LIFE E-VIA

“Electric Vehicle noIse control by Assessment and optimisation of tyre/road interaction”

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List of keywords and abbreviations

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Executive Summary

Briefly describe the project objectives, key deliverables and outputs in 1-3 pages.

Compare in a few paragraphs the activities planned to the progress made. Summarize the achievements, deviations, important problems and difficulties met during the project implementation. This summary should be a stand-alone text.

1 Introduction

1.1 The pilot case in Florence and Action B5

Action B5 is strictly related to the Project Objective n.5 dealing with the possibility of raising people's awareness on noise pollution and health effects and investigating people's perception regarding noise applying the soundscape methodology.

Specifically, Action B5 is dedicated to the implementation of a soundscape holistic approach to assess the benefits of the intervention carried out in the pilot road (Paisiello Street) and to raise participants awareness of the issue of traffic noise and the possible solutions offered by the increase in the use of electric vehicles and high-performance road pavements.

The abovementioned intervention refers to the re-pavement of a section of Paisiello street with an innovative low-noise asphalt, developed in the frame of the project, aiming to reduce traffic noise pollution (Figure 1). It is important to note that Paisiello street is characterized by a significant housing density and by a high level of traffic caused to its proximity to the Florence city center and to public offices (e.g. Regional Agency for Environment Protection ARPAT).

Figure 1 - The Pilot case in Florence

The intervention was carried out in mid July 2021 (Figure 2 The re-pavement of the Pilot streetFigure 2).

Figure 2 The re-pavement of the Pilot street

Action B5 is split into 3 sub-actions:

- B5.1 Soundwalks and interviews in the pilot area
- B5.2 Interview in the pilot road on an electric vehicle “taxi”
- B5.3 Ante and post operam interviews with residents

The following sections will present in detail how the three sub-actions were designed and expose the results of the interviews and survey conducted in each sub-action.

All the 3 sub-actions deal with the application of an holistic soundscape approach. Indeed, recent studies demonstrate that, in addition to the need to ensure noise levels complying with the values set out in the WHO guidelines (2018), it is very important to assess whether certain interventions are able to improve the perception of the soundscape by citizens. Notably, by using soundwalk holist approach scholars have pointed out that in some cases (post operam scenario) even if the noise levels are maintained or only slightly reduced with a change in the type and spectral characteristics, significant improvements in the soundscape's perception are detected.

2 Sub Action 5.1: soundwalks and interviews

2.1 Introduction

In order to assess the benefits of repaving a stretch of road with the optimised asphalt from the point of view of subjective perception and to involve the population, soundwalks and interviews were organised in the area. In particular, the experiences included:

(i) soundwalks with 5 listening points, with the aim of assessing the participants' perception of environmental noise;
(ii) binaural headphone listening of 4 audio recordings to assess the perceived soundscape inside a vehicle

A soundwalk is an excursion on foot with the intention of listening closely and consciously to sounds (Tausig, 2011). It is a practice that involves walking and listening and provide participants with a unique sensory experience that goes beyond the visual, physical features of a specific space. Generally, the essential purpose of a soundwalk is to encourage the participant to listen discriminately, to make a critical judgement about the sounds heard and their contribution to the balance or imbalance of the acoustic environment. Specifically, in this context, the soundwalk has been designed as a method to evaluate participants' perceptions of the soundscape (external/environmental noise) in selected locations close to the pilot area (including the sections of the pilot street.

Concerning binaural headphone listening of recordings, participants to soundwalks have been asked to listen to audio recordings made inside an EV and ICEV passing through different stretches of the pilot road with different type of asphalt pavements (see section 2.2.2 for details) and evaluate the quality of the soundscape. This experience was foreseen in order to analyse differences in terms of perception between the external perception of the soundscape (as assessed during soundwalks) and internal noise/soundscape inside a vehicle.

A questionnaire was designed and submitted to participants to be filled in during each experience.

2.2 Methods

2.2.1 Soundwalks

The soundwalks were organized in the area surrounding the project pilot street.

Concerning the itinerary of the soundwalk, 5 significant locations were selected (. Specifically:

- Listening point n.1 in a quiet area inside a garden of an association and close to sport facilities;
- Listening point n.2 at the section of the pilot street repaved with the optimized asphalt;
- Listening point n.3 at the section of the pilot street repaved with standard asphalt;
- Listening point n.4 in a street parallel to the pilot street;
- Listening point n.5 in the patio of an ex industrial renovated space (Manifattura Tabacchi)

Figure 3 -Soundwalks itinerary - 5 Listening Points

Each soundwalk was structured as follows:

1. Brief introduction to the soundwalk and to the LIFE E-VIA project;
2. Ear cleaning exercises;
3. Walk in silence with stops at the listening points;
4. At each listening point: listening in silence to the surrounding soundscape (3-4 minutes) and successively filling in the section of the questionnaire concerning each location;
5. Conclusion.

As regards ear cleaning exercise, they were designed based on a literature review in the field (Schafer, 1992) to help participants training conscious listening. Indeed while hearing is an automatic skill, listening requires a certain level of concentration and engagement with the surrounding environment (Çağlar, 2021). During the exercise participants are asked to focus on and write down different type of sounds perceived in the soundscape around them (specifically, pleasant/unpleasant, close/distant, in motion/static, natural/mechanical/anthropic sounds) and then to follow a sound source with closed eyes.

2.2.2 Audio recordings

Four different type of recordings were carried out and

1. Inside an ICEV while passing through a section of the road with Optimized Asphalt
2. Inside an EV - Optimized Asphalt
3. Inside an EV – New but standard Asphalt
4. Inside an ICEV - New but standard Asphalt

2.2.3 Questionnaire design

Section	**Question**
Personal Information	Age
	Gender
	Education
	Occupation
	City of residence
	Nationality
	Familiarity with the place
	Frequency
	Reasons
	Personal sensitivity to noise
Ear cleaning exercise	Sounds identification
Listening points (5 sections, one for each listening point)	Intensity of sounds
	Quality of soundscape
	Appropriateness of soundscape
	Characteristics of soundscape
	Quality of urban landscape
Audio recordings Vehicle-road interaction (1 question for each audio recording)	

2.3 Results

2.3.1 Results of the soundwalks' survey

Quanto é durato e da chi sono state fatte

2.3.2 Participants' evaluation of audio-recordings

3 Sub Action 5.2: interviews on an electric taxi

3.1 Introduction and method

3.2 Analysis of qualitative interviews

4 Sub Action 5.3: ante and post operam interviews with residents

4.1 Introduction

In the frame of Action B5, Sub-Action 5.3, we conducted a survey to evaluate citizens' responses to the project's interventions carried out in the pilot case in Florence (Paisiello Street). It is important to refer that the pilot case foreseen in the original project proposal changed.
Originally, it was foreseen to carry out an interview campaign with a semi-random sample of at least 100 people to be identified, by voluntary adherence, on one or more electric bus lines the route of which involved the passage on different types of asphalt (old, normal, optimized). In the new pilot street, selected after the writing of the proposal, no bus lines are present; consequently, the typology of survey and the questionnaires foreseen for the original pilot case were modified accordingly. In particular, instead of carrying out the survey on electric busses, an ante and post operam questionnaires have been designed and submitted to Paisiello street's residents to evaluate their soundscape perception before and after the interventions carried out in the frame of the LIFE E-VIA project (Action B.3). The main aim of the survey was to evaluate the improvement of acoustic perception related to the implementation of the noise optimized asphalt with respect to a standard one (hereafter also referred to as "the intervention").

4.2 Survey design

4.2.1 Ante operam questionnaire: design and distribution

The structure of the ante operam questionnaire consists of 16 questions divided into two sections. The first section on "Personal information", composed of 6 questions, was designed to collect data in relation to age, gender, education, occupation, city of residence and nationality of the respondents. The second section is composed of a set of 10 questions focusing on: i) dwelling location and windows orientation; ii) feelings regarding soundscape and landscape perception and noise annoyance; iii) expected effects of interventions and noise reduction; iv) sensitivity to noise.
The questions included in the questionnaire are closed-ended questions, in particular most of them are multiple-choice questions where only one answer can be selected. In specific cases, Matrix questions, a group of questions displayed in a matrix form were employed. Regarding the scales used in the questionnaire, eight questions adopted a Likert scale: two five-point Likert scale questions and six eleven-point Likert scale questions. Specifically, in one matrix question a five-point scale, ranging from "very low" to "very high", was provided to allow respondents to assess the intensity of external sounds perceived from dwelling (question D3, see Table 1). Moreover, in another matrix question, which focuses on the characteristics of the soundscape, a five-point scale ranging from "strongly disagree" to "strongly agree" was adopted. In addition, in six questions a scale ranging from 0 to 10 was employed to allow respondents to evaluate respectively: the quality of the soundscape (D4), the appropriateness of the soundscape (D5), the quality of urban landscape (D7), the importance of the effects of planned interventions for noise reduction on the value of the property (home/apartment) (D8) and on health (D9), personal sensitivity to noise (D10).
The schematic structure of the ante operam questionnaire is displayed in table 1. The full questionnaire template, translated in English language and including an introductory section presenting the project and the survey, is made available in Appendix I.

Section	Question	Question code
Personal Data	Age	I1
	Gender	I2
	Education	I3
	Occupation	I4
	City of residence	I5
	Nationality	I6
Dwelling Information	Windows orientation	D1
	Rooms with windows on Paisiello street	D2
Perception of Soundscape and Landscape	Intensity of sounds	D3
	Quality of soundscape	D4
	Appropriateness of soundscape	D5
	Characteristics of soundscape	D6
	Quality of urban landscape	D7
Expected effects of planned interventions	Effects on home value	D8
	Effects of noise reduction on health	D9
Sensitivity to noise	Personal sensitivity to noise	D10

Table 1 Structure of ante operam questionnaire

Before administering the questionnaire, a pilot test was carried out among a small group of colleagues who do not work in the field of acoustics. Good feedbacks as regards the structuring and understanding of the questions were given.

An informative letter (Figure 4) was provided to residents in the section of street selected for the re-paving intervention with noise optimized asphalt (**Errore. L'origine riferimento non è stata trovata.**) on the 5th of July 2021, a couple of days before the questionnaires' delivering. The letter presented the LIFE E-VIA project and its objectives and the main aim of the questionnaire to be delivered. Residents were selected as the survey target group as they are expected to be the main beneficiaries of the project intervention in terms of traffic noise reduction.

Successively, the questionnaire in Italian language was distributed door-to-door. Specifically, 92 ante-operam questionnaires were delivered between the 7th of July and the 9th of July 2021.

Figure 4 Informative letter

4.2.2 Post operam questionnaire: design and distribution

The structure of the post operam questionnaire consists of 18 questions divided into two sections (see Table 2). The first section was designed to collect data on personal information. The second section is composed of a set of 12 questions focusing on: i) dwelling location and windows orientation; ii) feelings regarding soundscape and landscape perception and noise annoyance; iii) traffic noise; iv) effects of interventions; v) sensitivity to noise.
The schematic structure of the ante operam questionnaire is displayed in table 2, while the full questionnaire template, translated in English language, is made available in Appendix II.
Fourteen questions are the same questions asked in the ante operam questionnaire, specifically: the set of questions of the section on personal data (I1-I6) and on dwelling information (D1-D2), the set of questions on soundscape and landscape perception (D3- D7) and the last question on personal sensitivity to noise (D12). This allows for a direct comparison of the answers given by respondents in the ante operam questionnaire with the answers to the post operam questionnaire that follows the implementation of the low noise asphalt in the selected section of Paisiello street. The specific section that focuses on the perceived effects of the concluded intervention is composed of questions that aims to evaluate: i) the type of effects (positive or negative) of the implementation of the new asphalt on the traffic noise perceived from home; ii) the effects of the intervention on the value of respondents' home and on their health. This section is preceded by a question on the changes of traffic noise perceived in the previous month (following the intervention).
As regards the Likert scales adopted, in the questionnaire there are two matrix questions using a five-point scale and eight questions with an eleven-point scale (from "0" to "10"). As an example, the section aiming to assess the effects of repaving the road with a low noise asphalt includes three questions adopting an eleven-point Likert scale (D9- D11).

Section	Question	Question code
Personal Data	Age	I1
	Gender	I2
	Education	I3
	Occupation	I4
	City of residence	I5
	Nationality	I6
Dwelling Information	Windows orientation	D1
	Rooms with windows on Paisiello street	D2
Perception of Soundscape and Landscape	Intensity of sounds	D3
	Quality of soundscape	D4
	Appropriateness of soundscape	D5
	Characteristics of soundscape	D6
	Quality of urban landscape	D7
Traffic Noise	Perceived changes in traffic noise	D8
Effects of interventions	Effects on traffic sounds	D9
	Effects of on property value	D10
	Effects on personal health	D11
Sensitivity to noise	Personal sensitivity to noise	D12

Table 2 Structure of the post operam questionnaire

101 post-operam questionnaires were distributed door-to-door between the 15th and the 17th of September 2021, that is two months after the installation of the low-noise asphalt.

4.3 Results

4.3.1 Descriptive analysis

Descriptive analysis has been adopted as initial approach for the quantitative analysis of collected data. This type of analysis allows the transformation of raw data into a form that makes them easy to understand and manipulate in order to generate deeper information.

4.3.1.1 Ante operam results

The total number of questionnaires distributed door-to-door was 92; 56 completed ones were returned, giving a response rate of roughly 60%.

Concerning the section on "personal data", the results show that the number of male participants is almost the same of female ones (27 versus 28) and the majority of the respondents are in an age range between 41 and 65 years (Table 3). A great majority of the respondents, corresponding to approximately 78%, have at least a high school diploma (Table 4). Moreover, as regards their occupation, the largest group, 22 out of the total of 56 respondents, corresponds to people who are employees in the public or private sector. In addition, a significant share of the sample, 21% of the total, is a retired person (Table 6). The great majority of respondents are Italian citizens, resident in Florence (Table 7; Table 5).

Note that in each table and graphic, answers not provided by respondents for each specific question are indicated as "NA": not answered.

Age	
Options	*Frequency*
18-25	4
26-40	9
41-55	17
56-65	14
66-75	8
>75	4

Table 3 Respondents' age (ante operam - AO)

Education	
Options	*Frequency*
Primary School	2
Middle School	5
High School	20
Bachelor's Degree	20
Ph.D	1
Master	3
N/A	5

Table 4 Respondents' level of education (AO)

Occupation	
Options	*Frequency*
Employee	22
Self-employed	11
Retired	12
Student	3
Other	4
N/A	4

Table 6 Respondents' occupation (AO)

City of residence	
Options	*Frequency*
Florence	51
Other	4
N/A	1

Table 7 Respondents residence (AO)

Nationality	
Options	*Frequency*
Italian	53
Other	2
N/A	1

Table 5 Respondents nationality (AO)

Concerning the section on dwellings, almost all the respondents (54 out of 56) live in a house or apartment with windows overlooking the pilot case street (Paisiello street) (Table 8). Specifically, the bedroom and the living room are the rooms which in most cases have the windows orientated on Paisiello street (Table 9).

House with windows overlooking the street	
Options	*Frequency*
Yes	54
No	2
N/A	0

Table 8 Dwelling location (AO)

Rooms overlooking the street	
Options	*Frequency*
Bedroom	39
Single bedroom	22
Living room	41
Kitchen	13
Bathroom	10
Other	9

Table 9 Rooms overlooking the street (AO)

The great majority of the respondents (89%) thought that the interventions planned to reduce noise could increase the value of their property (Figure 5). Additionally, a slightly narrower majority of the respondents (84%) answered that the reduction of noise levels close to their home could positively affect their health, selecting a value ranging from 7 to 10 on an eleven-point scale (Figure 6).

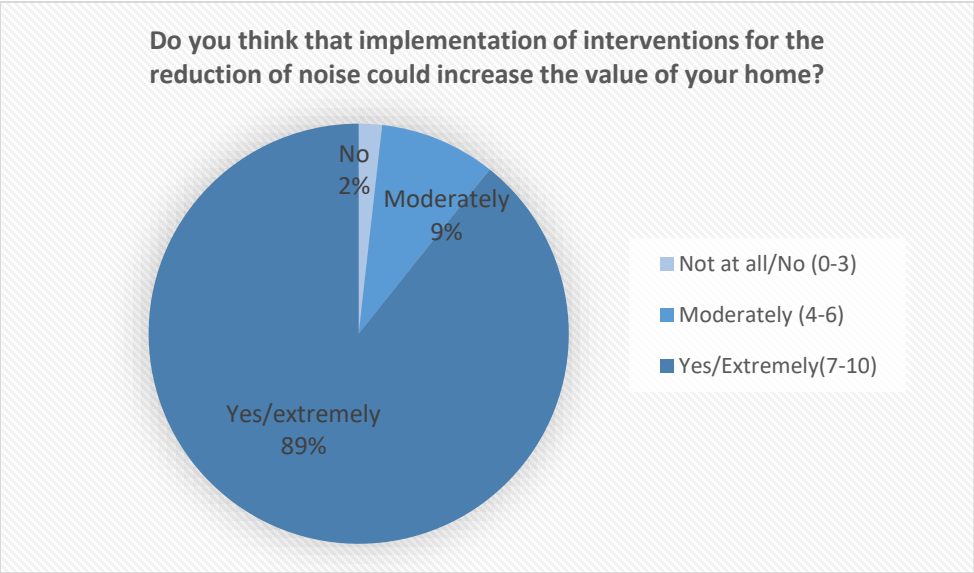

Figure 5 Expected effects of interventions on home value (AO)

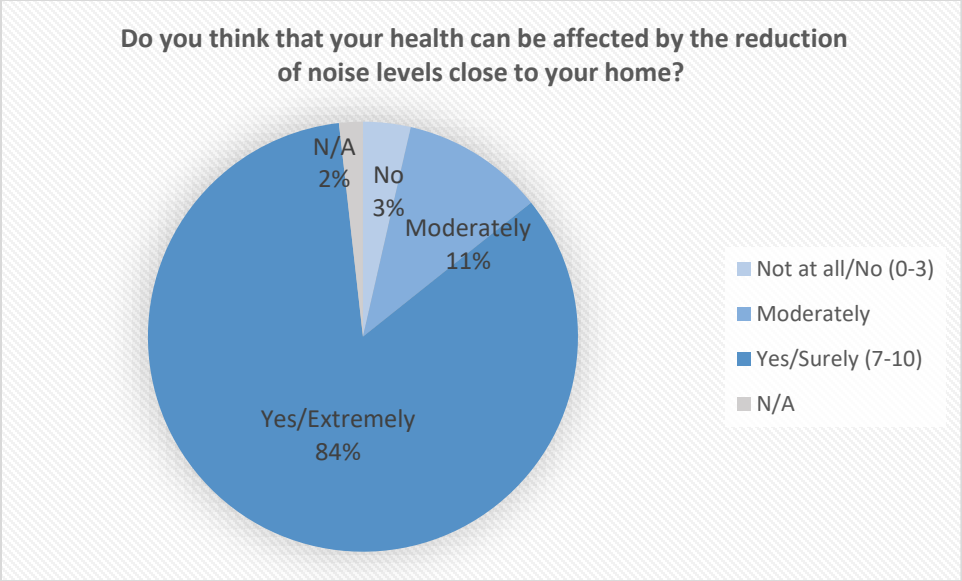

Figure 6 Expected effects of interventions on health

Table 10 shows the frequency of answers to the last question “how do you assess your sensitivity to sounds?”. It is important to note that 29 respondents out of 56 assessed their sensitivity to sounds selecting a value ranging from 8 to 10 in an eleven-point scale, corresponding to an “high” and “very high” sensitivity.

Noise sensitivity

Options	*Frequency*
0 (very low)	0
1	1
2	1
3	0
4	1
5	7
6	5
7	12
8	10
9	6
10 (very high)	13
N/A	0

Table 10 Respondents' noise sensitivity (AO)

The remaining results of the ante operam questionnaire that refer to the section focusing on citizens perception on soundscape and urban landscape will be presented in paragraph 1.3.1.3 on comparative analysis. Here they will be compared to the answers given to the same set of questions present in the post operam questionnaire.

4.3.1.2 Post operam results

The total number of the post operam questionnaires distributed door-to-door was 101; 56 completed ones were returned, giving a completion rate of roughly 55%.

The number of female respondents is slightly higher than the number of male participants (29 versus 26). The majority of the respondents are in an age range between 41 and 75 years (**Errore. L'origine riferimento non è stata trovata.**), and approximately 71% of the sample has at least a high school diploma (Table 12). As regards their occupation, the largest group, 22 out of the total of 56 respondents, corresponds to retired people, the second group in term of frequency consists of people who are employees in the public or private sector (**Errore. L'origine riferimento non è stata trovata.**). The great majority of respondent are Italian citizens, resident in Florence (**Errore. L'origine riferimento non è stata trovata.**; **Errore. L'origine riferimento non è stata trovata.**).

Age	
Options	*frequency*
18-25	4
26-40	9
41-55	16
56-65	9
66-75	12
>75	6

Table 11 Respondents' age

Education	
Options	*Frequency*
Primary School	6
Middle School	7
High School	23
Bachelor's Degree	14
Ph.D	1
Master	2
N/A	3

Table 12 Respondents' education level (PO)

Occupation	
Options	*Frequency*
Employee	16
Self-employed	7
Retired	22
Student	3
Other	7
N/A	1

Table 13 Respondents'occupation (PO)

City of residence	
Options	*Frequency*
Florence	53
Other	3
N/A	0

Table 15 Respondents' residence (PO)

Nationality	
Options	*Frequency*
Italian	49
Other	6
N/A	1

Table 14 Respondents' nationality (PO)

Concerning the section on dwellings, a great majority of the respondents (48 out of 56) live in a house or apartment with windows overlooking the pilot case street (Paisiello street) (**Errore. L'origine riferimento non è stata trovata.**). Specifically, the bedroom and the living room are the rooms which in most cases have the windows orientated on Paisiello street (Table 17).

House with windows overlooking the street	
Options	*Frequency*
Yes	48
No	8
N/A	0

Table 16 Dwellings location (PO)

Rooms overlooking the street	
Options	*Frequency*
Bedroom	27
Single bedroom	15
Living room	34
Kitchen	12
Bathroom	8
Other	10

Table 17 Rooms ovelooking the street (PO)

Noteworthily, according to 61% of the respondents to the post operam questionnaire, the perceived traffic noise had decreased during the preceding months (Figure 7). Indeed, the majority of the sample selected a value between 6 and 10 in an eleven-point Lickert scale. Moreover, a significant majority of the respondents (77%) positively assessed the effects of the re-paving of Paisiello road with a low noise asphalt (Figure 8). In particular, 31 respondents out of 56 valued the beneficial effect selecting a value between 8 and 10 (Table 18 Frequency of the evaluation of project's interventions (PO)Table 18). The number of the respondents that assessed the project interventions as negative, is very low (2 respondents).

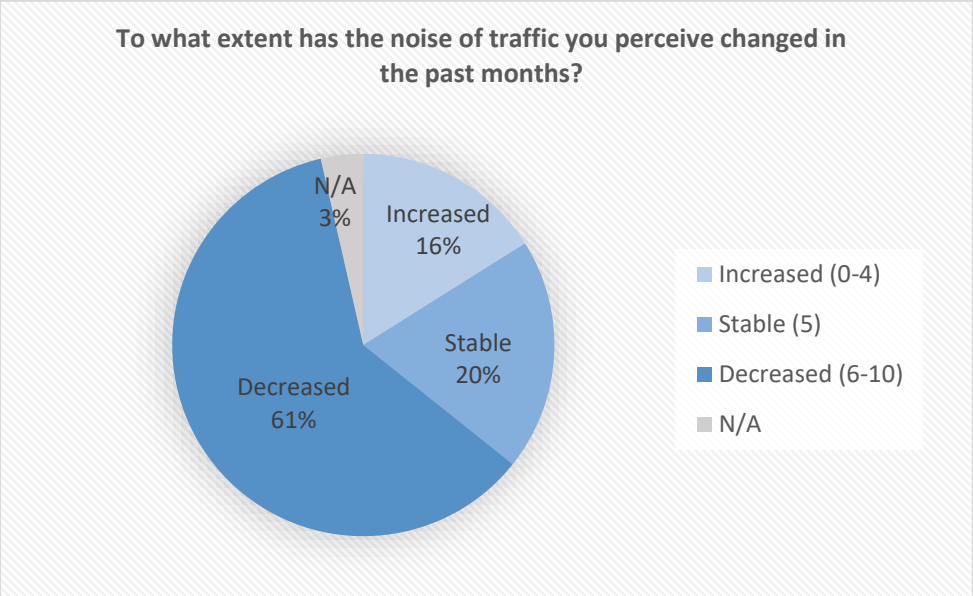

Figure 7 Changes in traffic noise (PO)

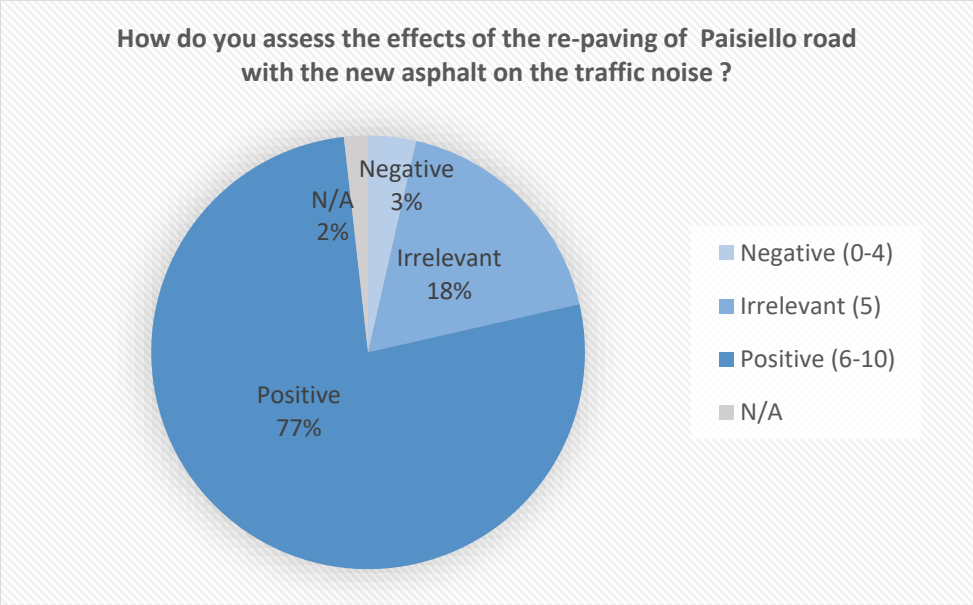

Figure 8 Evaluation of the effects of project's interventions (PO)

How do you assess the effects of re-paving of Paisiello road with the new asphalt, on the traffic noise?												
Options	0	1	2	3	4	5	6	7	8	9	10	N/A
Frequency	0	0	1	0	1	10	8	4	22	7	2	1

Table 18 Frequency of the evaluation of project's interventions (PO)

As regards the specific effects of the interventions, according to 32% of the subjects the implementation of the low-noise asphalt has increased the value of the property (house or apartment), while 53% of the respondents though that the value of the property had moderately increased (Figure 9). Moreover, 53% of the respondents thought that the reduction of noise levels close to their home, caused by the use of the new type of asphalt, will have positive effects on their health (Figure 10).

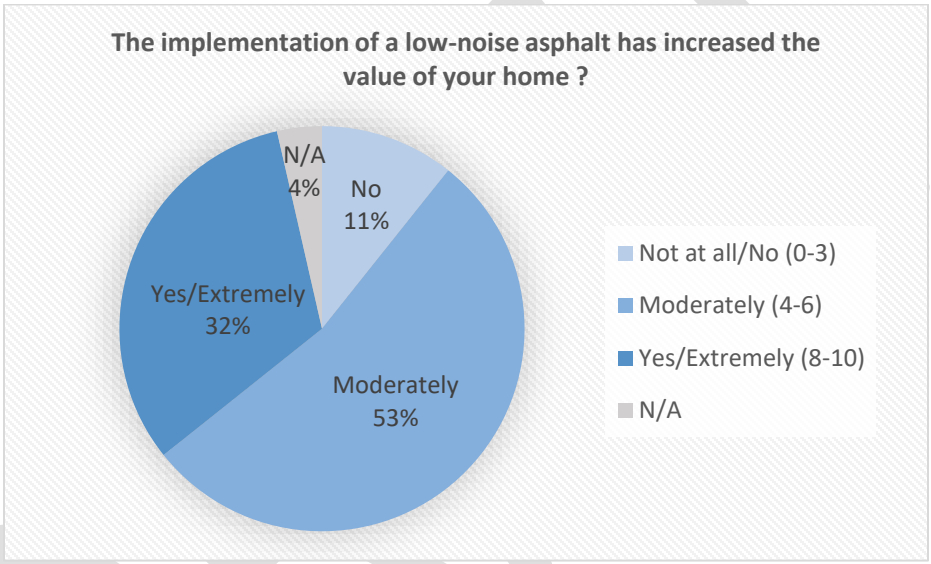

Figure 9 Effects of project interventions on home value (PO)

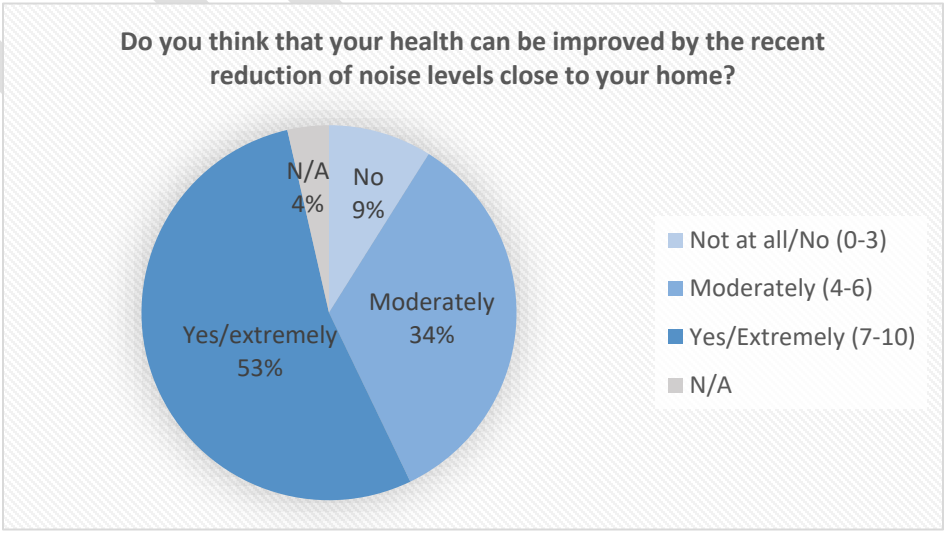

Figure 10 Effects of project interventions on health (PO)

As shown in Table 19, sensitivity to sounds is assessed by most of the respondents (45 subjects out of 56) with a value higher than “5”, on an eleven-point scale.

Noise sensitivity

Options	*Frequency*
0 (very low)	0
1	0
2	2
3	1
4	1
5	6
6	11
7	12
8	12
9	6
10 (very high)	4
N/A	1

Table 19 Respondents noise sensitivity (PO)

4.3.1.3 Comparative analysis

In this paragraph, a comparative analysis of the same questions included in the ante operam and post operam questionnaires will be provided.

In the ante operam period traffic noise was well perceived. As showed in Figure 11 and displayed in Table 20, 22 subjects out of 56 defined this type of sound as “very high”. In the post operam period, the number of people who perceived traffic sound as “very high” and “high” considerably decreased; indeed, results show a reduction of respectively -64% and -26% compared to the results of the ante operam questionnaire. Concurrently, residents who assessed the traffic sounds as “low” has quintupled following the implementation of project interventions, compared to the ante operam period. This is in line with the answers given to the question included in the post operam questionnaire “to what extent has the noise of traffic you perceive changed in the past months?” (see the above Figure 7 Changes in traffic noise (PO))

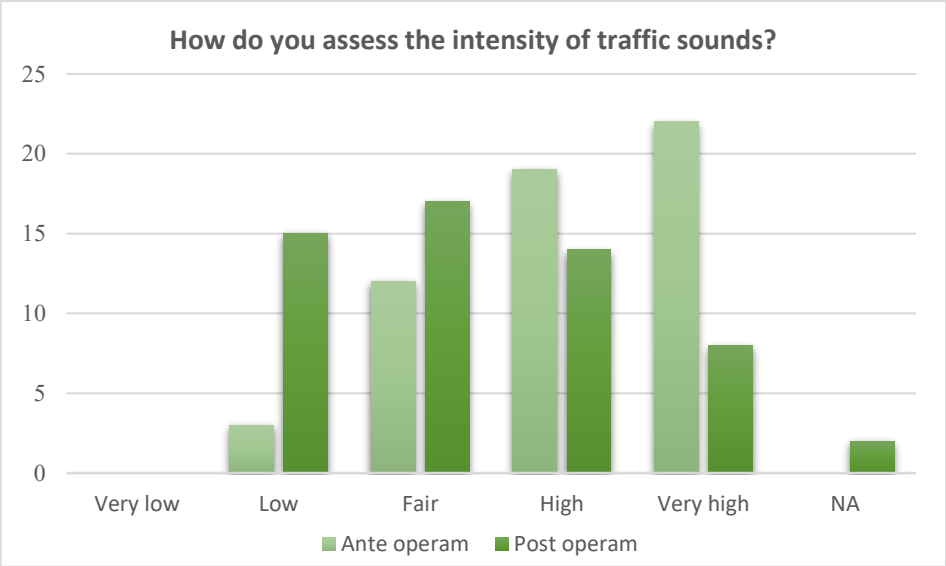

Figure 11 Intensity of traffic noise (AO-PO)

How do you assess the intensity of traffic sounds in the soundscape around you?		
Options	Ante operam questionnaire	Post operam questionnaire
Very Low	0	0
Low	3	15
Fair	12	17
High	19	14
Very high	22	8
N/A	0	2

Table 20 Intensity of traffic sounds - frequency distribution (AO-PO)

As regards the perception of technological sounds (e.g. sounds of sirens, constructions etc.), after the implementation of the low-noise asphalt, respondents who evaluated this type of sounds as “very high” decreased from 8 to 1 subjects (Table 22). Instead, Table 21 shows that the evaluation of anthropic sounds (e.g. voices, steps, children etc.) by respondents did not change significantly. If we take into consideration the sum of subjects who evaluated this type of sounds as “fair”, “high” or “very high” we observe a relatively small decrease of their number after the realization of the intervention. As displayed in Table 23, the perception of nature sounds did not significantly change; both in the ante operam period and in the post operam period most of the respondents assessed this type of sound in the soundscape close to their home as “low” or “fair”.

How do you assess the intensity of technological sounds in the soundscape around you?		
Options	Ante operam questionnaire	Post operam questionnaire
Very Low	7	5
Low	16	25
Fair	16	13
High	6	8
Very high	8	1
N/A	3	4

Table 22 Intensity of technological sounds (AO-PO)

How do you assess the intensity of anthropic sounds in the soundscape around you?		
Options	Ante operam questionnaire	Post operam questionnaire
Very Low	1	5
Low	27	24
Fair	17	17
High	7	7
Very high	3	1
N/A	1	2

Table 21 Intensity of anthropic sounds (AO-PO)

How do you assess the intensity of nature sounds in the soundscape around you?		
Options	Ante operam questionnaire	Post operam questionnaire
Very Low	8	7
Low	31	27
Fair	10	16
High	6	3
Very high	0	0
N/A	1	3

Table 23 Intensity of nature sounds (AO-PO)

Concerning the question “how do you assess the quality of the soundscape around you?”, we observe a significant reduction of respondents who evaluated the soundscape as a low-quality soundscape, rating it with a value ranging from 0 to 4 on a eleven-point scale (Figure 12). In particular, while before the intervention the highest share of respondents evaluated the quality of the soundscape close to their home as very bad or bad, after the repaving of the street the highest share of respondent evaluated it as fair.

Similarly, Figure 13 shows that the appropriateness of the soundscape has enhanced. While before the intervention 6 subjects out of 56 assessed the soundscape as appropriate to the urban context, corresponding to roughly 11%, after the re-pavement works 16 subjects out of 56, that is 29% of the respondents, assessed it as appropriate.

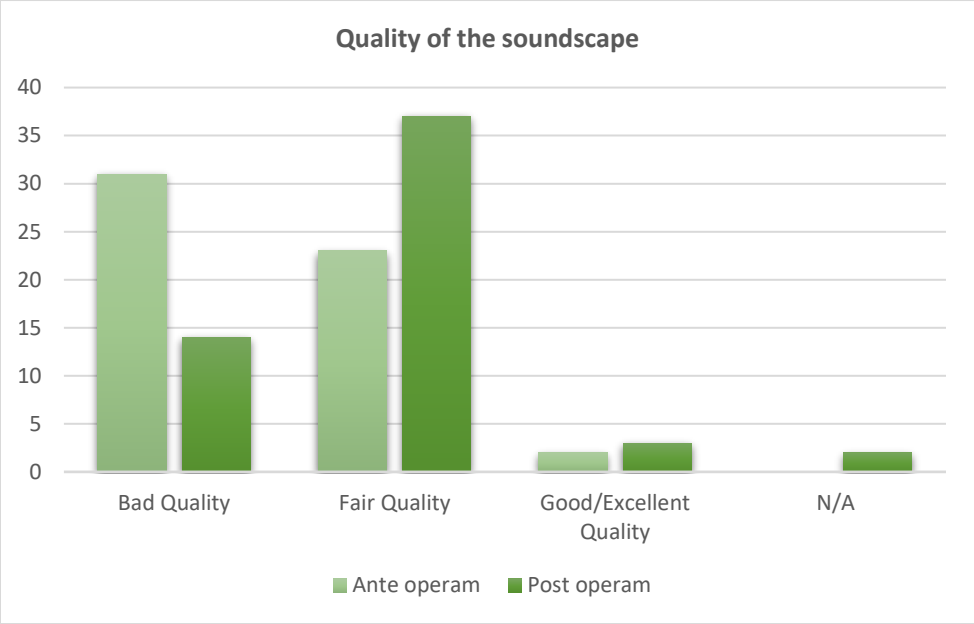

Figure 12 Quality of soundscape (AO-PO)

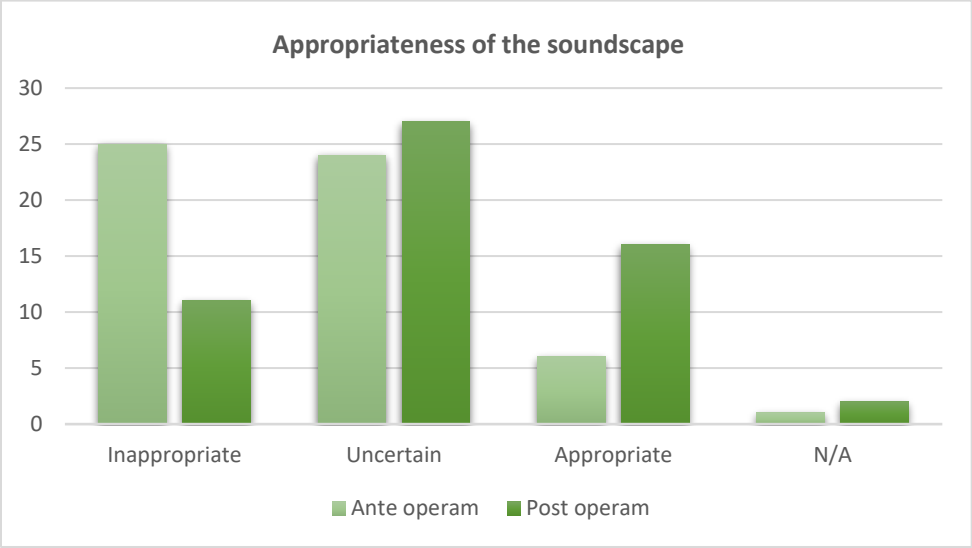

Figure 13 Appropriateness of the soundscape (AO-PO)

Instead, as shown in Figure 14, according to the respondents' perception the quality of the urban landscape slightly decreased after the re-pavement works. However, it is important to note that both in the ante operam and post operam questionnaires, the great majority of the sample assessed the quality of the urban landscape at least as fair.

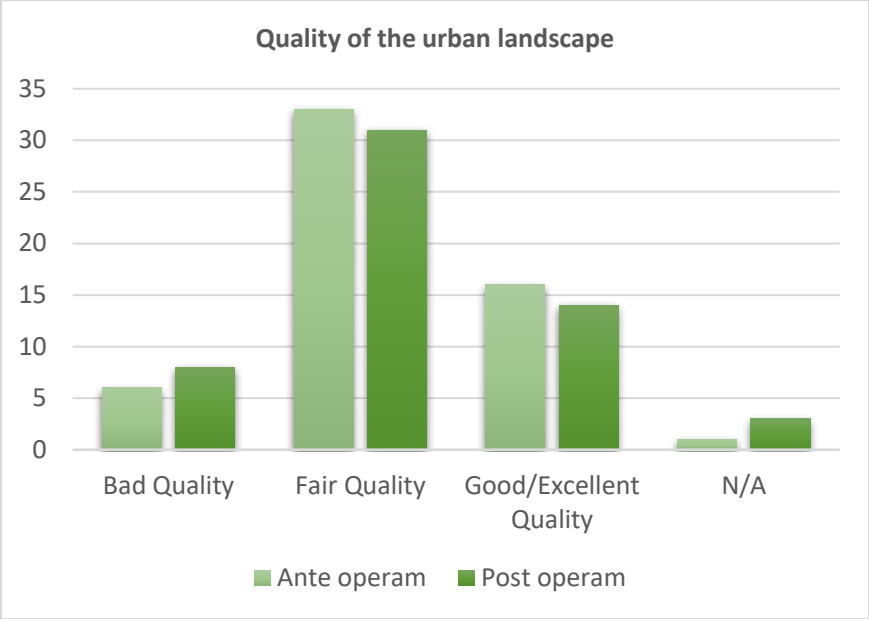

Figure 14 Quality of the urban landscape (AO-PO)

The abovementioned results regarding the assessment of the quality of the soundscape are in line with the results of the comparative analysis of the given answers to the question focusing on the characteristics of the soundscape (question matrix D6). Indeed, the percentage of the respondents who evaluated the soundscape with positive characteristics (enjoyable, interesting, relaxing, lively) increased after the realization of the interventions. Concurrently, as shown in Table 24, we observe a significant decrease of the number/percentage of the respondents assessing the soundscape as "disturbing".

To what extent do you agree with the following statements about the soundscape around you? (Ante Operam)								
Options	Enjoyable	Chaotic	Interesting	Boring	Relaxing	Disturbing	Lively	Monotonous
Strongly disagree	28,6%	10,7%	35,7%	12,5%	35,7%	3,6%	5,4%	21,4%
Disagree	33,9%	21,4%	23,2%	23,2%	32,1%	19,6%	23,2%	21,4%
Uncertain	21,4%	12,5%	23,2%	25,0%	8,9%	7,1%	35,7%	33,9%
Agree	8,9%	41,1%	10,7%	21,4%	16,1%	33,9%	25,0%	10,7%
Strongly Agree	3,6%	8,9%	0,0%	12,5%	0,0%	32,1%	5,4%	7,1%
N/A	3,6%	5,4%	7,1%	5,4%	7,1%	3,6%	5,4%	5,4%

To what extent do you agree with the following statements about the soundscape around you? (Post Operam)								
Options	Enjoyable	Chaotic	Interesting	Boring	Relaxing	Disturbing	Lively	Monotonous
Strongly disagree	17,9%	17,9%	32,1%	23,2%	28,6%	17,9%	7,1%	10,7%
Disagree	28,6%	28,6%	21,4%	17,9%	19,6%	25,0%	12,5%	26,8%
Uncertain	19,6%	16,1%	19,6%	26,8%	23,2%	16,1%	35,7%	46,4%
Agree	21,4%	23,2%	19,6%	19,6%	21,4%	28,6%	35,7%	8,9%
Strongly Agree	5,4%	7,1%	0,0%	3,6%	0,0%	8,9%	3,6%	1,8%
N/A	7,1%	7,1%	7,1%	8,9%	7,1%	3,6%	5,4%	5,4%
Difference								
Options	Enjoyable	Chaotic	Interesting	Boring	Relaxing	Disturbing	Lively	Monotonous
Strongly disagree	-10,7%	7,1%	-3,6%	10,7%	-7,1%	14,3%	1,8%	-10,7%
Disagree	-5,4%	7,1%	-1,8%	-5,4%	-12,5%	5,4%	-10,7%	5,4%
Uncertain	-1,8%	3,6%	-3,6%	1,8%	14,3%	8,9%	0,0%	12,5%
Agree	12,5%	-17,9%	8,9%	-1,8%	5,4%	-5,4%	10,7%	-1,8%
Strongly Agree	1,8%	-1,8%	0,0%	-8,9%	0,0%	-23,2%	-1,8%	-5,4%
N/A	3,6%	1,8%	0,0%	3,6%	0,0%	0,0%	0,0%	0,0%

Table 24 Soundscape characteristics (AO-PO)

To sum up, the comparison of the results of the ante operam questionnaire with the results of the post operam questionnaire shows that, according to residents in the pilot street, after the realization of the project interventions:

- The intensity of traffic noise has decreased
- The quality of the soundscape has improved
- The appropriateness of the soundscape with the urban context has improved

Specifically, in the post operam questionnaire a significant majority of the respondents (77%) positively assessed the effects on the perceived traffic noise from their home of the re-paving of a section of the street with a low noise asphalt.

As regards the effects of the interventions, in the ante operam period, 84% of the respondents thought that their health would be positively affected by a reduction of noise levels close to their home. In the post operam period, the majority of the sample (53%) thought that the perceived reduction of noise levels would significantly improve personal health.

However, while before the intervention 89% of the residents who responded to the questionnaire expected that the street repavement with a low noise asphalt would significantly increase the value of their home, the percentage declined to 32% in the post operam questionnaire, where we observe a high percentage of respondents according to whom the intervention has moderately increased the value of the home. This can be

explained by the fact that respondents are more likely to overreport the expected effects before an intervention they consider urgent, in this case to reduce the annoyance caused by road traffic noise.

Finally, it is important to point out that the positive results of the survey in terms of the reported beneficial effects of the re-paving are supported by the request of the residents to re-pave the whole street with the low noise asphalt developed in the context of the LIFE E-VIA project.

4.3.2 Statistical analysis

4.3.2.1 Link between Pearson chi-square test and regression model

Variable		χ^2	DoF	p-value
Age		2.3173	5	0.8037
Gender		2.1455	3	0.5428
Education		4.3015	6	0.636
Occupation		7.3956	5	0.1928
Residency		1.1813	2	0.554
Nationality		2.1569	2	0.3401
Windows overlooking via Paisiello		2.7451	1*	0.09755
Rooms overlooking via Paisiello		1.2243	5	0.9425
Intensity of perceived sounds		0.63894	3	0.8875
Perception of traffic sounds		**18.153**	**4***	**0.001152**
Perception of technological sounds		8.4923	5	0.1311
Perception of anthropic sounds		4.1765	5	0.5243
Perception of natural sounds		3.7271	4*	0.4442
Soundscape quality		**11.889**	**3**	**0.007774**
Soundscape congruence		**10.5**	**3**	**0.01476**
Soundscape attributes		13.709	7	0.0566
Soundscape	Enjoyable	5.4343	5	0.3652
	Chaotic	4.8532	5	0.4341
	Interesting	1.7825	4*	0.7757
	Boring	5.547	5	0.3528
	Relaxing	6.1182	4*	0.1905
	Disturbing	**15.221**	**5**	**0.009457**
	Lively	3.2017	5	0.6689
	Monotonuous	5.3131	5	0.3789
Landscape quality		1.4815	3	0.6865
Sound sensitivity		2.5753	3	0.4618

Table 25 Pearson's chi-square test

Table 25 represents the Pearson's chi-square test of independence. In general, this type of test is one of the most useful statistics for testing hypotheses when the variables are nominal. Unlike most statistics, the Chi-square (χ^2) can provide information not only on the significance of any observed differences, but also provides detailed

information on exactly which categories account for any differences found. With the data in table form, the researcher can proceed with calculating the χ2 statistic. In our case the hypotheses are:

H_0: a variable is independent on situation (ante and post)

H_1 (rejection p-value<0.05): variable depends on situation (ante and post)

The formula for calculating a Chi-Square is:

$$\sum \chi^2_{i-j} = \frac{(O-E)^2}{E}$$

Where O are the observed values an E the expected values. In the Chi-square statistic, the "expected" values represent an estimate of how the cases would be distributed if there were no situation effect. These values are calculated by multiplying each row and column total and dividing by the grand total. From the table above we note that four variable seems to be independent on situation (pre post). These variables are: "perception of traffic sound", "soundscape quality", "soundscape congruence" and "disturbing" soundscape attribute. To better analyze whether the work carried out has brought improvements in terms of perception of sounds we use the variable "soundscape quality" which is dependent on situation as dependent variable in a regression model. With the use of regression models, we can establish if there are relationships between the response variable ("soundscape quality") and other covariates relating to perceptions of sounds or characteristics of the surrounding environment in the ante/post intervention periods.

ORDINAL LOGIT MODEL

First, we compare all the response values, of the covariates and the response variable, between the two periods by creating original variables with a value of 0 if the value has decreased; 1 if it has remained unchanged and 2 if it has increased.

Given the nature of the variables created, we choose to use an ordinal logit model. The ordered logit model is a regression model for an ordinal response variable. The model is based on the cumulative probabilities of the response variable: in particular, the logit of each cumulative probability is assumed to be a linear function of the covariates with regression coefficients constant across response categories. Let Y_i be an ordinal response variable with C categories for the i-th subject, alongside with a vector of covariates $\mathbf{x}_i$. A regression model establishes a relationship between the covariates and the set of probabilities of the categories $p_{ci} = Pr(Y_i = y_c|\boldsymbol{x}_i)$, *c*=1,…,*C*. Usually, regression models for ordinal responses are not expressed in terms of probabilities of the categories, but they refer to convenient one-to-one transformations, such as the cumulative probabilities $g_{ci} = Pr(Y_i \leq y_c|\boldsymbol{x}_i)$, *c*=1,…,C. The last cumulative probability is necessarily equal to 1, so the model specifies only *C–1* cumulative probabilities. An ordered logit model for an ordinal response Y_i with *C* categories is defined by a set of *C-1* equations where the cumulative probabilities are related to a linear predictor $\beta'x_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots$ through the logit function:

$$logit(g_{ci}) = log\left(\frac{g_{ci}}{1-g_{ci}}\right) = \alpha_c - \boldsymbol{\beta}'\boldsymbol{x}_i$$

The parameters α_c, called thresholds or cutpoints, are in increasing order ($\alpha_1 < \alpha_2 < \ldots < \alpha_{C-1}$). The vector of the slopes β is not indexed by the category index *c*, thus the effects of the covariates are constant across response categories. This feature is called the parallel regression assumption: indeed, plotting logit(g_{ci}) against a covariate yields *C–1* parallel lines. In model above the minus before β implies that increasing a covariate with a positive slope is associated with a shift towards the right-end of the response scale, namely a rise of the probabilities of the higher categories (Fullerton 2009). In general, the cumulative probability for the category *c* is:

$$g_{ci} = \frac{e^{\alpha_c - \boldsymbol{\beta}' \boldsymbol{x}_i}}{1 + e^{\alpha_c - \boldsymbol{\beta}' \boldsymbol{x}_i}} = \frac{1}{1 + e^{-\alpha_c + \boldsymbol{\beta}' \boldsymbol{x}_i}}$$

The ordered logit model is also known as the proportional odds model because the parallel regression assumption implies the proportionality of the odds of not exceeding the *c*-th category $odds_{ci} = g_{ci}/(1 - g_{ci})$; in fact, the ratio of these odds for two units, say *i* and *j*, is $odds_{ci}/odds_{cj} = e^{\boldsymbol{\beta}'(\boldsymbol{x}_j - \boldsymbol{x}_i)}$, which is constant across response categories, because not depend on *c*.

In our case the resulting ordinal logit model is:

$$logit("soundscape\ quality"_{ci}) = \alpha_c - (\beta_1 * traffic\_sounds + \beta_2 * interesting\_soundscape + \beta_3 * nature\_dounds + \beta_4 * relaxing\_soundscape + \beta_5 * sensitivity\_sounds$$

qual_amb	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
traffico						
Unchanged	-7.047367	2.399337	-2.94	0.003	-11.74998	-2.344753
Yes	-8.004159	3.208891	-2.49	0.013	-14.29347	-1.714848
interessante						
Unchanged	5.320089	2.049402	2.60	0.009	1.303335	9.336843
Yes	1.914986	1.556173	1.23	0.218	-1.135057	4.96503
natura						
Unchanged	-.6013872	1.685393	-0.36	0.721	-3.904697	2.701922
Yes	9.055464	3.111493	2.91	0.004	2.957049	15.15388
rilassante						
Unchanged	4.754028	2.527349	1.88	0.060	-.1994857	9.707541
Yes	3.73245	2.311063	1.62	0.106	-.7971497	8.262049
sensibilita						
Unchanged	4.547256	2.190113	2.08	0.038	.2547141	8.839798
Yes	1.598098	1.349631	1.18	0.236	-1.047129	4.243325
/cut1	3.365244	2.201415			-.9494507	7.679939
/cut2	6.073346	2.42071			1.328842	10.81785

Table 26 results of the ordinal logit model

From the model above, we can see that, for the traffic_sounds variable who did not vary the response between the two periods or who responded that they heard less traffic in the post-intervention period tended to give a higher score on the soundscape quality than those who found a worsening in the traffic perception. Instead for the nature sounds the model shows that who hear more the sounds of nature in the post-intervention period than those who hear them less tend to perceive a better soundscape quality. Looking at the characteristics of the "interesting" and "relaxing" environment, we note that in the first case those who find the environment interesting in the same way in the two periods compared to those who find it less interesting tend to perceive a better soundscape quality. While for the "relaxing" characteristic, those who find the relaxing environment in the same way or more relaxing in the second period compared to who find the environment less relaxing tend

to perceive a higher soundscape quality. Finally, those who responded that they were sensitive to the environment in the same way tend to perceive a better soundscape quality than those who were less sensitive in the second period. So, from the model it emerges that for those who perceive between the two periods less noises considered annoying, such as those of traffic or perceive more sounds considered pleasant as those of nature, the perception of the surrounding sound environment is better.

5 Conclusions

In the frame of LIFE EVIA project an innovative low-noise asphalt that aims to reduce road traffic noise was laid down in a section of Paisiello street, the pilot case in Florence, in mid July 2021. The survey conducted through the distribution and collection of ante operam and post operam questionnaires to people living in the section of the street targeted by the intervention has demonstrated that the repaving has improved the quality of the soundscape and significantly reduced the perceived road traffic noise. As an illustration, according to 61% of the respondents to the post operam questionnaire traffic noise has decreased after the intervention. Indeed, the percentage of people who perceived traffic sound as “very high” and “high” significantly decreased in the post operam period compared to the percentage observed in the period before the intervention. Concurrently, 77% of the respondents assessed the intervention as positive, in terms of reduction of road traffic noise perceived from home. Therefore, the results of the survey demonstrate the success of the project’s action.

References

[1] Fullerton, A. S. "A conceptual framework for ordered logistic regression models." *Sociological methods & research* 38.2 (2009): 306-347.

Appendix I -The ante-operam questionnaire

LIFE/ENV/IT000201 LIFE E-VIA

THE PROJECT

Exposure data from the European Environment Agency demonstrate that more than 100 million EU citizens are affected by high noise levels negatively impacting human health. Traffic noise alone is harmful to the health of almost every third person in the World Health Organization European Region. 20% of Europeans are regularly exposed to night sound levels that could significantly damage health, especially in urban areas. The introduction of electric mobility is widely viewed as having the potential to reduce noise in urban areas, but the noise generated by tyres rolling on the road nevertheless needs careful study and further reduction. As emerged in Noise in Europe Conference (April 2017) and in the WHO guidelines published in October 2018, the increased stringency of EU at source standards needs to be balanced against other effective measures such as road surface and/or tyre improvements and urban planning measures as well. One of the solutions universally recognized as the best to reduce noise in urban areas, from both the point of view of noise and air quality, is the introduction of electric mobility.

Therefore, the project **LIFE E-VIA** (Electric Vehicle noIse control by Assessment and optimization of tyre/road interaction–www.life-evia.eu) intends to: - tackle noise pollution from road traffic noise focusing on a future perspective in which electric and hybrid vehicles will be a consistent portion of flow; - combine knowledge of road optimization and tyre development in order to test an optimized solution for reducing noise in urban areas and Life Cycle Cost with respect to actual best practices . The Project LIFE E-VIA, co-financed by the European Union through the Life programme, started in July 2019 and will end in January 2023. The project is coordinated by the Municipality of Florence and involves as partners the Mediterranean University of Reggio Calabria, Continental, Vie en.ro.se Ingegneria, University Gustave Eiffel and I-POOL.

THE SURVEY

The goal of this questionnaire is to collect data on the perception of the soundscape. In addition to some initial general questions, we kindly ask you to answer 10 questions related to the perception of the soundscape close to your home. Your personal data will be treated as strictly confidential and the publication of the survey results will ensure the non-recognition of the responses. Please answer all questions in order, following the instructions provided.

PERSONAL INFORMATION

I1. Age: ☐ 18-25 ☐ 26-40 ☐ 41-55 ☐ 56-65 ☐ 66-75 ☐ >75

I2. Gender: ☐ Female ☐ Male

I3. Education: ☐ Primary school ☐ Middle School ☐ High School ☐ Bachelor's Degree ☐ Ph.D. ☐ Master

I4. Occupation: _____

I5. City of Residence: _____

I6. Nationality: _____

D1. Does your home have windows overlooking via Paisiello? ☐ No ☐ Yes

D2. If so, which are the rooms that overlook via Paisiello?
(Make an X mark in the box for each room overlooking via Paisiello)

Room	*Overlooking via Paisiello*
Bedroom	☐
Single Bedroom	☐
Livingroom	☐
Kitchen	☐
Bathroom	☐
Other: …… (Please specify)	☐

D3. How do you assess the intensity of the following four types of sound in the soundscape around you?
(make an X mark for each type of sound in the box that best matches your opinion)

Type of sound	*Very Low*	*Low*	*Fair*	*High*	*Very High*
Traffic (eg. Cars, motorcycles, clacson …)	☐	☐	☐	☐	☐
Mechanical/electrical sounds (es. music, industries, sirens, constructions…)	☐	☐	☐	☐	☐
Anthropic sounds (es. voices, laughter, children, steps…)	☐	☐	☐	☐	☐
Nature sounds (es. wind, rustling leaves, birds …)	☐	☐	☐	☐	☐

D4. How do you assess the quality of the soundscape around you?

(Please, tick the box that best matches your opinion)

0	1	2	3	4	5	6	7	8	9	10
Very Bad										***Excellent***

D5. Do you think the soundscape around you is appropriate for this place?

(Please, tick the box that best matches your opinion)

Absolutely inappropriate	0	1	2	3	4	5	6	7	8	9	10	***Completely appropriate***

D6. To what extent does it agree with the following statements about the sound environment around it??
(Please tick the box that best matches your opinion for each row)

The soundscape is:	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Enjoyable	☐	☐	☐	☐	☐
Chaotic	☐	☐	☐	☐	☐
Interesting	☐	☐	☐	☐	☐
Boring	☐	☐	☐	☐	☐
Relaxing	☐	☐	☐	☐	☐
Disturbing	☐	☐	☐	☐	☐
Lively	☐	☐	☐	☐	☐
Monotonous	☐	☐	☐	☐	☐

D7. How do you assess the quality of the urban landscape around you?
(Please tick the box that best matches your opinion)

Very Bad	0	1	2	3	4	5	6	7	8	9	10	***Excellent***

D8. Do you think that implementation of interventions for the reduction of noise could increase the value of your home? (Please tick the box that best matches your opinion)

Not at all	0	1	2	3	4	5	6	7	8	9	10	***Surely***

D9. Do you think that your health can be affected by the reduction of noise levels close to your home?
(Please tick the box that best matches your opinion)

Not at all	0	1	2	3	4	5	6	7	8	9	10	***Surely***

D10. How do you assess your sensitivity to sounds?
(Please tick the box that best matches your opinion)

Very low	0	1	2	3	4	5	6	7	8	9	10	***Very High***

Appendix II - The post-operam questionnaire

LIFE/ENV/IT000201 LIFE E-VIA

THE PROJECT

Exposure data from the European Environment Agency demonstrate that more than 100 million EU citizens are affected by high noise levels negatively impacting human health. Traffic noise alone is harmful to the health of almost every third person in the World Health Organization European Region. 20% of Europeans are regularly exposed to night sound levels that could significantly damage health, especially in urban areas. The introduction of electric mobility is widely viewed as having the potential to reduce noise in urban areas, but the noise generated by tyres rolling on the road nevertheless needs careful study and further reduction. As emerged in Noise in Europe Conference (April 2017) and in the WHO guidelines published in October 2018, the increased stringency of EU at source standards needs to be balanced against other effective measures such as road surface and/or tyre improvements and urban planning measures as well. One of the solutions universally recognized as the best to reduce noise in urban areas, from both the point of view of noise and air quality, is the introduction of electric mobility.

Therefore, the project **LIFE E-VIA** (Electric Vehicle noIse control by Assessment and optimization of tyre/road interaction–www.life-evia.eu) intends to: - tackle noise pollution from road traffic noise focusing on a future perspective in which electric and hybrid vehicles will be a consistent portion of flow; - combine knowledge of road optimization and tyre development in order to test an optimized solution for reducing noise in urban areas and Life Cycle Cost with respect to actual best practices . The Project LIFE E-VIA, co-financed by the European Union through the Life programme, started in July 2019 and will end in January 2023. The project is coordinated by the Municipality of Florence and involves as partners the Mediterranean University of Reggio Calabria, Continental, Vie en.ro.se Ingegneria, University Gustave Eiffel and I-POOL.

THE SURVEY

The goal of this questionnaire is to collect data on the perception of the soundscape. In addition to some initial general questions, we kindly ask you to answer 12 questions related to the perception of the soundscape close to your home. Your personal data will be treated as strictly confidential and the publication of the survey results will ensure the non-recognition of the responses. Please answer all questions in order, following the instructions provided.

PERSONAL INFORMATION

I1. Age: ☐ 18-25 ☐ 26-40 ☐ 41-55 ☐ 56-65 ☐ 66-75 ☐ >75

I2. Gender: ☐ Female ☐ Male

I3. Education: ☐ Primary school ☐ Middle School ☐ High School ☐ Bachelor's Degree ☐ Ph.D. ☐ Master

I4. Occupation: _____

I5. City of Residence: _____

I6. Nationality: _____

D1. Does your home have windows overlooking via Paisiello? ☐ No ☐ Yes

D2. If so, which are the rooms that overlook via Paisiello?
(Make an X mark in the box for each room overlooking via Paisiello)

Room	*Overlooking via Paisiello*
Bedroom	☐
Single Bedroom	☐
Livingroom	☐
Kitchen	☐
Bathroom	☐
Other: …… (Please specify)	☐

D3. How do you assess the intensity of the following four types of sound in the soundscape around you?
(make an X mark for each type of sound in the box that best matches your opinion)

Type of sound	*Very Low*	*Low*	*Fair*	*High*	*Very High*
Traffic (eg. Cars, motorcycles, clacson …)	☐	☐	☐	☐	☐
Mechanical/electrical sounds (es. music, industries, sirens, constructions…)	☐	☐	☐	☐	☐
Anthropic sounds (es. voices, laughter, children, steps…)	☐	☐	☐	☐	☐
Nature sounds (es. wind, rustling leaves, birds …)	☐	☐	☐	☐	☐

D4. How do you assess the quality of the soundscape around you?
(Please, tick the box that best matches your opinion)

0	1	2	3	4	5	6	7	8	9	10
Very Bad										***Excellent***

D5. Do you think the soundscape around you is appropriate for this place?
(Please, tick the box that best matches your opinion)

Absolutely inappropriate	0	1	2	3	4	5	6	7	8	9	10	***Completely appropriate***

D6. To what extent do you agree with the following statements about the soundscape around you?
(Please tick the box that best matches your opinion for each row)

The soundscape is:	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Enjoyable	☐	☐	☐	☐	☐
Chaotic	☐	☐	☐	☐	☐
Interesting	☐	☐	☐	☐	☐
Boring	☐	☐	☐	☐	☐
Relaxing	☐	☐	☐	☐	☐
Disturbing	☐	☐	☐	☐	☐
Lively	☐	☐	☐	☐	☐
Monotonous	☐	☐	☐	☐	☐

D7. How do you assess the quality of the urban landscape around you?
(Please tick the box that best matches your opinion)

Very Bad	0	1	2	3	4	5	6	7	8	9	10	***Excellent***

D8. To what extent has the noise of traffic you perceive changed in the past months?
(Please tick the box that best matches your opinion)

Increased					***Stable***	***Decreased***				
Very much		fairly		slightly		Slightly		Fairly		Very much
0	1	2	3	4	5	6	7	8	9	10

D9. How do you assess the effects of the re-paving of via Paisiello with the new asphalt on the traffic sound you perceive from your home?
(Please tick the box that best matches your opinion)

Negative					***Irrelevant***	***Positive***				
Very much		fairly		slightly		Slightly		Fairly		Very much
0	1	2	3	4	5	6	7	8	9	10

D10. Do you think that the implementation of a low-noise asphalt has increased the value of your home?
(Please tick the box that best matches your opinion)

Not at all	0	1	2	3	4	5	6	7	8	9	10	***Surely***

D11. Do you think that your health can be improved by the recent reduction of noise levels close to your home?
(Please tick the box that best matches your opinion)

Not at all	0	1	2	3	4	5	6	7	8	9	10	***Surely***

D12. How do you assess your sensitivity to sounds?

(Please tick the box that best matches your opinion)

Very low	0	1	2	3	4	5	6	7	8	9	10	***Very High***