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Noise Low Emission Zone implementation in urban planning: results of monitoring activities in pilot area of LIFE MONZA project

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ABSTRACT

The main objective of LIFE MONZA (Methodologies fOr Noise low emission Zones introduction And management) concerns an easy-replicable method for the identification and management of the Noise Low Emission Zones, urban areas subject to traffic restrictions, whose impacts and benefits regarding noise issues are testing in the pilot area of the city of Monza, located in North Italy. Noise LEZ has been introduced in Libertà district, by *top-down actions* (infrastructural interventions) and encouraging an active involvement of the people, in the definition of a more sustainable lifestyle (*bottom-up actions*). Monitoring activities in pilot area regarding noise, air quality and the wellbeing conditions of the citizens have been carried out, and they are still ongoing, before and after the Noise LEZ implementation and the available results are described in this paper, in order to discuss and to evaluate the main effects of Noise LEZ introduction in urban planning and in lifestyle of the inhabitants.

Keywords: Noise Low Emission Zone, Noise monitoring sensors, Noise urban planning.

1. INTRODUCTION

Noise is a major environmental problem in Europe, the exposure can lead to auditory and non-auditory effects on health and traffic is the most dominant source with an estimated 100 million people affected by harmful levels. The implementation of Low Emission Zones (LEZs), urban areas subject to road traffic restrictions, primarily in order to ensure compliance with the air pollutants limit values, set by the European Directive on ambient air quality 2008/50/EC, is a common and well-established action carried out by the cities and the impacts on air quality are widely analyzed, whereas the potential benefits concerning noise have not been addressed in a comprehensive manner. LEZ implementation is the most common measure adopted in EU, considering road traffic planning and many different kinds, distinguished by vehicle types, speeds and emission standards, have been introduced in Europe, mostly in Italy and in Germany and the decision can be taken at local or national levels (1). The procedures vary widely among cities, there is a lack of a comprehensive and integrated management process, particularly regarding the environmental effects and an European policy framework is needed. LIFE MONZA aims at introducing an easy-replicable method, and related guidelines, for the identification and the management of the *Noise Low Emission Zone* (NLEZ), an urban area subject to traffic restrictions, whose impacts and benefits regarding noise issues are being analyzed and tested in the pilot area of the city of Monza, located in North Italy. *Top-down measures*

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have been carried out by the municipality, in order to turn up the pilot area of Libertà district in Monza in a permanent NLEZ, by the restriction of vehicles speed, the definition of traffic zone with forbidden access to trucks, the lanes-width reduction and pedestrian crossings introduction and the substitution of the current asphalt with a silent one. In order to involve the inhabitants of the area, *Bottom up measures*, as meetings in primary and high schools to raise awareness about noise effects, ideas contest for students, *pedibus* service for schoolchildren, have been realized. Further objectives of the project are the reduction of the noise levels in the pilot area of Libertà district, with positive complementary effects on the air quality and benefits on wellbeing conditions of the residents. The methodology that will be developed will contribute to the implementation of the EU Directive 2002/49/EC, related to the assessment and management of environmental noise (Environmental Noise Directive - END), which introduces noise action plans, designed to manage noise issues and their effects. Libertà district is identified as a hotspot in the noise action plan of Monza, characterized by significant average levels of noise pollution, affecting a large number of citizens. Concerning the EU policies, the EU Directive 2008/50/EC on ambient air quality and cleaner air for Europe considers the establishment of LEZ as a measure to be adopted in air quality action plans, whereas the END does not specify about its adoption, which can be included in traffic planning measures, as suggested by the Annex V, *Minimum requirements for action plans*. The results of the monitoring activities carried out in pilot area and the definition of criteria for NLEZ introduction and management will increase knowledge about its environmental effects, giving the opportunities to evaluate its adoption in the framework of noise action plans.

2. NOISE LOW EMISSION ZONE IMPLEMENTATION

The easy-replicable method for the introduction and management of NLEZ is being tested in the pilot area of the city of Monza, located in Libertà district, a densely populated zone of about 15.000 inhabitants, placed in the North-East side of the city of Monza, crossed by a major road (Viale Libertà), used, inappropriately, as one of the most important access roads to Monza and to Northern surrounding cities from the Eastern neighboring area. Considering the buffers of 30 meters from Viale Libertà, almost all the receivers are exposed to levels higher than 65 dB(A) Lden, and higher than 55 dB(A) Lnight, identifying the area as a hotspot in the noise action plan. LEZ introduction in urban areas has a direct impact on the citizens' habits and quality of life and, in order to facilitate the dialogue between the municipality and the residents, two groups of actions have been foreseen by the project: *top-down measures*, technical interventions carried out by public bodies and able to turn up the area in a permanent NLEZ, and *bottom-up measures*, people involvement in an active management system of a more sustainable lifestyle choices, related to the reduction of noise and the improvement of air quality and wellbeing conditions, in their living and working environment.

2.1 Top-down activities: infrastructural interventions for NLEZ establishment

The main *top-down measures* undertaken by the municipality of Monza for the NLEZ implementation concern the access restrictions to the transit of heavy vehicles, the speed vehicles reduction, the design of pedestrian crossings and road reshaping and the laying of new low-noise asphalt on Viale Libertà. Traffic restrictions are differently and progressively achieved: from December 2018 to June 2019, the access to Viale Libertà is restricted to vehicles over 3,5 t and from July 2019 to July 2020 is foreseen that the access will be restricted to the vehicles over 7,5 t. Two safer pedestrian crossings have been built, both to slow down the traffic flows and to safeguard the crossing to achieve schools, civic center and shops. A traffic island has been designed, and a new illuminated road sign has been installed to make pedestrian crossing more visible at night. Furthermore, a new dense-graded low-noise paving was designed, with particular reference to the types analyzed within the Leopoldo project, carried out by Tuscany Region, which provides guidelines for design, construction and maintenance of ordinary road paving. The new flooring was built in September 2018, using the typology "*Dense graded at optimized weaving*", which guarantees results of 3-4 dB in term of acoustic abatement and an efficiency period of about five years from the laying. The old asphalt of the section of Viale Libertà (Figure 1) has been removed, for a depth of 8 cm, then the laying of 4 cm of Binder, able to allow the distribution of vertical loads generated on the surface layer of the pavement to the underlying base layer and to avoid the permanent deformation of the pavement itself, has been performed, and subsequently the laying of 4 cm of *Dense Graded surface*. The *Dense Graded* types are mixtures of bituminous conglomerate with granulometric characteristics able to reduce, compared to the traditional ones, the sound emissions generated by the wheel-flooring contact.

Figure 1 – Area of the intervention for the laying of dense-graded low-noise paving in Viale Libertà

2.2 Bottom-up activities: people involvement

Public involvement constitutes one of the main roles during the implementation phases of the NLEZ. People habits and voluntary actions implemented by the citizens can produce positive effects on the achievement of the environmental targets in the urban area where they live. A more sustainable lifestyle can have productive effects on noise reduction and on air quality improvement (car-sharing, public transport, *pedibus*). Activities able to raise awareness towards noise impacts are also considered very important. The direct involvement of the inhabitants of the pilot area is also aimed at a better understanding of their requests and expectations, also regarding the acceptance of the infrastructural interventions carried out in the Libertà district in order to implement a permanent NLEZ. The main beneficiaries of the participatory approach are the residents of the pilot area and all the citizens of Monza, the students, parents and teachers of the schools placed in pilot area, the citizen associations of the city of Monza, particularly the neighborhood civic center of Libertà district, the NLEZ users, as companies and traders working in pilot area. The main activities carried out are the following: participation of some schools in the activities of Noise Awareness Days, organized by the Italian Acoustics Association; many training and information activities in different schools, concerning sound perception, noise impacts and acoustic comfort; ideas contest, dedicated to the students, for the design of a logo and a slogan for promotion of NLEZ of the Libertà district; implementation of the *pedibus* service; definition and distribution, in the ante and post-operam phase of the project, of a questionnaire on social perception of living conditions, noise, air quality and quality of life; development of a free App to be used by citizens for the management of the *pedibus* service and to provide information on the progress of the project.

3. NOISE MONITORING IN PILOT AREA

Noise monitoring has been planned in the ante and post-operam phase of NLEZ institution, by using both Class I instrumentation and a new low cost Smart Noise Monitoring System (SNMS) developed in the framework of the project. After the interventions realized in pilot area, preliminary results of noise monitoring carried out in winter period (January 2019) show a reduction in terms of sound pressure levels, measured during day period, between ante and post-operam, equal to 2 dB; during the evening and night periods the reduction is higher, until 6 dB in the night. Noise levels obtained between the two different measurement systems are coherent each other (2). Following, the SNMS network and calibration procedures will be described, as contribution for development of a shared method.

3.1 Smart Noise Monitoring System

The SNMS network is meant to adequately cover the pilot area and the different types of roads. The possibility to have a connection to the electric energy network (avoiding the use a solar panel) is considered as an added value for the selection of measuring positions.

Ten monitoring stations have been installed in the pilot area, (Figure 2). In particular, 2 microphones have been placed along the Viale Libertà, the main street where the traffic flow mix is expected to mainly change from ante to post operam scenario.

The other microphones have been uniformly distributed in other streets. The 10 control units were installed on 19-20 June 2017 and from the 20th of June 2017 are continuously monitoring noise levels. It should be noted that the systems with the name "*hc*" have been installed on the facade of public buildings such as schools and the civic center, whereas those whose name starts with the letter "*T*" have been installed on light poles.

Figure 2– Pilot Area, Libertà District in Monza. Smart Noise Monitoring System stations

The SNMS technical specifications were defined keeping in mind the aim of a long-term monitoring of acoustic parameters. These are expected to be useful to understand the variability of acoustic climate in the pilot area with mainly reference to the overall A-weighted continuous equivalent sound pressure level. According to the outcome of the state-of-the-art analysis, the main specifications of monitoring units have been defined (3). Data will be acquired with a time basis of 1 second in order to permit the recognition of unusual events in the eventual analysis phase, the sensor types are ¼ or ½ inch low-cost microphone with removable rain protection and the floor noise < 35 dB(A). Referring to the hardware components, each monitoring unit has an average variable electric absorption among 200 mW and 400 mW, depending on uplink transmitting power in function of the distance to the nearest radio base station of cellular network and the kind of used transmission protocol (2G, 3G). They thus can be powered through solar panels (size 30cm x 35cm) and an integrated power battery with the possibility of being directly connected to the electricity network. In order to obtain high performances of energy efficiency, digital MEMS microphones were used that do not require the use of an external ADC. The MEMS microphones have been adapted onto a ½ inch cylindrical plastic support to allow the insertion of a standard acoustic calibrator.

For sensors placed on façades that use power supply connection, electret microphones have been used. For reasons related to shielding for electromagnetic compatibility they have been adapted onto a ¼ inch cylindrical plastic support to allow the insertion of a standard acoustic calibrator. These units are also equipped with a low-power microcontroller able to perform, by mean of IIR digital filtering, the calculation of the A-weighted continuous equivalent sound pressure level, “LAeq”, and, by mean of FFT, of the 1/3 octave band continuous equivalent sound pressure level, “Leq”. In the usage scenario foreseen for the pilot area, the units will periodically (every hour) connect to the internet and transfer the gathered acoustic data, together with statistics on battery level and quality of the transmission signal.

The data will populate a dedicated database, optimized for handling large amounts of data. From the platform the user can download data collected by each sensor according to the LAeq, parameter also in terms of frequency bands in 1/3 octave, and in a selectable time span. Once the data for the ten sensors had been downloaded, they have been post-processed by using the Matlab software. First of all, LAeq,1s values which were lower than 35 dB and higher than 80 dB were automatically excluded as they were associated with exceptional events. It is not possible to recognize in real time exceptional events, especially due to rainy periods, but it is only possible to make a post-identification by analyzing data provided by a weather station located in the proximity of the Libertà district.

3.2 Smart Noise Monitoring System calibration procedures

The low-cost sensors challenge consists in maintaining network performance during long term periods of outdoor operation. The periodic check of the system is designed and performed to understand if the measurement accuracy is maintained in time or if sensors need to be repaired or replaced. Two system check procedures have been proposed to verify the noise monitoring system performances: a preliminary check procedure; an on-site, long-term site verification procedure. The preliminary check has been performed for a reduced time period (two months) before the official monitoring period started in the pilot area began. As preliminary check activities, the following time-stability verifications, two-weeks based, have been performed:

1 – a calibration check at the frequency 1 kHz (by using a sound pressure class I calibrator), assuming as requirements for preliminary check that the sound pressure level does not deviate more than 0.5 dB from the calibration one;

2 – a comparison between the LAeq,60s obtained from the low-cost sensors and a class I equipment referring to an environmental noise recorded in the range 45/105 dB(A) by assuming as requirements for preliminary check a difference between the two systems within 1.5 dB(A).

Referring to the long-term on-site verifications, they are planned to be performed every four months at least for two years during the noise monitoring period in the pilot area (1 year in the ante-operam scenario and 1 year in the post-operam scenario). As on-site check activities, the following time-stability verifications, four-months based, have been performed:

1 – 1 kHz calibration check: a calibration check at the frequency 1 kHz (by using a sound pressure class I calibrator), assuming as requirements for long term check that the sound pressure level does not deviate more than 1.0 dB from the calibration one. Calibration is performed by the operator by inserting the microphone into the calibrator. Given the position of the sensors at a height of 4 m from the ground, the activity requires an elevated platform or a ladder.

2 – Broad band check: a comparison between the LAeq,30s* obtained from the low-cost sensors and a class I equipment both subjected to the same broad band noise signal (e.g. pink noise produced by an electroacoustic equipment **) in the range 45/105 dBA by, assuming as requirements for long term check a difference between the two systems within 2.0 dB(A).

* This analysis also permits a check of low-cost equipment in different one-third octave band.

** For this analysis also road traffic noise is usable. In this case measurement time period should be extended up to 5-10 minutes to be significant.

In the configuration with electroacoustic source, the control is carried out from the ground. Various configurations have been studied that work for the positioning of the electroacoustic speaker on the ground but presenting a problem of interference with the noise produced by road traffic. An ad-hoc system has been designed to raise the speaker together with the class I microphone to the height of the low-cost microphone. This setup has envisaged the study of a special support on which are placed both the playback electroacoustic system and the class I microphone.

3 – Measurements to determine free field correction in order to evaluate the correction necessary to move from the sensor position to a similar free field position, in the initial phase of the monitoring, matched one-hour measurements were carried out in which the low-cost sensor measurement was matched to the one with class I instrumentation by placing the microphone near the sensor but in free field conditions, i.e. at least 1m from the pole for pole installations and 1m from the façade surface for façade installations. At the current time, six on site verifications were performed: in July and November 2017, in March and July 2018 and in January 2019. Results obtained according to the application of the 1 kHz calibration check procedures are reported. For each SNMS a check procedure by using a class I, mono-frequency (1000 Hz) calibrator has been carried out during the on-site verifications, also in order to understand if some variations in time could be highlighted. Regarding the sensors placed on poles it could be noted a reduction up to 3 dB of the calibration noise levels from the first to the second survey and, subsequently, a stabilization of the calibration values (Figure 3).

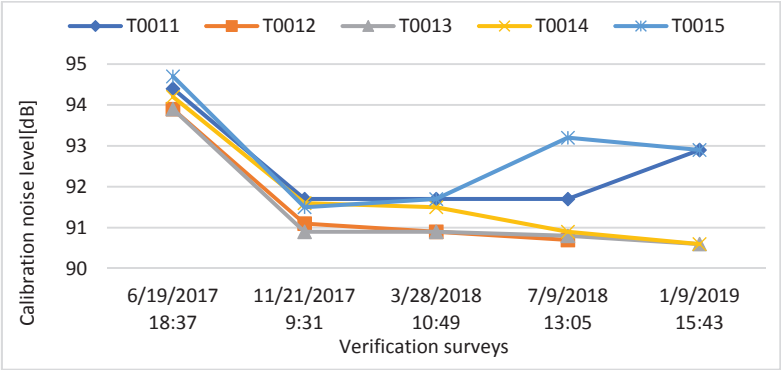

Figure 3– 1 kHz calibration check – MEMs sensors placed on poles.

It should be noted that the microphone of the smart sensor T0011 has been replaced in January 2019 before the calibration check and this could have led to an increase in the calibration noise level. Similarly, a microphone substitution has taken place in July 2018 for the smart sensor T0015. Regarding the sensors placed on building's façades (Figure 4), such trend is not evident and calibration noise levels turn out to be more constant and generally between 93 dB and 94 dB.

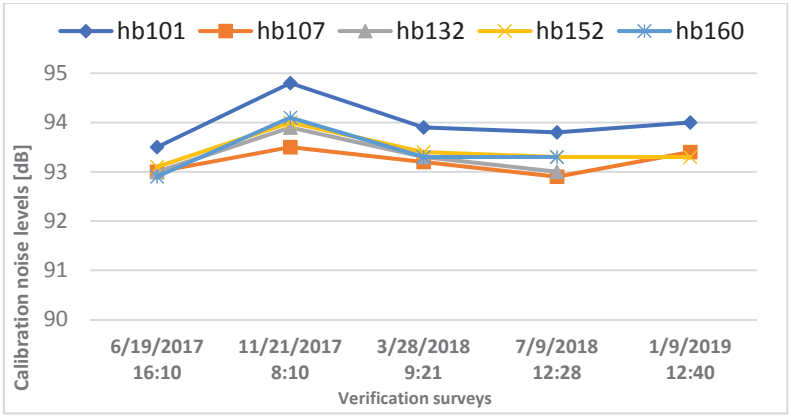

Figure 4– 1 kHz calibration check – Electret sensors placed on building's façades.

4. AIR QUALITY MONITORING AND PRELIMINARY RESULTS

Another project objective was to assess whether the implementation of the NLEZ contributes, as an ancillary effects, to reduce air pollution levels in the study area. The variation that could be due to the NLEZ implementation in the temporal profile of several pollutant will be studied by comparing co-located measurement, before and after the NLEZs zone implementation using statistical techniques aimed to remove the influence of confounding factors at local level. Four measurement campaigns were performed before the NLEZ implementation in Via della Libertà (inside the NLEZ, using a mobile laboratory) and at a fixed site, belonging to the regional air quality network, in the urban area of Monza (outside the NLEZ). Measurements lasts 3 weeks during each seasons from spring 2017 to winter 2017/2018 and will be repeated during 2019/2020 with the same schedule. Hourly (SO_2, CO, NO_2, NO_X, O_3, benzene and toluene) and daily (mass concentration of PM_{10} and $PM_{2.5}$) averages were measured using the respective European reference methods. Moreover the particle number concentration (PNC) and size distribution in the 0.3 ÷ 10 µm range, was measured with an aerosol particle sizer (Grimm 107). The mass concentration of the organic carbon and elemental carbon content in PM_{10} samples was measured by Thermo-Optical-Reflection/Thermo-Optical-Trasmission technique. Result for the ex-ante campaigns shown that the temporal pattern was, as expected, those typical of traffic road affected monitoring sites. The data collected showed a marked seasonality for NO_2, benzene, PM_{10}, $PM_{2.5}$ and Black Carbon, with much higher concentrations in the colder months of the campaign. This is due both to the additional sources present during the winter (for example heating) and to the particular meteorological conditions, more favorable to the accumulation of pollutants. The NO_2 and PM_{10} concentrations measured within and outside the NLEZ, before implementation, fall within the range of the regional variability, typically found at urban traffic stations of the Milan agglomeration. In order to compare the spatial variability of traffic related air pollutant before and after the NLEZ implementation, toluene and benzene land use regression models in a 4 km^2 around the NLEZ, will be developed. Benzene and toluene, as traffic sources indicators, were measured at 25 locations (Figure 5), using diffusive sampling technique within and outside the noise LEZ, in winter and summer (14 days each) before the noise LEZ implementation.

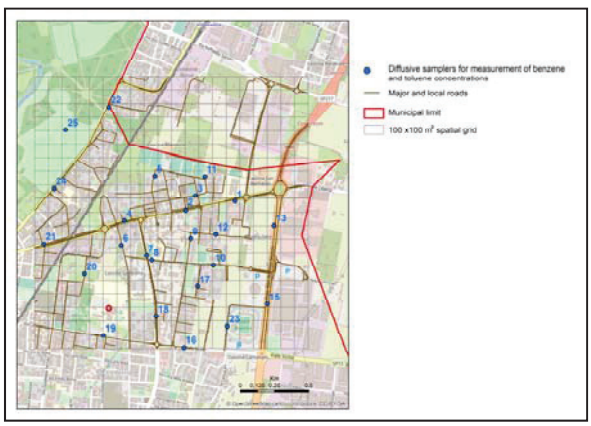

Figure 5 – Pilot area: diffusive samplers for measurement of benzene and toluene concentrations

Radiello RAD 130 were used for aromatic VOCs. Duplicate VOCs samplers, provided with weather protective shelters, were deployed at 2.5 m above the ground, placed on lamp post, utility poles or street signals then removed 14 days after their installation. Benzene mean concentration ranging between 0.20 (urban background, inside a park) and 0.83 μg/m³ (road side, Viale della Libertà 93), while in winter the range was 0.94 - 1.67 μg/m³. The 25 sampling point thus allow to capture a relevant spatial and seasonal gradient. A similar pattern was found for the mean concentration of toluene, ranging between 2.4 and 5.4 during summer, and between 2.6 and 6.0 μg/m³ in winter (4). Air quality monitoring is carried out by Lombardia Enviromental Protection Agency. The monitoring after the implementation of NLEZ is currently ongoing.

5. SURVEY ON THE PERCEPTION OF LIVING CONDITIONS, NOISE, AIR QUALITY AND QUALITY OF LIFE IN PILOT AREA

In order to study the effects of the actions foreseen by LIFE MONZA (infrastructural interventions, management methods and awareness-raising activities) on the local social system, it was decided to adopt research methods aimed at detecting, analyzing and evaluating judgments, perceptions and attitudes of the population involved, towards several aspects related to the livability of the neighborhood and the conditions of environmental and social well-being. To this end, a diachronic survey was designed and launched on the social perception of living conditions, noise and air quality in the Libertà district of Monza, by a path that includes two surveys: the first (pre-test), already carried out, aimed at defining the ex-ante situation, the second (post-test), started in the last days of April 2019, aimed at defining the conditions detectable after the implementation of the infrastructural interventions and other measures foreseen by the project, in order to evaluate the changes occurred. The pre-test questionnaires were sent by mail, through post-offices, filled in the self-administration mode and delivered directly by the respondents at collection points provided for the purpose. Furthermore, a second way to fill in the questionnaire is carried out, making it available on internet. Concerning the identification of the sample, both for the pre and post test, a random sampling strategy stratified by gender (M / F), age (18-35 / 36-60 /> 60) and positioning with respect to Viale Libertà (≤30 meters/>30 meters) has been adopted. Results of the pre-test survey can provide some evaluating aspects. The subsequent phases and, particularly, the second survey, which, as mentioned above, is still ongoing, will allow a detailed comparison between the post-intervention situation and the previous one. Despite the limited number of responses received through self-administered questionnaire, in paper or electronic format (the pre-test total involved 177 subjects, approximately 31% of cases provided by the sample project), the variety in the responses was enough to allow all comparisons and analyzes in T_0 conditions *(pre-test)* and will allow to carry them out even between T_0 e T_1 situations *(pre and post-test)*. Have been reached, in fact, all types required in the sampling plan and a certain proportionality between the different types has been respected, except for subjects living within 30 meters from Viale Libertà, who responded more consistently (97% of the original sample, whereas for those residing over 30 meters, the coverage stops at 24%). It seems likely that the daily proximity of those respondents to the most problematic road of the district makes them more sensitive to the issues to which the project is dedicated, with a consequent greater level of interest and a greater willingness to participate in the survey. The sample achieved has a significant incidence of licentiates (48.3%) and graduates (30.1%), and from the point of view of the employment conditions, it includes mainly employed persons (48.6%) and retirees (34.9%). Values related to judgments on the *quality of life in the neighborhood* have asymmetric distributions on the right (i.e. higher frequencies for high scores than for low ones). Among the explored constitutive dimensions, *safety and legality* represent the least appreciated aspect, with a higher frequency of low scores (the average of the scores expressed is equal to 5.26 out of 10, the lowest compared to the other aspects considered in the set of questions). The *hygienic conditions* and the *social relationships* are instead the aspects on which the respondents are more in agreement, with distributions of scores more concentrated and with an average that, in the case of hygienic conditions, exceeds, albeit slightly, the value of 6; the *commercial offer variety* and the *green areas* have higher but also less uniform scores and the average approximates but does not reach the sufficiency. The distribution of judgments on *quiet* does not differ much from the others; however, there is a relatively high share of 5 and 7 values at the expense of the sufficient score and high scores (8, 9 and 10), and the average value stops at 5.7. The opinions expressed on the *air quality* in the district and close to house have similar profiles, with a higher incidence for scores around 5, even if those referring to the house surroundings are slightly higher (the average values are equal, respectively,

to 4.39 and 4.54). The importance assigned to the air quality is quite high in both cases, although it is more felt if referring to the dwelling area (with the largest share of the assigned scores equal to 10) rather than to the neighborhood in general (with the highest share of assigned scores equal to 9). The difference between the two groups is less consistent when considering air quality in the neighborhood. Using two defined weighted indexes related to air quality it is possible to highlight a general worsening of the judgments. The citizens who have judged the air quality as insufficient are also those that, to a greater extent, have declared that the air quality is indeed a very important factor: those who are more dissatisfied are also more attentive and look at this environmental aspect more carefully. Most respondents (77.3%) report road private traffic as the main cause of air pollution in the neighborhood. Also for *noise*, which seems to be perceived as a prevailing problem with respect to air quality, road traffic is identified as one of the main causes (91% of respondents). The judgment on *public transport* highlights that over 33% of respondents declare themselves *very dissatisfied* (11.5%) or *dissatisfied* (21.8%), whereas the 35% consider themselves *satisfied* (32.8%) or *very satisfied* (2.3%). In Figure 6 the average score ratings on the quality of life in the neighborhood (total, for residents within and over 30 meters from Viale Libertà).

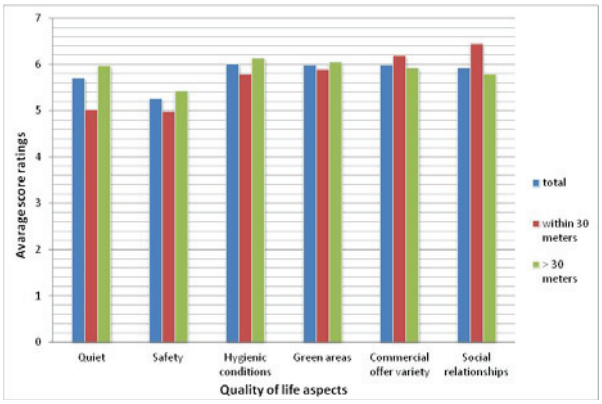

Figure 6 – Average score ratings of the quality of life aspects in the district

Just over a fifth of respondents (21.7%, 44 cases) knows LIFE MONZA; among those, the level of trust for the different aspects that the project could affect is in most cases rather moderate (the *little* and *enough* options are the most frequent choices). It is worth noting, however, that 38.1% believe that the project will have a significant impact on environmental noise, but only 11.6% of them have this opinion with respect to public transport.

6. CONCLUSIONS

LIFE MONZA objectives and monitoring activities carried out in pilot area have been described. Positive preliminary results, due to both *top-down* and *bottom-up measures* implementation can be found, especially concerning noise impact. The completion of all monitoring campaigns and surveys even in post-operam phase will allow a completed and more detailed evaluation of the project actions.

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