stratified sampling based on the Italian legislative classification of roads, as in any stratified sampling the variability of the variables under study in each stratum should be minimized and lower than that between strata. On the other hand, stratified sampling of urban noise based on road categorization is widely used and has been further analyzed in some recent researches(Carmona del Rio et al., 2011; Rey Gozalo et al., 2015; Barrigon Morillas et al., 2005).To investigate how improving the efficiency of road categorization, cluster analysis has been thought worth to explore as proposed in previous studies (Brambilla et al., 2010; Angelini et al., 2012).Thus, unsupervised clustering algorithms were applied to group together the 24 h hourly LAeqh level profiles found to be "close" to one another. The following algorithms were applied:

Hierarchical agglomeration using Ward algorithm (Ward, 1963);

K-means algorithm (Hartigan et al., 1979);

Partitioning Around Medoids (PAM) Kaufmann et al., 1990);

Expectation Maximization algorithm implemented in the "mclust" package (Fraley et al., 2011)

and their results compared. The range of solutions for clustering was set from four groups (for a straightforward comparison with the Italian legislativeroad classes considered) to two (corresponding to the minimal discrimination between the data). Euclidean distance was chosen as the metric of the distance among observations.The open source software "R"(R Core Team, 2015)was applied for clustering and the package "clValid" (Brock et al., 2008; Package "clValid", 2013) was used for validating the results of the different cluster algorithms.All the clustering algorithms were ranked based on their performance as determined simultaneously by all the validation measures (Pihur et al., 2007).

In stratified spatial samplingthe sample is split up into strata (sub-samples) in order to decrease variances of sample estimates, to use partly non-random methods applied to sub-groups or clusters or to study strata individually (Kish, 1965). As a consequence of the central limit theorem, the maximum error E, that is the largest expected deviation of the sample mean from the population mean with the stated confidence level
1-α (for 1-α = 95%, z_α = 1.96) is:

$$E = z_\alpha \cdot \sigma_x \qquad (2)$$

The minimum number of elements of a sample nmin for a correct estimation of the mean of the population within an accuracy ± E is (for nmin< 30):

$$n_{\min} = \frac{t^2_{n-1,\alpha} \cdot s^2}{E^2} \qquad (3)$$

where is the value of the Student's t distribution for a confidence level (1-) and = (n-1) number ofobservations and s is the sample standard deviation. According to van Bell (2008), s can be evaluated by:

$$\frac{Max - Min}{\sqrt{2(n-1)}} \leq s \leq \frac{n}{n-1} \cdot \frac{Max - Min}{2} \qquad (4)$$

where n is the number of samples with range = Max - Min.

RESULTS & DISCUSSION

The outcome of the "clValid" R-package showed that the hierarchical clustering with Ward algorithm provided the best performancefor the three agglomerations into 2, 3 and 4 groups.
The obtained clusters wereformed of roads belonging to different legislative classes, as reported in Table 1.

The 4-group solution,directly comparable with the four legislativeroad classes, shows a clear mismatch between legislative road classes and cluster partitioning. Roads in "F" class are distributed over all the 4 groups, whereasthe roads in the remainingclasses ("A", "D"and"E") are distributed in two groups only (namely groups 1 and 2). This confirms that road traffic noise is mainly linked to the effective role of the road in the urban mobility, rather than the legislativeclassification of the road itself, as already shown by the results ofa previous study (Brambilla et al., 2010).The 2-groupsolution appears to be a satisfactory balance between a satisfactory discrimination among profiles and the need to get a simple solution easy to be applied.As shown at the bottom of Table 1, the two clusters areformed primarily by temporal profiles belonging to roads of legislative classes"A", "D" and "E" for cluster 1 (made up of 13 temporal profiles corresponding to 37.1% out of the total), whereas cluster 2 (made up of 22 temporal profiles corresponding to 62.9% out of the total) is mainly formed by"F"legislative class roads.

Fig. 1 shows the profiles of mean values ijand the corresponding ± theirmean standard error for each cluster. Cluster 2average profile (black solidline) shows two peaks: the first at the time interval 7-8 h and the second at 17 h. It remains close to LAeqd until 19 h, afterwards it goes down in the night period till 3 h, after which it starts raising again. Cluster 1 average profile (grey dashed line) has just one lower peak at 7-8 h and higher values at nighttime. In the remaining time periods it shows a similar behavior ofcluster 2 average profile.

Table 1. Clusters' composition

Cluster		Road class	A	D	E	F	Total
Number of groups	4	Group 1	2 (66.7%)	1 (50%)	7 (53.8%)	3 (17.6%)	13
		Group 2	1 (33.3%)	1 (50%)	6 (46.2%)	8 (47.1%)	16
		Group 3	---	---	---	5 (29.4%)	5
		Group 4	---	---	---	1 (5.9%)	1
	3	Group 1	2 (66.7%)	1 (50%)	7 (53.8%)	3 (17.6%)	13
		Group 2	1 (33.3%)	1 (50%)	6 (46.2%)	13 (76.5%)	21
		Group 3	---	---	---	1 (5.9%)	1
	2	Group 1	2 (66.7%)	1 (50%)	7 (53.8%)	3 (17.6%)	13
		Group 2	1(33.3%)	1 (50%)	6 (46.2%)	14 (82.4%)	22

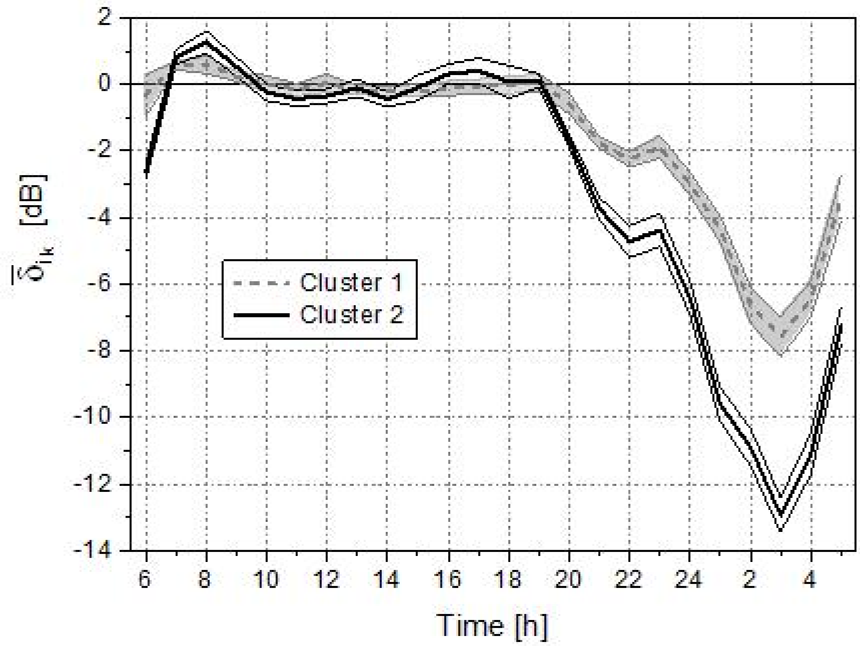

Fig. 1. Mean values of and their standard error for each cluster

The data were not normally distributed over the whole day period, as shown by the Shapiro-Wilk's test results,Thus, to check if the difference between the two average cluster profiles are statistically significant, theMann-Whitney-Wilcoxon test was performed for the hourly data. The hourly intervals showing significant differences at $\alpha = 0.05$ significance level resulted from 20 to 9 h. The mean values of the differences L_{Aeqd} - LAeqn, L_{Aeqd} - L_{Aeq24}, L_{Aeqn} - L_{Aeq24} and their standard deviation s foreach average cluster profile are listed in Table 2.

The average cluster profile P1 shows a difference 3 $\overline{L_{Aeqd} - L_{Aeqn}}$ dB less than the profile P2, but with similar standard deviations s. The Root Mean Squared Error (RMSE)yielded a minimum at the time intervals of 13-14 h (0.41 dB) and 15-16 h (0.39 dB) for the cluster 1 and 19-20 h (0.96 dB) 20-21 h (0.95 dB). These intervals are recommended for taking measurements as they provide the best accuracy in the estimate of L_{Aeqd} from measured L_{Aeqh}.

Unlike the legislative classification of roads, the two obtained cluster profiles cannot be applied straightforward without any indicationlinking them to a specific feature easier to be known.To overcome suchdifficulty in their application, each average cluster profile was associated with the corresponding traffic flow rate at rush hour for each of the 35 roads under consideration. Fig. 2 shows the box plots for this parameter for the two average cluster profiles.It is interesting to observe that the interquartile range of the two clusters does not overlap.

The receiver operating characteristics analysis (ROC)(Fawcett, 2006) was applied to evaluate the threshold of the traffic flow rate at rush hour (the classifier variable) most suitable to discriminate the cluster membership of the sites (the class variable).In general, the ROC curve is a graphical method to evaluate the performance of a binary classifier. The curve is created by plotting the true positive rate (TPR) against the false positive rate (FPR) at various threshold settings. The

Table 2. Mean values of the differences LAeqd - LAeqn, LAeqd - LAeq24, LAeqn - LAeq24 and their standard deviations s foreach average cluster profile

Cluster profile	$\overline{L_{Aeqd} - L_{Aeqn}}$ and (s) [dB]	$\overline{L_{Aeqd} - L_{Aeq24}}$ and (s) [dB]	$\overline{L_{Aeqn} - L_{Aeq24}}$ and (s) [dB]
P1	3.9 (1.23)	0.9 (0.23)	-3.0 (1.00)
P2	6.8 (1.29)	1.3 (0.10)	-5.4 (1.20)

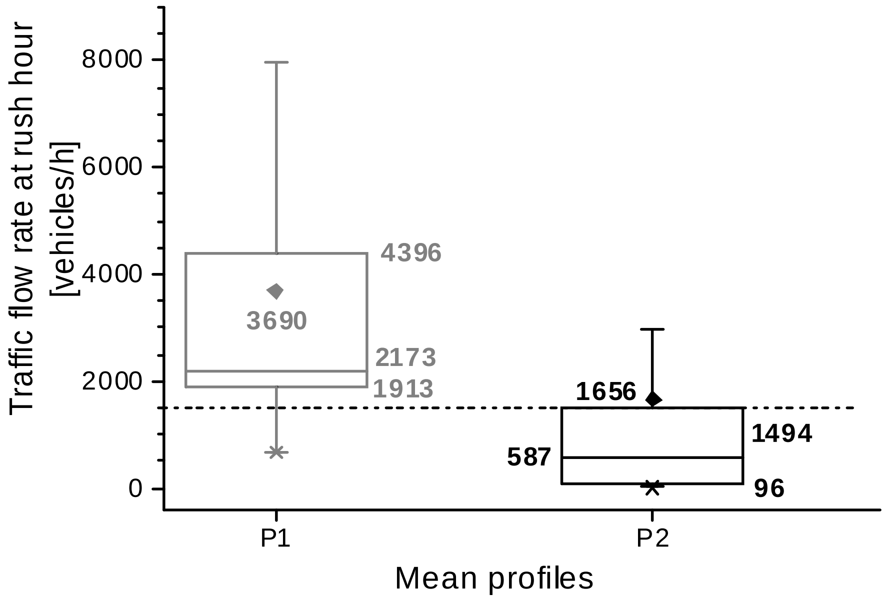

Fig. 2. Box plots of the traffic flow rate at rush hour (7:30-8:30 a.m.) for the two average cluster profiles. The dotted line is the threshold obtained by ROC curve that discriminates profile P1 from profile P2

index related to the Area Under the Curve (AUC) is equivalent to the probability that the result of the test on a group of roads with non-acoustic parameter over the threshold belongs to the proper cluster. For this purpose, the package "pROC" in the "R" environment was used (Robin et al., 2011). The resulted AUC was equal to 0.8007 (Fig. 3), corresponding to a good discrimination, and the above threshold, that is the cut-off point of the ROC curve,was determined by the Youden index (Youden, 1950), that maximizes the sum of specificityand sensitivity. Theresult was 1500 vehicles/ hour at rush hour and, therefore, roads featuring higher values(> 1500 vehicles/hour) can be associated withcluster profile P1, whereas lower flow rates (≤ 1500 vehicles/hour) withcluster profile P2.

In general, applying eq. (3) to the four legislativeroad classes is not straightforward because, usually, the sample standard deviation s of sound levels for each road class is unknown and its value can be estimated by eq. (4) as proposed by van Bell et al. (2008). Because of the non-homogeneity of the dataset levels obtained in different environmental conditions, each j-th value of daytime LAeqdj and nighttime LAeqnj levels at the 35 siteswas referred to the corresponding 24 hours L_{Aeq24j}value. The range of variability sof the differences L_{Aeqdj} - L_{Aeq24j} and L_{Aeqnj} - $L_{Aeq24j}$was evaluated using eq. (4).

Table 3 shows the experimentals values and the estimated values for s_{min} and s_{max} determined for the road classes "E" and "F". Road classes "A" and "D" have been not considered in this analysis due to their poor sample size (3 and 2 observations respectively).

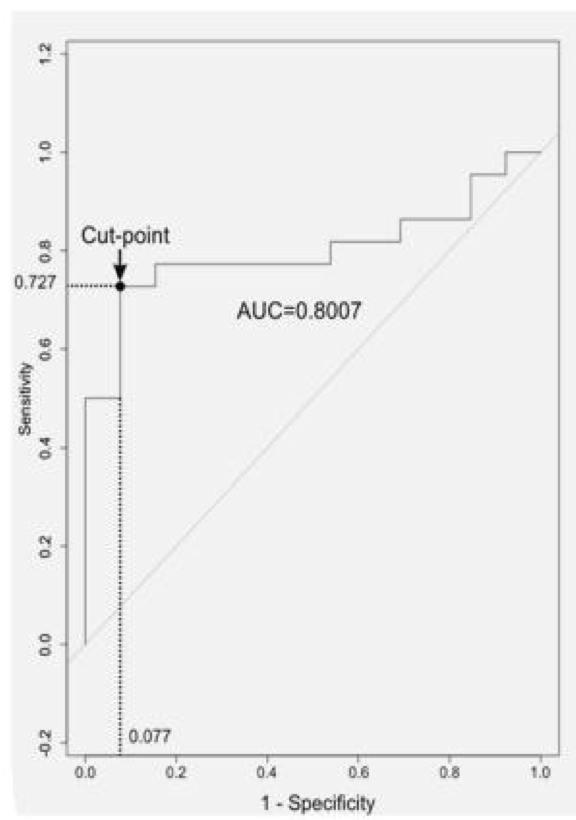

Fig. 3. ROC curve to determine the cut point to associate the traffic flow rate at rush hour with the cluster membership

Table 3. Standard deviation s of daytime L_{Aeqd} - L_{Aeq24} (06-22) and nighttime L_{Aeqn} - L_{Aeq24} (22-06) levels for road classes "E" and "F".

Legislative road class	N°of sites n	Sample standard deviation s [dB]		Estimated sample standard deviation [dB]			
				$L_{Aeqd} - L_{Aeq24}$		$L_{Aeqn} - L_{Aeq24}$	
		$L_{Aeqd} - L_{Aeq24}$	$L_{Aeqn} - L_{Aeq24}$	s_{min}	s_{max}	s_{min}	s_{max}
Urban roads (E)	13	0.21	1.40	0.13	0.34	0.86	2.27
Local roads (F)	17	0.16	2.10	0.12	0.35	1.59	4.77

In addition, by the Shapiro-Wilk test the differences L_{Aeqdj} - L_{Aeq24j} and L_{Aeqnj} - L_{Aeq24j} for the road classes "E" and "F" and cluster profiles P1 and P2 have been checked to be normally distributed in order to apply eq. (3). The results are reported in the box plot in Fig. 4 where LAeqRT (RT = Reference Time) represents either L_{Aeqd} or L_{Aeqn}.

Assuming an accuracy E = ± 1 dB for the estimate of the mean values of L_{Aeqd} - L_{Aeq24} and L_{Aeqn} - L_{Aeq24}, eq. (3) provides the minimum sample dimension nmin to be required. The results are reported in Table 4, where the sample dimension corresponding to smax is a conservative estimate. The values show that the data collected n are enough to estimate the mean of L_{Aeqd} - L_{Aeq24} and L_{Aeqn} - L_{Aeq24} within the fixed accuracy E as $n > n_{min}$, excepting for the L_{Aeqn} - L_{Aeq24} at road class "F" where more measurements are required.

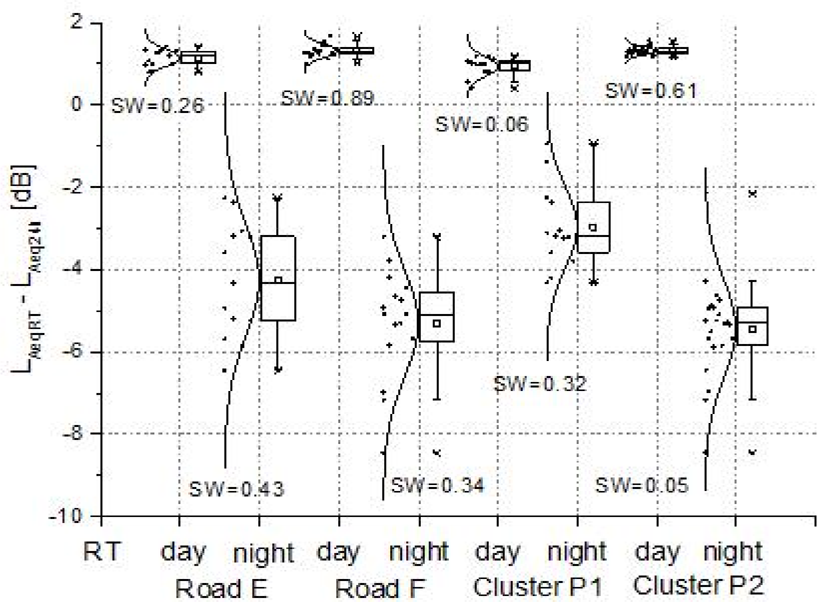

Fig. 4. Box plot of LAeqRT - LAeq24 for legislative road classes "E" and "F" andcluster profiles P1 and P2 with p-values of Shapiro-Wilk (SW)test for normality at = 0.05

Table 4. Minimum sample dimension for the estimate of the mean of LAeqd - LAeq24 and LAeqn - LAeq24 with an accuracy E = ± 1 dB calculated for s and smax

Legislative road class	N°of site n	$t_{n-1,\sim}$ ~ = 0.05	Minimum sample dimension n_{min}			
			s		s_{max}	
			$L_{Aeqd} - L_{Aeq24}$	$L_{Aeqn} - L_{Aeq24}$	$L_{Aeqd} - L_{Aeq24}$	$L_{Aeqn} - L_{Aeq24}$
Urban roads (E)	13	2.18	0	9	1	24
Local roads (F)	17	2.12	0	20	1	102

The minimum sample dimension n_{min} strongly depends on the variability of collected data and, therefore, it would be recommended to choose representative sites with a high variability (high s values). For this reason, it would be preferable to refer to s_{max}.

The above procedure for road classes "E" and "F" has been applied also on the classification based on cluster analysis, that is the profiles P1 and P2. First of all, the Shapiro-Wilk test was performed to L_{Aeqd} - L_{Aeq24} and L_{Aeqn} - L_{Aeq24} data to check if they were normally distributed: the p-values of L_{Aeqd} - L_{Aeq24} data for P1 and of L_{Aeqn} - L_{Aeq24} for P2 are just a bit greater than the limit at = 0.05 (Fig. 4). Thus, eq. (3) can be applied and the results for s values are given in Table 5 The minimum sample dimension n_{min} is reported in Table 6.

These results ($n>n_{min}$) show that the amount of collected data is sufficient to estimate the mean value of L_{Aeqd} - L_{Aeq24} and of L_{Aeqn} - L_{Aeq24} within the given accuracy $E = \pm 1$ dB.

In particular, as shown in Fig. 5, the benefit to use cluster profiles instead of legislative road classes is clear for the mean L_{Aeqn} - L_{Aeq24} estimate as for "F" road class at least 20 monitoring points are required, whereas profile P2, mainly formed by "F" road class, requires 6 monitoring points only for the same estimate.

Table 5. Standard deviation s of daytime L_{Aeqd} - L_{Aeq24} (06-22) and nighttime L_{Aeqn} - L_{Aeq24} and (22-06) levels for cluster profiles

Cluster profile	N° of 24-hour samples n	Sample standard deviation s [dB]		Estimated sample standard deviation [dB]			
				$L_{Aeqd} - L_{Aeq24}$		$L_{Aeqn} - L_{Aeq24}$	
		$L_{Aeqd} - L_{Aeq24}$	$L_{Aeqn} - L_{Aeq24}$	s_{min}	s_{max}	s_{min}	s_{max}
P1	13	0.23	1.00	0.19	0.51	0.42	1.12
P2	22	0.10	1.20	0.04	0.13	0.64	2.18

Table 6. Minimum sample dimension for the estimate of the mean of L_{Aeqd} - L_{Aeq24} and L_{Aeqn} - L_{Aeq24} with an accuracy $E = \pm 1$ dB calculated for s and s_{max}.

Cluster profile	N° of 24-hour samples n	$t_{n-1,\alpha}$ $\alpha = 0.05$	Minimum sample dimension n_{min}			
			s		s_{max}	
			$L_{Aeqd} - L_{Aeq24}$	$L_{Aeqn} - L_{Aeq24}$	$L_{Aeqd} - L_{Aeq24}$	$L_{Aeqn} - L_{Aeq24}$
P1	13	2.18	0	5	1	6
P2	22	2.08	0	6	0	21

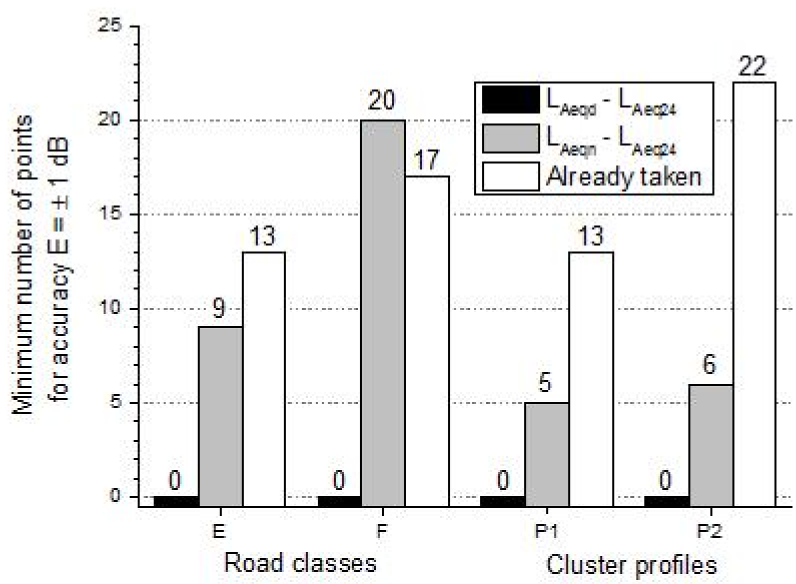

Fig. 5. Comparison between the minimum sample dimensions as calculated for the legislative classification of roads and the cluster profiles

The data-base used to set up the proposed procedure for classifying roads in urban areas based on their noise immission is rather limited in number of sites and refers to the city of Milan only. Thus, it can be considered only as a preliminary step towards collecting a wider data set more representative of the road traffic reality in Milan.Notwithstanding, the cluster profiles procedure performs better than that based on legislative road classification and, at least for the estimate of the mean value of L_{Aeqn} - L_{Aeq24}, the proposed procedure looks to be promising, as it requires a lower number of monitoring sites than those demanded by the legislative road classification.

Of course, due to the nature of current samples, the results at this stage cannot be generalized to the entire road network of Milan and, even more, to other cities. For this reason, road traffic noise monitoring is still in progress to enlarge the data base and refining the results and improving their statistical robustness.Thus, the proposed procedure should be viewed as a methodological approach hopefully to stimulate its further applications in other cities to look at differences and commonalities.

To illustrate the features of the proposed procedure, the 24 h L_{Aeqh} values monitored in seven roads not included in the dataset used for developing the procedure have been considered as test cases. The main characteristics are given in Table 7. Both the procedures based on legislative road classification and cluster profiles have been applied and the results compared, as reported in Table 7 in terms of the differences between estimated and measured values. The hourly L_{Aeqh}

Table 7. Main characteristics of the seven test sites and results of procedures

Test site	*Legislative road class*	*Traffic flow rate at rush hour (7:30-8:30 a.m.) [vehicles/h]*	*Cluster profile*	*Estimated (e) – measured levels (m) [dB]*			
				Cluster profile		*Road class*	
				L_{Aeqde} - L_{Aeqdm}	L_{Aeqne} - L_{Aeqnm}	L_{Aeqde} - L_{Aeqdm}	L_{Aeqne} - L_{Aeqnm}
1	*E*	*2083*	*P1*	-0.18	0.47	1.11	0.26
2	*E*	*1191*	*P2*	0.11	0.03	-0.26	1.06
3	*E*	*4394*	*P1*	0.04	0.04	1.33	-0.17
4	*E*	*2918*	*P1*	-0.53	1.29	0.76	1.08
5	*F*	*1350*	*P2*	0.18	-0.68	0.54	-1.06
6	*F*	*708*	*P2*	0.43	0.01	0.79	-0.62
7	*F*	*895*	*P2*	0.80	0.00	1.20	-1.00
			Median	0.11	0.03	0.79	-0.17

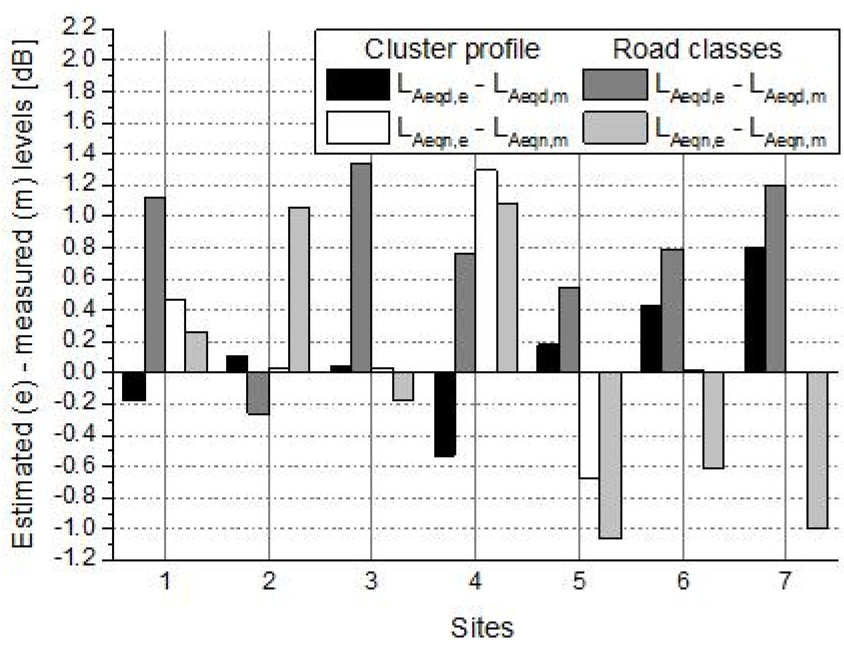

Fig. 6. Differences between estimated and measured values of LAeqd and LAeqnobtained by both procedures applied to test sites

measured at the hourly intervals at which the RMSE was the lowest (see § Results & Discussion) have been considered for the cluster profiles procedure and kept for the legislative road classification procedure too. Then the estimate of both L_{Aeqd} and L_{Aeqn} have been calculated according to the profile. As can be seen from the median values in Table 7 and from the bar plot in Fig. 6, the cluster profiles procedure performs better than that based on legislative road classification.

CONCLUSIONS

The average profiles obtained by cluster analysis applied to the 24h continuous monitoring of the hourly equivalent levels LAeqhof urban road traffic noise only partially match the legislative road classification, most likely because the latter, on the contrary of the former, often do not correspond to the actual use of the road in the urban mobility network. This positive feature of the cluster profiles can be usefully applied in the stratified spatial sampling in order to improve its efficiency, i. e. reducing the monitoring points required to estimate the mean values of L_{Aeqd}-L_{Aeq24}or L_{Aeqn}- $L_{Aeq24}$with a predetermined accuracyE. In the preliminary available data, only the road traffic flow at the morning rush hour (7:30-8:30 a.m.) was known and the ROC analysis has given the value of 1500 vehicles/hour as discrimination between the two clusters.

Of course, the outcome of this preliminary study cannot be generalized straightforwardly, and it should be compared with those from other surveys carried out or planned in other cities, both in Italy and foreign countries.In addition, further data, especially dealing with traffic flow, are planned to be considered to get more insights in clustering and application of profiles. Notwithstanding the proposed procedure, even though at this preliminary stage, shows its potentialin being a tool to improve the efficiency of stratified spatial sampling of road traffic noise and saving resources.

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