DELIVERABLE 2.3.1[1]

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ACRONYM	**CITYHUSH**		
TITLE	**Acoustically Green Road Vehicles and City Areas**		
Work Package WP2	**Cost/benefit analysis of Q-zones**		
2.3	**Cost/benefit analysis of mitigation measures against potential benefits for local residents and park visitors**		
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RE	Restrictec to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for the members of the consortium (including the Commission Services)	

Nature of Deliverable

R	Report	✓
P	Prototype	
D	Demonstrator	
O	Other	

SEVENTH FRAMEWORK PROGRAMME

[1] see List of Deliverables, DoW – Annex I to the contract, p.32 (document 233655_CITYHUSH_AnnexI_DoW_2010-01-31_Corrections.pdf - available on the ftp-server)

This deliverable has been quality checked and approved by CityHush Coordinator Martin Höjer

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0. EXECUTIVE SUMMARY

0.1 OBJECTIVE OF THE DELIVERABLE

The aim of Work Package 2.3 (WP2.3) is to establish the cost benefits of different intervention/mitigation measures in order to establish the most cost effective measures in terms of maximum noise gains and best outcomes for residents and park visitors.

0.2 DESCRIPTION OF THE WORK PERFORMED SINCE THE BEGINNING OF THE PROJECT

The Noise Rating Scores (NRS's) which have been established as part of Work Package 2.1 (WP2.1), have been used in calculations using different traffic flow data scenarios (based on a range of implementation measures e. g. electric vehicles, tolling etc) to calculate NRS's for both local residents and park visitors. We have therefore adopted a specific methodology for determining the cost benefits of competing intervention schemes in respect of costed health effects on those residents within the vicinity of the parks. Additionally, the noise modelling has been utilised to identify the effective useable area of the park after the implementation of the various schemes. The decision to add a physical measure to the monetarisation of the benefits of the proposals, which is largely related to health benefits; was carried out because it provided a better understanding of the 'useable area' of an embedded park. This is important when examining a wide range of competing intervention strategies as it provides a metric which administrators and planners may find easier to understand. Additionally, within the framework of the noise modelling software CadnaA [1], it was relatively easy to implement and demonstrate the versatility of the software for add-on tools and outcomes.

0.3 MAIN RESULTS ACHIEVED SO FAR

Cost-benefit analysis (CBA) provides a means for systematically comparing the value of outcomes with the value of resources with a view to achieving the outcomes, which are best suited to provide measurable benefits in this case to those residents near the parks, and for those visitors to the park. An extensive literature search and review of cost benefit analysis methods and noise (primarily, transportation noise) has been carried out in order to determine an appropriate methodology for the costs and benefits related to specific intervention measures.

A meeting was held in Stockholm to consider the benefits of various cost beenfit methodolgies and to decide which method could most readily be implemented in such a way as to interface with the outputs from the noise modelling carried out for the Q-zones and embedded parks.

Ultimately, the HEATCO methodology (Developing **H**armonised **E**uropean **A**pproaches for **T**ransport **Co**sting and Project Assessment, December 2006 [1]) was chosen as the preferred method for cost benefit analysis of noise impacts. HEATCO was chosen because the methodology had been tested and agreed as appropriate for other European studies. Importantly, the methodology utilises different cost factors for the different countries across Europe, such that the methodology for the pilot studies undertaken in this research can readily be implemented within individual member countries in the future for actual assessments. Importantly, by choosing an agreed methodology which could be used in diffrent countries any monetary skew, which could otherwise occur between different member states could be avoided.

The methodology has initially been piloted for the City of Bratislava and this has proven the overall utility of the method.

0.4 EXPECTED FINAL RESULTS

Cost benefit analysis is a method that facilitates decision makers to evaluate potential outcomes and choose technologies to achieve these outcomes. Decisions that are well intended can lead to losses in results as unexpected outcomes develop, or as outcomes have unexpected consequences. Decision makers therefore invariably have a need for a framework, which structures information in a way, which makes the complexity of cost benefit analysis more manageable; but which still takes into account the implications of the overall complexity. Formal cost-benefit analysis (CBA) techniques are an analytical tool, which have the potential to significantly advance this process. Importantly, the methodology utilised in this study can be presented with the costs of a variety of implementation measures, in order to fully understand both the actual costs and the often somewhat more intangible health costs related to noise.

0.5 POTENTIAL IMPACT AND USE[2]

The impact of the proposed methodology should provide a better tool for determining the effects of multiple intervention strategies such that noise is not merely considered just in respect of changes in population annoyed but also with respect to the potential health effects of these interventions.

The tools for noise modelling have been set up in such a way that outputs from the noise mapping can be readily imported into the CBA analysis tool to provide decision makers with a better understanding of the benefits and dis-benefits of the various multiple intervention scenarios.

2 *including the socio-economic impact and the wider societal implications of the project so far*

0.6 PARTNERS INVOLVED AND THEIR CONTRIBUTION

ACCON is responsible for the calculation and comparison of the Noise Rating Scores before and after implementation of the Q-zones as defined in WP1. Cost benefit analysis has also been undertaken by ACCON to establish the most cost effective mitigation strategies. Additionally, input from Staffan Algers of KTH has been important in understanding what effect various intervention measures would have on traffic flows within the immediate vicinity of the proposed Q-zones and also the optimum size of the Q-zone.

0.7 CONCLUSIONS

Utilising the HEATCO methodology alongside the transportation costs has allowed a detailed analysis of a range of intervention measures to be analysed. Utilising multi-variant traffic noise modelling has proven that such analyses can be readily carried out in a cost efficient manner (within the CadnaA noise modelling framework) in order to determine the most appropriate intervention for an area.

Whilst, the adopted methodology has been proven, it is apparent that the anticipated noise gains identified at the early stages of the study cannot be realised. This occurs because during the daytime period, when parks are generally used, a large part of the noise environment is driven by more distant traffic sources. What this means is that whilst removing local noisy traffic in its entirety from the park area, the overall period noise levels (L_{Aeq}) do not reduce by any significant amount. It will of course be the case that some of the localised peak noise levels from traffic will be reduced dramatically in close proximity to and within the park area; which may well result in beneficial results for health, which are not presently able to be identified in the study.

1. INTRODUCTION

1.1. PURPOSE

The specific project aim of Work Package 2.3 is to obtain cost/benefit information of Q-zones.

1.2. BACKGROUND

The CityHush project supports city administrations in the production and implementation of noise action plans according to the directive 2002/49/EC [3].

The identified hot spots and noise action plans made with the existing technology have a number of significant identified shortcomings:

a) poor correlation between hot spots with annoyance and complaints;
b) most measures lead to increased emissions;
c) only indoor noise comfort is addressed.

Step change solutions are proposed to reduce noise in the city environment. The project deals with developing suitable problem identification and evaluation tools and with designing and developing solutions for hot spots, which show high correlation with annoyance and complaints.

Step change solutions are proposed to reduce noise in the city environment. The project deals with developing suitable problem identification and evaluation tools and also with the design and development of solutions for hot spots, which should ultimately demonstrate a high correlation with annoyance and complaints.
The following innovative solutions and tools will be developed:

1. **Concept of Q-zones (zones in an inner city area where only quiet low emission vehicles are tolerated).**
2. **Concept of parks embedded in Q-zones.**
3. Improved indoor noise score rating models by integrating low frequency noise and the occurrence of high single noise events.
4. Noise score rating models for the outdoors.
5. Objective and psychoacoustic evaluation tool for low noise low emission vehicles.
6. Mathematical synthesis tool for noise from low noise low emission vehicles.
7. General performance noise specifications for low noise low emission vehicles.
8. Novel concepts for low noise roads based upon dense elastic road surfaces.
9. Novel concepts for low noise roads based upon grinding of asphalt top layers.
10. Novel concepts for tyre's for low noise vehicles, including heavy vehicles.
11. Criteria for use of low noise motorcycles.
12. Active and passive noise attenuation measures within the tyre hood (wheel arch).

13. Solutions for high low frequency absorption at facades of buildings.
14. Solutions for high low frequency isolation in the propagation path.

All of the above solutions and tools will be designed, prototyped and validated. Once all of the above elements are complete, they could result in the achievement of the anticipated noise outcomes/benefits.

1.3. What the report covers

The report is based upon the reference situations/scenarios, which have been investigated as part of the task undertaken in **Point 1**, in **Section 1.2** above. Calculations have been carried out and comparisons have been made between the Noise Rating Scores 'before' and 'after' the implementation of the Q-zones as defined within the deliverables from Work Package 1 (WP1) of the CityHush project.

The Noise Rating Scores have been calculated for both the local residents and park visitors. The calculations have been conducted using data from traffic flow simulations, which were input into the noise prediction software. A cost/benefit analysis has been carried out in order to determine the extent to which the costs of implementing mitigation measures are outweighed by the potential benefits to the local residents and park visitors. The conclusions which have been derived can than be used in the decision making process when deciding on the most cost effective mitigation strategies to employ to achieve maximum gains in noise reduction in Q-zones and embedded parks.

1.4. Information collected

1.4.1 Traffic data

Traffic data have been collected from the various municipalities and transportation engineers for input into a transportation model covering an area within the vicinity of the identified parks and potential Q-zone areas for the individual cities. A range of transportation scenarios have then been run within the transportation model in order to identify the optimum size of the Q-zone, the way in which traffic diverts onto and from the local highway network.

Typically, the transportation link locations are matched to the actual road network configuration as shown in the example below:

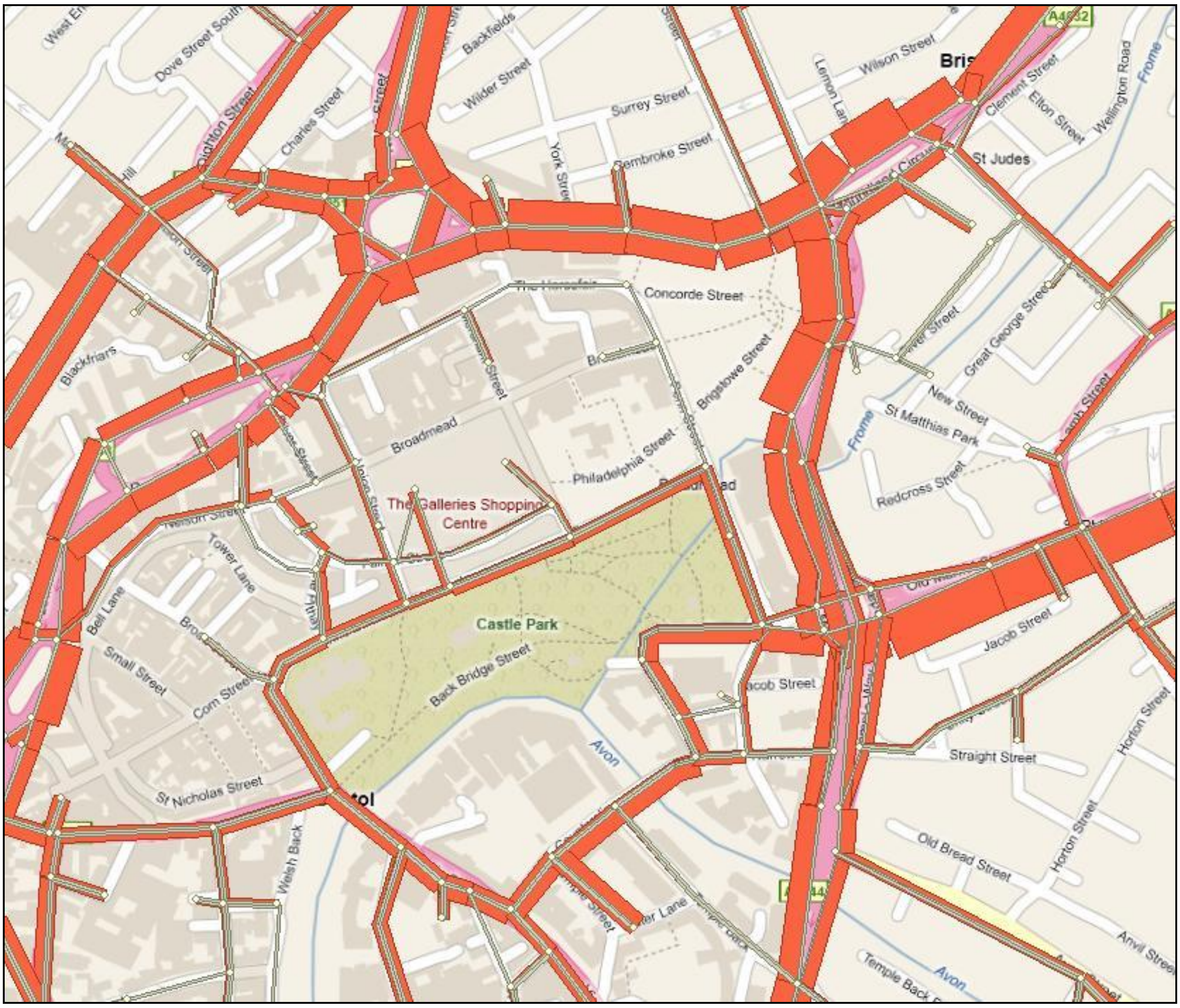

Figure 1.4.1: Transportation link locations at Bristol Test site (Example)

1.4.2 Noise rating scores

Noise Rating Scores have been implemented into the noise modelling software in line with the reporting for that work stream.

1.4.3 Mitigation strategies

A variety of mitigation/implementation strategies have been tested which include electric/quiet vehicles, tolling, vehicle bans etc.

1.5. LIMITATION OF REPORT

1.5.1 Other mitigation measures have not been considered

The strategies, which have been piloted in this assessment, relate only to traffic management implementation measures and no physical measures have been considered with respect to Q-zones or embedded parks. It would be possible to consider the use of noise barriers to achieve reductions in noise within the embedded parks and potential noise reduced surfaces within the Q-zones. Such measures may be an alternative to the transportation strategies which have been piloted and could potentially result in greater immediate benefits, with respect to reductions in noise, although would not provide the other more sustainable benefits which could accrue from the transportation initiatives reported here.

2. GENERAL FRAMEWORK FOR COST BENEFIT ANALYSIS

This chapter provides a very brief overview of approaches to appraising options and also identifies some of the advantages and disadvantages of these approaches. Firstly, however, it provides context regarding option appraisal.

Cost-benefit analysis (CBA) provides a means for systematically comparing the value of outcomes with the value of resources achieving the outcomes required. It measures the economic efficiency of the proposed approach. When all else is equal more efficient approaches should be chosen over less efficient ones. When there are many options to consider during a decision-making task, it is useful to evaluate the options with a common metric. Cost-benefit analysis refers to any type of structured method for evaluating decision options.

CBA has become widely accepted among business and governmental organisations. Although CBA has definite limitations, especially in the non-standard way that the payoff function is derived and calculated, its potential for making decisions more rational is comforting to those who must make the decisions. The presentation of a cost-benefit analysis is the preferred way to demonstrate the reasoning behind investments.

The analysis has to include alternative solutions, including the baseline case, that consider alternative ways of fulfilling the project, a number of traffic scenarios have been used in this pilot study defining the outcomes of the different analysis options in the project.

At the end of the analysis a sensitivity analysis for the costs and the benefits considered during the previous steps should generally be undertaken. Sensitivity analysis identifies those input parameters that have the greatest influence on the outcome, repeats the analysis with different input parameter values, and evaluates the results to determine which, if any, input parameters are sensitive. If a relatively small change in the value of an input parameter changes the alternative selected, then the analysis is considered to be sensitive to that parameter.

2.1. OPTIONS APPRAISAL

There are many countrywide examples of best practice guidance for conducting the assessment of projects, policies and programmes. The guidance is usually binding for government departments and executive agencies, although it can be (and is) supplemented by guidance in specific areas e.g. transport.

The stated purpose of CBA and its implementation is to ensure that no policy, programme, or project is adopted without first checking if the best method is being used to achieve the objectives in question, in this case, how best to mitigate against noise in embedded parks an Q-zones.

The essential technique advocated is option appraisal. In brief, this comprises in the context of this project: justifying the rationale for deciding upon the use of particular noise mitigation measures; setting the objectives for the proposed measures; creating and short-listing potential options for making changes to traffic flows; and comparing (ideally in monetary terms) the costs and benefits of these various options, including wider social costs and benefits.

Recognising one of the disadvantages of CBA, there are recommendations that the approach is proportionate. As a result, it is usual for CBAs to include non-monetised impacts (expressed either quantitatively or qualitatively), in this case noise reductions. The approach to non-monetised impacts has been adopted within the noise modelling and reporting to include changes in the 'useable area' of the embedded parks.

3. ADOPTED APPRAISAL METHODOLOGY

3.1. HEATCO

As explained earlier, following a literature review, which considered different methodologies for carrying out CBA, principally on transportation related projects and for differing country methodologies; it was determined that the general methodology identified in the HEATCO methodology [1] should be utilised.

HEATCO's primary objective was the development of harmonised guidelines for project assessment at an EU level. This included the provision of a consistent framework for monetary valuation with transport costing. The first step was a comparison of current practice with theoretical and empirical evidence from the literature. The study recognised that the principles for project appraisal and transport costing vary considerably across countries and transport modes. The vast majority of the countries in the North/West region of the EU had developed comprehensive guidelines for project appraisal, whereas the guidelines in the South and East regions seemed to be somewhat less developed.

Based on current practice and thinking at that time the HEATCO team identified certain elements of a consistent framework for project appraisal on an EU-level. Part of that framework included:

- Value of time and congestion (incl. business passenger traffic, non-work passenger traffic etc, and most importantly;
- Environmental costs (incl. air pollution, noise and global warming).

The choice of the HEATCO methodology for this study was primarily related to the proposals for dealing with noise within a health/annoyance type framework and for noise costs it was suggested that it would be possible to use country-specific values per person exposed to a certain level of noise. The suggested impact indicator, which should be reported alongside the monetary results, is the number of persons highly annoyed. All values include health effects and annoyance and central values comprise the WTP for reducing annoyance based on stated preference studies (see Working group on health and socio-economic aspects, 2003). Annoyance was based on dose-response functions; monetary values were taken from the HEATCO surveys (see Navrud et al. 2006 [4]). High values include annoyance valuation based on hedonic pricing as applied in UNITE (see Bickel et al. 2003 [5]).

Elsewhere, studies carried out by the World Health Organisation (WHO - Burden of disease from environmental noise, 2011) have considered the extent to which exposure to noise results in a reduction in life expectancy, which is expressed as **D**isability **A**djusted **L**ife **Y**ears (DALYS). Whilst, the study is useful in understanding the effects of exposure to high levels of noise it does not provide any additional information in respect of the costs of noise exposure.

The recommended calculation procedure from the HEATCO study is as follows:

Step 1: quantification of the number of persons exposed to certain noise levels (which should be available from noise calculations) for the Do-Minimum case and the Do-Something case.

Step 2: preparation of the cost factor table by increasing the cost factor according to the assumed country-specific GDP per capita growth for each year of the analysis.

Step 3: calculation of impacts (multiply percentage of highly annoyed persons by number of persons exposed) and costs (multiply cost per person by number of persons exposed) for both cases.

Step 4: subtraction of total costs for the Do-Something case from Do-Minimum case.

Step 5: reporting of costs and impacts (change in number of people highly annoyed).

The Table below identifies an example of the central values for noise exposure in Euros (2002) expressed as factor costs per person exposed.

Table 3.1.1: Central values for noise exposure in Euros per person exposed

L_{den}	France			Germany		
dB(A)	Road	Rail	Aircraft	Road	Rail	Aircraft
≥51	9	0	15	10	0	15
≥52	19	0	29	19	0	30
≥53	28	0	44	29	0	45
≥54	38	0	59	39	0	60
≥55	47	0	73	49	0	75
≥56	57	9	88	58	10	91
≥57	66	19	103	68	19	106
≥58	76	28	118	78	29	121
≥59	85	38	132	88	39	136
≥60	95	47	147	97	49	151
≥61	104	57	162	107	58	166
≥62	114	66	176	117	68	181
≥63	123	76	191	127	78	196
≥64	133	85	206	136	88	211
≥65	142	95	220	146	97	226
≥66	152	104	235	156	107	242
≥67	161	114	250	166	117	257
≥68	171	123	265	175	127	272
≥69	180	133	279	185	136	287
≥70	190	142	294	195	146	302
≥71	252	204	361	259	210	371
≥72	268	220	382	275	226	393
≥73	283	236	403	291	242	414
≥74	299	252	424	307	259	436
≥75	315	268	445	324	275	458
≥76	331	284	467	340	291	479
≥77	347	299	488	356	308	501
≥78	363	315	509	373	324	523
≥79	379	331	530	389	340	544
≥80	394	347	551	405	357	566
≥81	410	363	572	422	373	588

The underlying principle in the 'value of travel time savings' (**VTTS**) guidelines from the HEATCO study is that local values should be used wherever possible, provided that they have been developed using an appropriate methodology. If no such local values exist for an individual country then 'default' or 'fallback' values derived from international meta-analyses of value of time studies should be used. The transport costs utilized in this overall assessment are shown in the Table below with the Value of Travel (**VTTS**) expressed as Euros/hr. In this way, where an intervention on the local traffic network is proposed which results in increased or reduced journey times then costs can be attributed to that intervention.

Table 3.1.2: Transport cost (VTTS in Euros/hr)

Car VTTS Euro/h	Business	Commute	Other	Average
Slovakia	12.6	5.73	4.81	6.049
Germany	27.78	9.48	7.95	10.698
Sweden	30.55	10.82	9.07	12.093
United Kingdom	29.37	10.24	8.59	11.493
EU Average	**24**	**10.29**	**8.63**	**10.997**

The average factor utilized in the travel costs assessment is based on the following assumptions with respect to the distribution of trip purpose shares: **Business 0.1**, **Commute 0.5** and **Other 0.4**. Where calculations are made the 2010 values should be used in all calculations with any appropriate updating, to take into account the GDP per capita growth figure for the individual countries. When calculating the travel time costs the average VTTS has not been used as people with lower VTTS are more inclined to utilise detours that would otherwise exaggerate the costs. Accordingly, the values for each VTTS segment have been used and the same VTTS as in the assignment have been used for this calculation. However, for the highest VTTS a median VTTS has been utilised as opposed to the mean VTTS, in order to better reflect the route choice behaviour (as this would better correspond to average behaviour). For evaluation purposes the mean value should be used. Another aspect of travel costs are the running costs, which have not been included in the calculations to date.

3.1.1 Unvalued mitigation measures

The costs and benefits of unvalued mitigation measures, may well in the longer term, need to be identified and considered. The use of other mitigation measures, other than traffic changes may also be economically beneficial in terms of residents and park visitors. Scoring and weighting techniques could be applied (if appropriate), by non-monetary quantification, or (as an absolute minimum) by a qualitative assessment.

3.2. Design life and acoustic life

For maximum noise reduction gains, a remediation measure applied in one or all of the test cities may need to comprise a number of combined measures (say for example traffic changes, low noise tyres and low noise road surfaces).

As part of a CBA, a possible approach would be to value the individual noise remediation measures separately and to integrate the costs and benefits over the relevant assessment period for a full value of the combined measure. However, it may not always be appropriate to assess multiple noise control options separately. Appropriate assumptions may need to be made to deal with these on a case by case basis.

3.3. UNVALUED IMPACTS

In selecting the best option, it is likely that the best option will be the one with the highest risk adjusted net present value (for a cost benefit analysis) or the option with the lowest net present cost (for a cost effectiveness analysis).

However in practice other factors, and in particular, unvalued costs and benefits will ultimately affect the selection of the best option. This would be where a significant impact has been identified but is not currently valued. For example, the visual impacts of a proposed noise barrier could be considered to be an 'unvalued' cost or benefit.

3.4. CHAPTER SUMMARY

This chapter highlighted some of the practical considerations of valuing (the cost factors) the benefits of noise reduction for residents and park visitors, which should be balanced as part of the other CityHush initiatives as a whole and against the costs of remediation measures. In particular, it has identified that the HEATCO methodology is considered a robust tool for carrying out this comparison within a CBA framework.

4. COST BENEFIT ANALYSIS OF BRATISLAVA

The use of the recommended CBA will be shown in the following based on detailed investigations within the WP 1.1 at Bratislava test-site, where traffic simulations were undertaken to determine the influence of gate fees level, size of Q-zone and percentage ownership of quiet cars.

4.1. CITY DESCRIPTION

Bratislava is situated in south-western Slovakia, within the Bratislava Region. The city has a total area of 367 km². Bratislava straddles the Danube River, which crosses the city from the west to the south-east. The city location is shown in the Figure below.

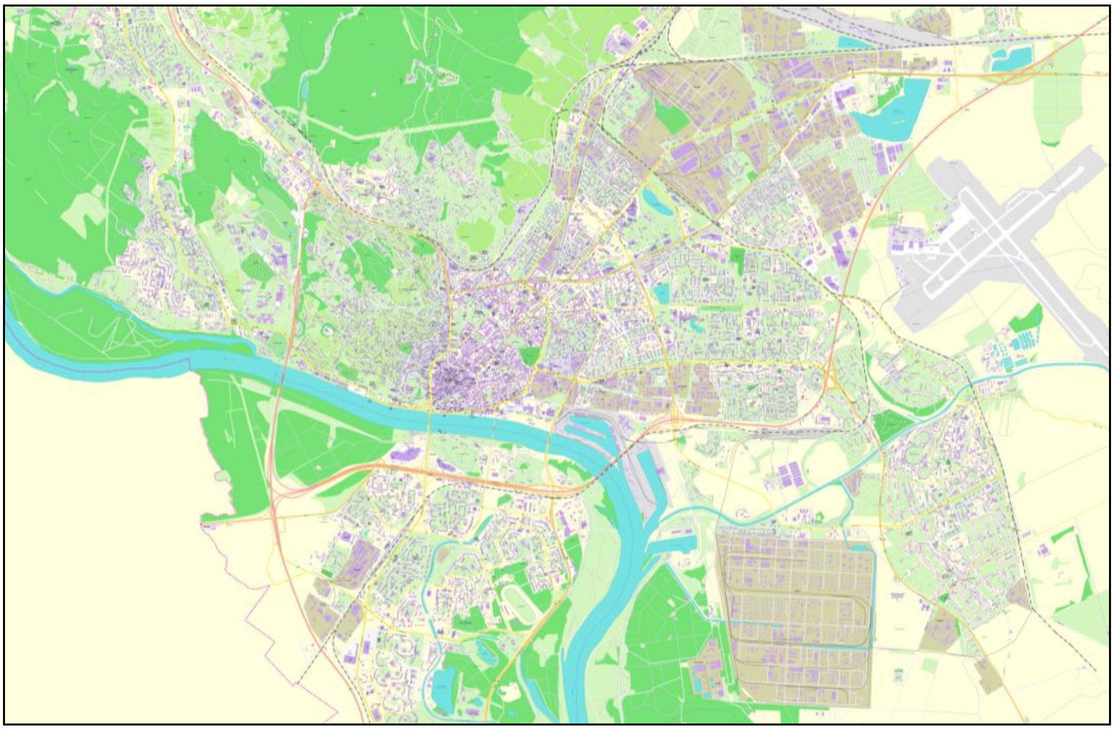

Figure 4.1.1: City of Bratislava

4.2. DESCRIPTION OF PARKS

The City of Bratislava is already planning for and developing areas along the Danube River. The Danube embankment offers excellent possibilities to create an enjoyable recreational environment, and reshaping dockland areas to a mix of commercial and residential land use is under way. Such developments are located east and west of the area south of the old town.

The identified park area straddles the Danube, which is shown in the figure below.

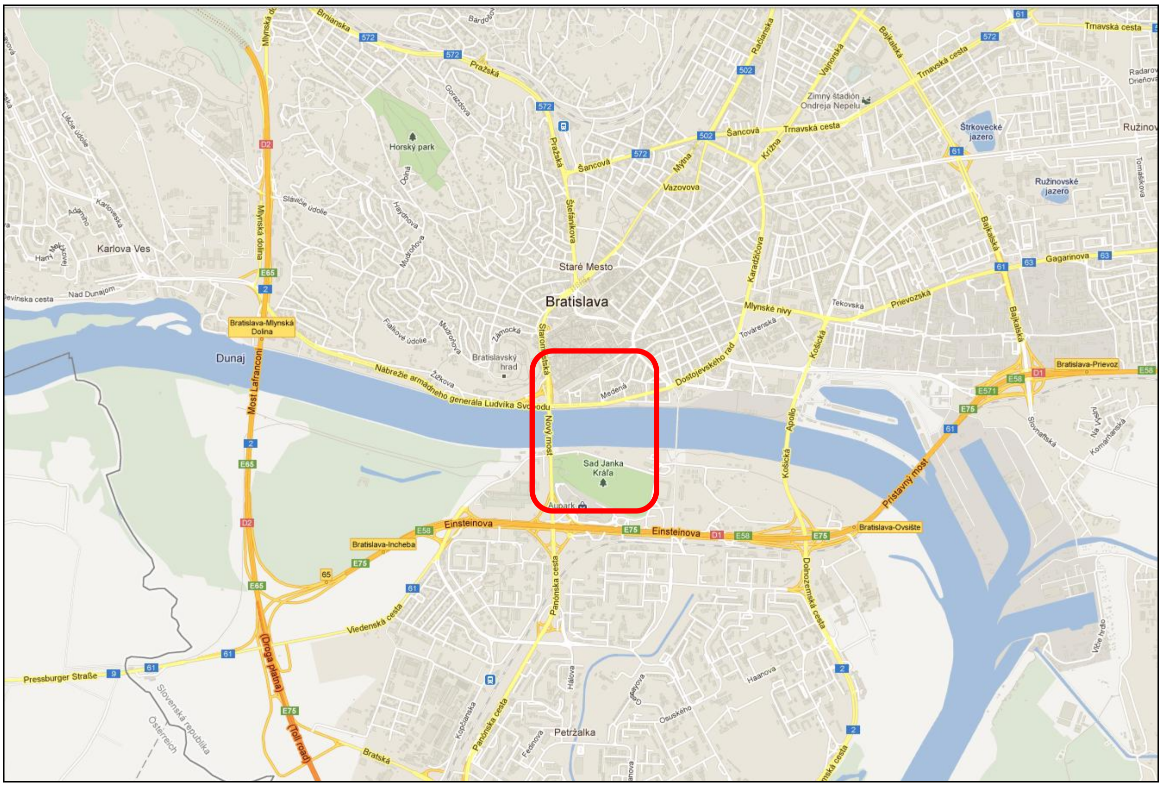

Figure 4.2.1: Investigated area in the City of Bratislava

4.3. Noise environment

For Bratislava, noise mapping has previously been undertaken for the whole of the Bratislava agglomeration area. Major roads along the riverbanks cause a high level of noise disturbances in the central areas south of the old town. This disturbance extends to the other side of the river, where the large park area is identified above.

4.4. Local issues

After discussions with local representatives and a site visit, the opportunity for transforming the area south of the old town to a Q-zone seemed to be the most interesting Q-zone application within Bratislava to test. This area also includes a park-like avenue, bordering the pedestrian area of the old town. The arterial traffic route along the riverbank is a major challenge, and different methods of dealing with this difficulty have been analyzed.

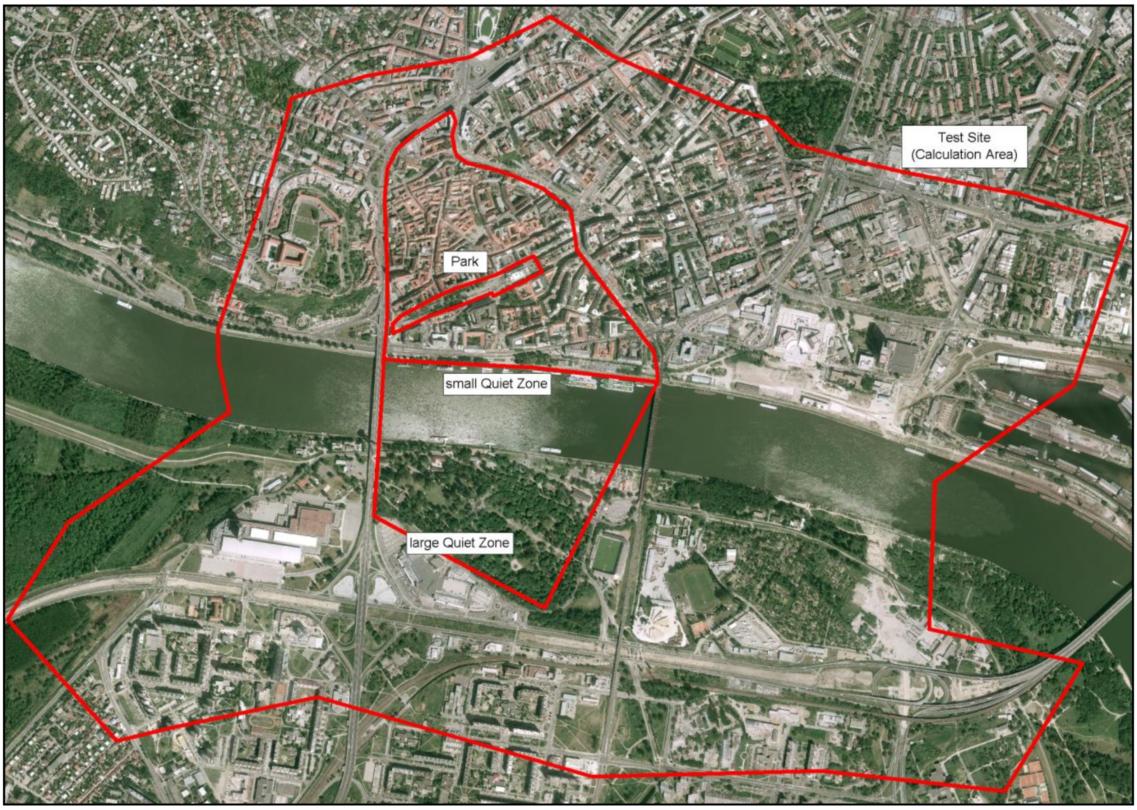

Figure 4.4.1: Intended Q-zone area (red line) with park areas inside existing development and the River Danube

4.5. WORKED EXAMPLE

The methodology identified in **Section 3** has been implemented into the noise modeling with the identified outputs, which initially are presented as noise distribution (grid calculation) and noise facade levels at residential property within the test-site for Bratislava. From this information it is possible to derive the various CBA outputs and this has been done as an output of the model.

The output from the noise modeling is provided below for the scenarios tested with the individual steps in the procedure identified.

Step 1: Quantification of number of persons exposed to certain noise levels:

Table 4.5.1: Number of people affected by road noise for different scenarios at test site Bratislava

L_{den}' dB(A)		Number of people affected by road noise - Test site Bratislava														
from	**to**	**S16**	**S17**	**S18**	**S19**	**S20**	**S21**	**S22**	**S23**	**S24**	**S25**	**S26**	**S27**	**S28**	**S29**	**S30**
	<45	2442	2416	2419	2419	2413	2416	2416	2465	2416	2419	2419	2505	2472	2494	2494
45	**46**	64	59	60	60	59	60	60	65	59	66	66	202	829	828	828
46	**47**	201	731	812	812	145	163	163	847	835	837	837	1204	468	553	553
47	**48**	1252	472	449	429	1103	1081	1081	657	436	466	466	505	479	394	394
48	**49**	467	326	296	298	269	348	365	442	370	421	421	255	637	606	606
49	**50**	465	814	864	820	841	832	815	471	736	657	672	972	723	732	732
50	**51**	1171	733	723	775	791	723	723	1116	725	795	780	554	212	649	622
51	**52**	142	195	231	241	197	231	172	194	249	309	309	210	763	371	398
52	**53**	246	332	657	283	256	655	714	289	762	681	681	312	342	224	224
53	**54**	297	654	274	700	687	252	300	220	149	199	199	688	148	201	201
54	**55**	1153	774	720	668	748	747	700	1141	786	680	671	702	1271	1312	1313
55	**56**	251	541	1232	1283	548	559	607	264	1281	1396	1343	1409	1466	1334	1385
56	**57**	2324	1425	1314	1252	2428	2455	2396	2314	1799	1773	1820	2052	1455	1432	1422
57	**58**	1169	3337	2788	2862	1256	1354	1366	1188	2499	2499	2514	1465	2585	2644	2602
58	**59**	1655	612	1538	1448	1875	1797	1795	2929	1300	1238	1242	2548	2781	2824	2769
59	**60**	2676	3003	2036	2048	2580	2726	2726	1391	2206	2095	2082	1300	342	420	519
60	**61**	1122	846	759	777	927	722	685	1192	699	657	675	1551	2000	1982	1938
61	**62**	1710	1721	1737	1820	1742	1784	1843	2029	1980	1940	1931	1481	2015	1932	1932
62	**63**	1573	1867	2155	2069	1922	1952	2002	1285	1779	2123	2123	1382	909	1021	995
63	**64**	1253	1223	933	933	1309	1139	1067	1335	1215	1110	1110	1226	1513	1398	1408
64	**65**	1322	1162	1401	1401	1146	1401	1401	1256	1200	1131	1131	907	607	665	733
65	**66**	760	680	538	537	680	537	537	686	676	746	696	1006	1162	1155	1132
66	**67**	1513	1207	1242	1243	1187	1240	1240	1725	1040	966	1016	1216	647	665	636
67	**68**	490	540	539	539	560	542	542	269	840	841	841	528	1225	1215	1215
68	**69**	933	1535	1488	1488	1447	1508	1513	881	1286	1285	1285	1009	318	318	318
69	**70**	679	154	154	154	247	139	134	679	71	76	76	175	267	266	266
70	**71**	79	280	280	280	271	270	271	79	261	252	252	330	131	107	122
71	**72**	288	157	157	157	156	163	162	298	151	152	152	95	88	103	88
72	**73**	116	49	49	49	55	49	49	131	39	35	35	194	21	31	31
73	**74**	175	17	0	0	17	131	21	150	131	131	131	52	158	173	173
74	**75**	47	188	204	204	187	73	183	57	74	89	89	133	80	64	64
75	**76**	168	53	72	72	72	72	72	158	81	56	56	77	119	120	120
76	**77**	42	123	95	95	105	95	95	43	95	95	105	12	27	27	27
77	**78**	13	11	43	43	11	43	43	12	34	43	34	15	4	4	4
78	**79**	14	24	12	12	24	12	12	14	14	13	12	10	87	87	87
79	**80**	10	90	80	80	90	80	80	61	77	79	79	51	0	0	0
>80		206	137	137	137	137	137	137	155	137	137	137	155	137	137	137

Step 2: Preparation of the cost factor table

For comparable results within the different test sites of the City Hush project and for comparison purposes it was decided that it was most appropriate to use the same "factor costs per person exposed" regardless of the country within which the pilot site is located. The actual central values for noise exposure, which were developed based on the approach within the HEATCO study, are provided below:

Table 4.5.2: Central values [€] for noise exposure according to the HEATCO study

L_{den}	Germany 2002	Germany 2010	Slovakia 2002	Slovakia 2010	Sweden 2002	Sweden 2010	UK 2002	UK 2010	Total Average	Ger, Swe & UK Average 2002	Ger, Swe & UK Average 2010
51	10	13	2	Not known	11	14	11	14	10	11	**14**
52	19	24	4	Not known	22	28	21	26	20	21	**26**
53	29	37	5	Not known	33	43	32	40	30	31	**40**
54	39	50	7	Not known	44	57	43	54	40	42	**53**
55	49	63	9	Not known	55	71	53	66	50	52	**66**
56	58	74	11	Not known	66	85	64	80	60	63	**80**
57	68	87	13	Not known	77	99	75	94	70	73	**93**
58	78	100	14	Not known	88	114	85	106	80	84	**106**
59	88	113	16	Not known	99	128	96	120	90	94	**120**
60	97	124	18	Not known	110	142	107	134	100	105	**133**
61	107	137	20	Not known	120	155	117	146	109	115	**146**
62	117	150	22	Not known	131	169	128	160	119	125	**159**
63	127	163	23	Not known	142	183	139	174	129	136	**173**
64	136	174	25	Not known	153	197	149	186	139	146	**185**
65	146	187	27	Not known	164	212	160	200	149	157	**199**
66	156	200	29	Not known	175	226	171	214	159	167	**213**
67	166	212	31	Not known	186	240	181	226	169	178	**226**
68	175	224	32	Not known	197	254	192	240	179	188	**239**
69	185	237	34	Not known	208	268	203	254	189	199	**252**
70	195	250	36	Not known	219	283	213	266	199	209	**265**
71	259	332	48	Not known	291	375	283	354	265	278	**353**
72	275	352	51	Not known	309	399	301	376	281	295	**375**
73	291	372	54	Not known	327	422	319	399	298	312	**397**
74	307	393	57	Not known	346	446	337	421	314	330	**419**
75	324	415	60	Not known	364	470	355	444	331	348	**442**
76	340	435	63	Not known	382	493	372	465	347	365	**463**
77	356	456	66	Not known	401	517	390	488	364	382	**486**
78	373	477	69	Not known	419	541	408	510	381	400	**508**
79	389	498	72	Not known	437	564	426	533	398	417	**530**
80	405	518	75	Not known	456	588	444	555	414	435	**552**
81	422	540	78	Not known	474	611	462	578	431	453	**575**

Step 3: calculation of impacts and costs

The calculation of impacts is based on the percentage highly annoyed people and number of persons exposed:

Table 4.5.3: Number of highly annoyed people for different scenarios at test site Bratislava

L_{den}'	Road	Highly Annoyed People														
dB(A)	%	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30
≥44	0.8	20	19	19	19	19	19	19	20	19	19	19	20	20	20	20
≥45	1.1	1	1	1	1	1	1	1	1	1	1	1	2	9	9	9
≥46	1.5	3	11	12	12	2	2	2	13	13	13	13	18	7	8	8
≥47	1.9	24	9	9	8	21	21	21	12	8	9	9	10	9	7	7
≥48	2.2	10	7	7	7	6	8	8	10	8	9	9	6	14	13	13
≥49	2.6	12	21	22	21	22	22	21	12	19	17	17	25	19	19	19
≥50	2.9	34	21	21	22	23	21	21	32	21	23	23	16	6	19	18
≥51	3.3	5	6	8	8	7	8	6	6	8	10	10	7	25	12	13
≥52	3.7	9	12	24	10	9	24	26	11	28	25	25	12	13	8	8
≥53	4.2	12	27	12	29	29	11	13	9	6	8	8	29	6	8	8
≥54	4.6	53	36	33	31	34	34	32	52	36	31	31	32	58	60	60
≥55	5.1	13	28	63	65	28	29	31	13	65	71	68	72	75	68	71
≥56	5.6	130	80	74	70	136	137	134	130	101	99	102	115	81	80	80
≥57	6.2	72	207	173	177	78	84	85	74	155	155	156	91	160	164	161
≥58	6.8	113	42	105	98	128	122	122	199	88	84	84	173	189	192	188
≥59	7.5	201	225	153	154	194	204	204	104	165	157	156	98	26	32	39
≥60	8.3	93	70	63	64	77	60	57	99	58	55	56	129	166	165	161
≥61	9	154	155	156	164	157	161	166	183	178	175	174	133	181	174	174
≥62	9.9	156	185	213	205	190	193	198	127	176	210	210	137	90	101	99
≥63	10.8	135	132	101	101	141	123	115	144	131	120	120	132	163	151	152
≥64	11.9	157	138	167	167	136	167	167	149	143	135	135	108	72	79	87
≥65	12.9	98	88	69	69	88	69	69	88	87	96	90	130	150	149	146
≥66	14.1	213	170	175	175	167	175	175	243	147	136	143	171	91	94	90
≥67	15.4	75	83	83	83	86	83	83	41	129	130	130	81	189	187	187
≥68	16.8	156	257	249	249	242	252	253	147	215	215	215	169	52	52	52
≥69	18.2	124	28	28	28	45	25	24	124	13	14	14	32	49	48	48
≥70	19.8	16	55	55	55	54	53	54	16	52	50	50	65	26	21	24
≥71	21.5	62	34	34	34	34	35	35	64	32	33	33	20	19	22	19
≥72	23.3	27	11	11	11	13	11	11	31	9	8	8	45	5	7	7
≥73	25.2	44	4	0	0	4	33	5	38	33	33	33	13	40	44	44
≥74	27.2	13	51	55	55	51	20	50	16	20	24	24	36	22	17	17
≥75	29.4	49	16	21	21	21	21	21	46	24	16	16	23	35	35	35
≥76	31.7	13	39	30	30	33	30	30	14	30	30	33	4	9	9	9
≥77	34.1	4	4	15	15	4	15	15	4	12	15	12	5	1	1	1
≥78	36.7	5	9	4	4	9	4	4	5	5	5	4	4	32	32	32
≥79	39.4	4	35	32	32	35	32	32	24	30	31	31	20	0	0	0
≥80	42.3	90	60	60	60	60	60	60	68	60	60	60	68	60	60	60
Sum		2400	2378	2357	2358	2384	2370	2372	2370	2328	2323	2323	2251	2170	2170	2169

Using the Average 2010 factor costs for Germany, Swede and UK, the noise band specific costs (shown as L_{den} levels in dB(A)) and the total noise costs can be determined as shown below:

Table 4.5.4: Noise costs [€] per year for different scenarios at test site Bratislava

L_{den},	Cost factors	Noise Costs - Costs per Year														
dB(A)	€	S16	S17	S18	S19	S20	S21	S22	S23	S24	S25	S26	S27	S28	S29	S30
≥51	14	1924	2642	3129	3265	2669	3129	2330	2628	3373	4186	4186	2845	10336	5026	5392
≥52	26	6457	8714	17244	7428	6719	17192	18740	7585	20000	17874	17874	8189	8976	5879	5879
≥53	40	11819	26025	10903	27855	27338	10028	11938	8755	5929	7919	7919	27378	5889	7998	7998
≥54	53	61501	41285	38405	35631	39898	39845	37338	60861	41925	36271	35791	37445	67795	69982	70035
≥55	66	16682	35957	81883	85272	36422	37153	40343	17546	85140	92783	89260	93647	97435	88662	92052
≥56	80	184959	113411	104577	99643	193236	195385	190690	184164	143176	141107	144848	163312	115799	113968	113172
≥57	93	108873	310786	259656	266548	116975	126103	127220	110642	232740	232740	234137	136440	240750	246245	242333
≥58	106	175855	65029	163423	153860	199231	190943	190731	311226	138134	131546	131971	270742	295500	300069	294225
≥59	120	320594	359769	243920	245357	309093	326584	326584	166646	264286	250988	249431	155744	40973	50317	62178
≥60	133	149144	112456	100891	103284	123223	95973	91055	158449	92916	87333	89726	206169	265853	263461	257612
≥61	146	249022	250623	252954	265041	253682	259798	268390	295477	288341	282516	281205	215673	293438	281351	281351
≥62	159	250380	297177	343019	329330	305931	310706	318665	204538	283169	337925	337925	219978	144689	162516	158377
≥63	173	216418	211237	161148	161148	226090	196728	184292	230581	209855	191719	191719	211755	261325	241463	243190
≥64	185	245125	215458	259773	259773	212491	259773	259773	232888	222504	209710	209710	168176	112550	123304	135913
≥65	199	151215	135297	107044	106845	135297	106845	106845	136491	134501	148429	138481	200160	231199	229807	225230
≥66	213	321533	256504	263942	264154	252253	263517	263517	366586	221014	205288	215914	258416	137496	141321	135158
≥67	226	110562	121844	121618	121618	126357	122295	122295	60696	189535	189760	189760	119136	276405	274149	274149
≥68	239	221331	365064	353842	353842	344053	358618	359811	208915	305613	305374	305374	239476	74493	74493	74493
≥69	252	171316	38855	38855	38855	62320	35071	33809	171316	17914	19175	19175	44154	67366	67114	67114
≥70	265	20969	74320	74320	74320	71932	71666	71932	20969	69277	66888	66888	87592	34771	28401	32382
≥71	353	101559	55364	55364	55364	55011	57480	57127	105086	53248	53601	53601	33500	31032	36322	31032
≥72	375	43459	18358	18358	18358	20606	18358	18358	49079	14611	13113	13113	72682	7868	11614	11614
≥73	397	69416	6743	0	0	6743	51963	8330	59500	51963	51963	51963	20626	62673	68623	68623
≥74	419	19698	78791	85496	85496	78372	30594	76695	23889	31013	37300	37300	55740	33528	26822	26822
≥75	442	74178	23401	31791	31791	31791	31791	31791	69763	35764	24726	24726	33998	52543	52984	52984
≥76	463	19451	56965	43997	43997	48628	43997	43997	19914	43997	43997	48628	5558	12504	12504	12504
≥77	486	6312	5341	20879	20879	5341	20879	20879	5827	16509	20879	16509	7283	1942	1942	1942
≥78	508	7112	12192	6096	6096	12192	6096	6096	7112	7112	6604	6096	5080	44196	44196	44196
≥79	530	5300	47701	42401	42401	47701	42401	42401	32331	40811	41871	41871	27031	0	0	0
≥80	552	117119	79000	79000	79000	79000	79000	79000	88944	79000	79000	79000	88944	79000	79000	79000
Sum		3459282	3426309	3383928	3386452	3430597	3409911	3410972	3418402	3343372	3332586	3334101	3216871	3108325	3109533	3106952

The traffic costs for each scenario can be calculated by multiplying the traffic distance of each scenario with the traffic cost-factors (HEATCO). The results are shown in the Table below:

Table 4.5.5: Transport costs (€) per year caused by traffic distribution within the Q-zone

	S 16 base case	S 17	S 18	S 19	S 20	S 21	S 22	S 23	S 24	S 25	S 26	S27	S 28	S 29	S 30
Traffic costs / year	671.809.784	690.731.336	680.410.005	678.998.594	689.608.414	679.812.318	677.814.216	671.809.784	687.845.920	679.154.314	677.188.059	671.809.784	679.972.049	675.959.695	674.953.438

Step 4 and Step 5: total cost variation for different scenarios compared to impacts and improvements (benefits):

Table 4.5.6: Comparison of total costs [€] of different scenarios at test site Bratislava

	S 16 base case	S 17	S 18	S 19	S 20	S 21	S 22	S 23	S 24	S 25	S 26	S27	S 28	S 29	S 30
Number highly annoyed residents	1.642	1.632	1.625	1.624	1.635	1.629	1.629	1.620	1.601	1.596	1.596	1.642	1.475	1.478	1.476
Delta HAP	-	10	17	18	7	13	13	22	41	46	46	0	167	164	166
Noise costs / year	1.549.565	1.532.957	1.523.316	1.521.983	1.535.323	1.529.056	1.527.707	1.525.290	1.498.478	1.492.791	1.492.990	1.549.580	1.364.135	1.368.185	1.365.494
Traffic costs / year	671.809.784	690.731.336	680.410.005	678.998.594	689.608.414	679.812.318	677.814.216	671.809.784	687.845.920	679.154.314	677.188.059	671.809.784	679.972.049	675.959.695	674.953.438
Fee (€) / year			8.352.346	16.407.293		8.330.521	16.406.535			7.282.309	1.4394.873			3.214.663	6.322.904
Total costs	673.359.349	692.264.293	690.285.667	696.927.870	691.143.737	689.671.895	695.748.458	673.335.074	689.344.398	687.929.414	693.075.922	673.359.364	681.336.184	680.542.543	682.641.836
Yearly Costs / reduced HAP		1.890.494	995.666	1.309.362	2.540.627	1.254.811	1.722.239	-1.103	389.879	316.741	428.621	-	47.765	43.800	55.919

The total costs include the "traffic costs", the "noise costs" and the "fees" (toll/gate fee) for entering the Q-zone.

The total benefit in this case is only the "reduction of highly annoyed people". It should be noted that the improvement in the overall reduction in noise within the area of the test site, especially in the embedded park area, have not been included. It will be noted from Table 4.5.6 that for some scenarios the noise costs reduce and these therefore result in an improvement in the overall noise situation, however the overall costs which include traffic costs invariably outweigh, by a considerable margin, the noise related cost benefits. A comparison of the base case (S16) against the different scenarios identifies the change in noise costs per year.

5. PRACTICAL ISSUES AND ASSUMPTIONS

In determining the outcomes of the modelling, it is necessary at this stage to make certain assumptions about population density, building heights, speed of traffic on the network etc. Whilst, this will invariable affect the absolute level of certainty within the noise modelling it should not affect the comparison of options/scenarios where they have been delivered within the same framework assumptions.

6. CONCLUSION

The pilot study for Bratislava has proven the methodology adopted for a comparison of the CBAs associated with a range of implementation measures. In particular, it has demonstrated the relative ease by which implementation measures can be compared with each other; and specific tools developed within the framework of the CadnaA noise software format.

7. REFERENCES

[1] CadnaA, software for calculation, presentation, assessment and prediction of environmental noise, Datakustik GmbH, Greifenberg

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