EUROPEAN COMMISSION
TRANSPORT RTD PROGRAMME

# Workpackage 3

# Deliverable 3

**List of most cost-efficient non-technical measures**

# CANTIQUE

Concerted Action on Non Technical Measures and their Impact on Air Quality and Emissions

***Project Contract No.: ST-98-CA.3002***

10/02/00
Circulation: CANTIQUE partners, CEC - DG VII
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# 1. Introduction

Non-technical measures (NTM) aimed at improving urban air quality as well as overall efficiency in transportation find dramatic justification also in that traffic congestion entails huge financial burdens. It is difficult to quantify these costs; it is an estimated that they reach for Europe the level of 130 GEuro/year including environmental costs and externalities. Actual impacts of non-technical measures on reducing emissions are unevenly documented. Consequently we address here also more general measures of effectiveness and in particular the effects of telematics.

## 1.1 Measures of Effectiveness

The effectiveness of a complex technological system may be measured by means of MOE's - Measures of Effectiveness. These should possess the following characteristics:

- correspond to situations which actually reflect the reaching of important objectives of the system (rather than secondary considerations even if related to the former)
- be expressed quantitatively in a univocal way (e.g.: the average speed of vehicles at a given abscissa on a street or the waiting times at a signalised intersection are indicators more significant than the number of traffic jams which occur in a given day in a certain area)
- be measured with a low cost (possibly automatically with no human intervention) and present a fairly low variance
- possess physical meaning.

It is often appropriate to use several measures of effectiveness simultaneously, possibly attributing to them weights determined in an intuitive fashion recurring to the opinion of experts. In this way we attempt to assess how far the performance of a system satisfies different users having aims and interests which are diverse and even contrasting.

It is interesting to read some examples taken from the sector of urban transportation, quoted 40 years ago by Goode and Machol in their book *System Engineering* (McGraw-Hill 1957):

*"It happens that people confuse the area of permissible solutions with the statement of the problem. "The problem is that there is inadequate control at intersections" or "insufficient off-street parking" or "excessively narrow streets" or "too many vehicles permitted to enter the city" and so on. Some group may be certain that the solution of one of there problems will solve the traffic problem, whereas detailed study will show that a solution to this problem will actually help very little or that a far less drastic approach is adequate.*

*For example, provision of extra off-street parking may reduce double parking and the number of vehicles cruising while looking for parking space. But extra off-street parking may also attract more vehicles to the crowded downtown area and thus aggravate the traffic situation."*

Extreme caution has to be used, instead, in recurring to opinion surveys. This is true, in particular, if interviewees are asked not only how satisfying (effective) they consider a situation of which they've had direct experience, but also how desirable they consider a future situation not yet realised. Even if questionnaires are not inductive and if samples are duly representative, it is hardly possible to eliminate interviewees superficiality and misinformation. These negative factors are present also when recourse is made to so-called privileged testimonials which should feature an expertise - often just assumed but not factual.

An indicator of the quality of traffic flows, which could be used more widely to advantage, is defined as:

$$Q = \int V(t) \cdot s(t) \, dt$$

where: V(t) is the volume of traffic in vehicles/h which goes past a given

street abscissa

s(t) is the speed of vehicles in km/h

so that the dimensions of Q are Vehicle.km/h. The concept is that of a trade-off between volumes of traffic and their speeds. The level of service is higher if, with the same traffic volume, average speed is higher and, if, with the same average speed, larger volumes are flowing. The Q indicator may be easily measured automatically installing appropriate detectors on the street. These, and also adequate data processing equipment, are found to exist in cities where large computerised Urban Traffic Control systems have been installed. The Q indicator may be considered as a synthetic expression of traffic conditions prevailing with a given street system and a given control system. Said conditions are more accurately represented by means of a Volume-Density diagram, which, however, is more laborious to build.

### 1. 2 The Example of Telematics applied to Transportation

We report fairly extensively the example of Telematics applied to transport, not so much because this type of intervention is directly relevant to improve urban air quality, but because trends and forecast of the sector are well defined and constitute a significant element for producing future scenarios.

A study by ISFORT ("Telecomunicazioni e Informatica per i Trasporti: tecnologia e mercato al 2005", Carlo Mario Guerci editor, Il Mulino, 1996) was centred on the use of telematics for real time control of traffic, information to users and operators, automatic management of systems and vehicles (minimising transit times, increasing throughput, safety, comfort) and to replace transportation by telefunctions.

The study attempts to produce rational projections, an example of the results of which is given by the following table relative to the Italian market. This depicts the situation that can be expected in 2005. The data supplied may be used to suggest a global view from which reasonable guidelines may be deduced.

| MEASURE Italian Market Levels | 1996 Level | Forecast at 2005 | Increment (times) |
|---|---|---|---|
| Market for Transport telematics | 67 GL | 2.380 GL | 35 |
| Radio Data System/Traffic Message Channel (Nr of units) | 50 k (1998) | 4,3 M | 86 |
| Global System for Mobile Comm (assisted navigation) (Nr of units) | 2 k | 66.4 k | 33 |
| Route guidance (Nr.of units) | 3.5 k | 113 k | 30 |
| Autonomous navigation (Nr.of units) | 0.5 k | 715 k | 1430 |
| Real time assisted navigation (Nr.of units) | 8 k (year 2000) | 300 k | 37 |
| Urban access control (road pricing) | 10 | 880 | 88 |
| Intelligent Traffic Control Systems | 1000 | 1870 | 1.87 |
| Variable Message Signs | 270 | 816 | 3 |

The telematics sector is clearly expected to develop considerably. The public appears to be oriented towards applications, which allow autonomous decisions and supply real time information on actual conditions along possible travel paths - at a reasonable cost.

The last 3 items in the table are systems aimed at informing or steering the behaviour of users by means of equipment chosen or mandated by public authorities. Here we face the well-known problem that implementation decisions are not taken by the same actors who will benefit from the functions of the installed systems.

Telematics (in general ITS) systems are designed and implemented by different organisations and operators. It would be obviously advantageous to integrate them. This is clearly possible as concerns real time information gathering. It is harder, but also promising, to rationalise objectives, times and methods of all activities in the various sectors making use of transportation.

## 2. Methodology

Deliverable 2 of WP2 has highlighted the complexity of establishing significant comparisons of the results obtained by different studies. Not all of these include explicit emissions evaluation or modelling and they provide quantitative answers obtained under different assumptions and using different approaches. Hence, one of the main conclusions of Deliverable 2 was that transferability from one scheme to another scheme is limited.

Consequently we have applied the following methodology.

1. Produce a list of non technical measures and of combinations of measures which emerged as relevant from WP2

2. Add measures and complement the analysis to fill data gaps

3. Determine the (presumably positive) impacts of the above measures and their combinations as supplied by the different studies

4. Depict in table form the above quantitative results and then single out the measures, which do have significant impacts across the different studies. This task entails an analysis of the quality of the data and an in-depth investigation of the sources whenever credibility is doubtful (outliers).

5. Produce a report highlighting the most promising measure- and integrate it with data on the costs of measures implementation aiming at producing cost-effectiveness assessments.

We will then try to define which packages or combinations appear to have been overlooked by all previous analysed studies.

The fact has to be faced that the data and conclusions obtainable from the studies are hardly sufficient for a comprehensive cost-effectiveness analysis. Even when data are abundant, their comparability is limited. This eventuality was foreseen at the time the Technical Annex was drafted. In fact the TA spells out the following caveat:

"*In case of insufficient data situation and literature information, it is intended to provide judgements from experts and authorities in the respective field*."

A questionnaire (see Annex I) has been prepared in order to integrate limited information from costs and impacts with experts’ opinion. This questionnaire was submitted to the experts during the Cantique Workshop in Rome, January 24 2000 venue.

Participating experts were asked to state (possibly quantitatively):

- a general qualitative opinion on the information supplied
- quantitative estimates based on their experience of costs and benefits (possibly indicating original sources and empirical data)
- opinion on combinations of interventions and possible synergies

The experts' answers have been analysed in Annex II.

## 3. Data sources and lists of measures, impacts and costs

We have complemented the results of the WP2 analysis with data from:

- ERTICO (ERTICO ITS Toolbox, ITS City Pioneers Consortium, Brussels 1998). The study reflects mainly measures consisting in ITS/UTC systems and their impact;

- ISFORT "Telecomunicazioni e informatica per i Trasporti", Il Mulino 1996;

- AOI II - AUTOIL II PROGRAMME - Working Group 5, Report to EC Directorate E, October 1999;

- MURE TRANSPORT DATABASE. In the Mure Database, collected under the Save Programme, D.G. XVII, directorate General for Energy, is available a list of non technical measures with information on their impacts and, sometimes, costs;

- BPA (1999), *Does Bus-Based Park and Ride Assist the Integration of Local Transport?* Article in *Parking News*, British Parking Association, Haywards Heath, UK.

- Carlsson G (1997), *Cost-Effectiveness of information, campaigns and enforcement and the costs and benefits of speed changes*, presented at the seminar “Cost-Effectiveness of Road Safety Work and Measures", Working Session 3, Luxembourg.

- ENDS (2000), *Italian car bans cut particulate matter sharply*, ENDS Daily 18-01-2000, Elsevier Publishers.

- ETSU (1999), *personal communication with Mr Simon Collings*, ETSU Energy Efficiency Best Practice Programme for the UK Department for the Environment, Transport and the Regions, ETSU, Harwell, Tel. +44 1235 432965.

- ETSU (2000), *personal communication with Mr Richard Bungey*, who is working as a consultant for the ETSU Energy Efficiency Best Practice Programme, for the UK Department for the Environment, Transport and the Regions, Tel. +44 1635 248109.

- Evans R (2000), *Three-Way Catalytic Converter Retrofit - Questions and Answers*, Johnson Matthey, Royston, Hertfordshire, UK.

- HBEFA (1999), *German/Swiss Handbook for Emissions Factors for Road Vehicles*, Version 1.2 of January 1999, INFRAS SA, Bern, Switzerland.

- Parkhurst G (1997), *The Economic and Environmental Roles of Park and Ride*, ESRC Transport Studies Unit, Centre for Transport Studies, University College London.

- TRL (1998), *Low Emission Zone Study*, Transport Research Laboratory, for the City of Westminster and the Department of Environment, Transport and the Regions, Crowthorne, UK.

- TSU (1999), *Environmental cost-benefits of bus-based park and ride systems*, ESRC Transport Studies Unit Research Paper 1999/4, University College London, UK.

- WS Atkins (1998), *The Travel Effects of Park and Ride*, WS Atkins Planning Consultants, Epsom for Department of Environment Transport and the Regions, UK (Authors: Harris C, Cooper B & Whitfield S).


Finally we will summarise impacts which were described in qualitative fashion in some of the studies analysed by WP2. We intend, in this way, to provide a reference framework on which we will gather and process further evaluations and opinions of the experts through the questionnaire analysis..

We list here all the measures, the impacts and the indication of the study (or source) of information.

## 3.1 Measures

1. Park & Ride
2. Car Pooling
3. Dial-A-Ride
4. Road pricing
5. Parking pricing
6. PT fare structure
7. Access control, including Low Emission Zones
8. Parking management
9. Pedestrian and cycling
10. Public transport measures (priority, increased frequency)
11. Intelligent Transport Systems / Urban Traffic Control measures
12. Ramp metering
13. Staggered activity time
14. Taxes (on fuel, vehicles)
15. Fleet and freight management
16. Tele-working
17. Information to users

## *3.2 Indicators of impacts*

A. CO emissions
B. $CO_2$ "
C. $C_6H_6$ "
D. HC "
E. $NO_x$ "
F. Particulate "

G. Vehicle*km
H. Traffic volume (hourly average)
I. Average speed
J. Energy/fuel consumption
K. Passenger, tonne*km
L. Travel time
M. Public transport use

## 3.3 Research projects

I. ADONIS
II. AIUTO
III. Evaluation (NAQS objectives)

IV. CAPTURE
V. CITY LOGISTIC COLOGNE
VI. CLEOPATRA
VII. COST 321
VIII. Reduce CO2 emissions up to 2005
IX. ESTEEM
X. EUROTOLL
XI. GAUDI
XII. INCOME
XIII. MASTER
XIV. Reduce NOx NMVOC
XV. Reduce CO2 in Austria
XVI. QUARTET PLUS
XVII. REFORM
XVIII. Road Pricing & Toll (Oslo, Stockholm)
XIX. SPARTACUS
XX. START
XXI. SURFF TR1053
XXII. TRANSPRICE
XXIII. TRENEN II - STRAN

### *3.4 Cost data*

Cost data are available for projects: I, II, III, V, VI, X, XIII, XIV, XV, XVI (see List 3.3. above) as well as some of the additional sources of information (see beginning of Chapter 3), that is only about 50% of the projects. Consequently cost/benefit assessment will be limited in their scope.

However, additional cost data are available (mainly for ITS measures) from ISFORT "Telecomunicazioni e informatica per i Trasporti", Il Mulino 1996, and from other sources, mainly in the UK (see above). These will be used to improve the depth and quality of the analysis.

## 4. Synthesis Tables

The tables on the following pages are a summary of data processed so far.

From a methodological point of view, in order to facilitate the non-technical measures impact analysis; two distinct tables are elaborated:

- a table that examines the impact on emissions and traffic indicators with reference to a list of single, “stand alone” measures, without combination with other accompanying and/or complementary measures;

- a table that examines the impact of package of measures, classified under very broad non technical measures typologies, such as “road pricing”, “traffic lights ITS-UTC measures”, and so on. The meaning of this classification is only for sake of convenience, e.g. to use an arrangement criterion, not in order to identify precisely the packages of measures effects’.

Some of the projects report impacts in absolute terms (e.g. decrease in the emission of pollutants expressed in tons - with no reference to a standard production prior to the adoption of the non-technical measure). These data have not been inserted in the tables, as obviously they cannot be compared to results from other sources. In the meanwhile messages have been sent to the authors of the relevant projects asking for the remittal of adequate reference data.

## IMPACT OF NON TECHNICAL MEASURES – SYNTHESIS TABLE FROM PROJECTS SREENINGS

- “STAND ALONE” MEASURES -

| **IMPACT** / **MEASURE** | **POLLUTANT EMISSIONS** CO | CO2 | C6H6 | HC | NOx | Particulate | **TRAFFIC INDICATORS** Vehicle km | Traffic volume | Average Speed | Fuel Consumption | Pass.km ton.km | Travel time | P.T use | Projects (or studies) & Location |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Park & Ride | -2% | -2% | -2% | -2% | -2% | -2% | -1% | | | | | | | LfU (German cities < 20.000 inhabitants) |
| Car Pooling | | | | | | | *-31%* | | | | | | | START (Italian urban areas) |
| Dial-A-Ride | -.1% | | | | -.1% | | | | | -.1% | | | | AIUTO (Como) |
| Road pricing | -8,3% | | | | -7,7% | | -8% | | | -13% | | | | AIUTO (Como) |
| | -7% | -7% | | -7% | -7% | | | -4,3% | | | | | | START (London – inner -) |
| | | | | | | | -5% | | | | | | | START (Italian urban areas) |
| | -47% | -21% | | | | | -22% | | | | | | | START (London) |
| | | | | | | | | -7% | | | | -1% | | TRANSPRICE (Athens) |
| | - 4.1% | - 8.7% | | | - 4.2% | - 4.1% | | | + 2.7% | | - 12.% (car) | | | AUTO OIL II (Athens) |
| | - 12.2% | - 7.9% | | | - 3.4% | - 5.7% | | | + 3.6% | | - 11% (car) | | | AUTO OIL II (Lyon) |
| | - 12.9% | - 9.8% | | - 11.9% | - 7.9% | - 7.1% | - 9.6% | | | | | | | EUROTOLL (Stuttgart) |
| | - 17.1% | - 12.3% | | - 15.8% | - 9.8% | - 9.2% | - 11.6% | | | | | | | EUROTOLL (Stuttgart) |
| | - 16.8% | - 9.7% | | - 15.3% | - 7.5% | - 7.5% | - 8.8% | | | | | | | EUROTOLL (Stuttgart) |
| | | | | | | | | -6% | | | | | | GAUDI (Trondheim) |
| Parking pricing | -4,8% | | | | -3,9% | | -4% | | | -6,3% | | | | AIUTO (Como) |
| | | | | | | | -1,2% | | | | | -0,2% | | SPARTACUS (Helsinki) |
| | | | | | | | 0,1% | | | | | -0,3% | | SPARTACUS (Bilbao) |
| | | | | | | | -1,9% | | | | | -1,1% | | SPARTACUS (Naples) |
| | - 7.9% | - 13.2% | | | - 3.9% | + .6% | | | + 3.1% | | -20% (car) | | | AUTO OIL II (Athens) |
| | - 18.7% | - 11.1% | | | - 3.0% | - 7.8% | | | + 3.4% | | -22% (car) | | | AUTO OIL II (Lyon) |
| PT fare structure | -14,4% | | | | -12,8% | | -13% | | | -18,9% | | | | AIUTO (Como) |
| | -3,1% | | | | | | | | | | | | | START (Basque Country) |
| | -0.6% | - 1.2% | | | +.5% | +1.2% | | | + .3% | | -3.0% (car) | | | AUTO OIL II (Athens) |
| | -1.9% | | | | | | | -1% (cars) | | | | | | AIUTO (Salerno) |
| | | | | | | | | | | | | | +30% | COST CITAIR 616 |
| Access control & limitation (speed limit) | +11% | | | + .4% | -4% | | | | | | | | | MASTER(Hungary) |
| | | | | | | | | -33/78% | | | | -18% | +50% | ERTICO ITS (Barcelona) |
| | | | | | | | -4,6% | | | | | +10,9% | | SPARTACUS (Helsinhi) |
| | | | | | | | -1,3% | | | | | + .2% | | SPARTACUS (Bilbao) |
| | | | | | | | -1,3% | | | | | + .6% | | SPARTACUS (Naples) |
| | | | | -17% | -10% | | | | | | | | | LfU (Stuttgart) |
| | | | | | -6/-9% | | | | | | | | | PISHINGER e al. (Graz) |
| | | -3% | | | | | | | | | | | | F.E.A (Germany) |
| Parking management | | | | | | | | -15% | | | | | | LfU (Stuttgart) |
| | | | | | | | | | | | | -35% | | ERTICO ITS |
| | | | | | | | | -.7% (car) | | -2,1% | | | | START |
| | | | | | | | | -5% | | | | | | M.HERRY, et alVienna |

**IMPACT OF NON TECHNICAL MEASURES – SYNTHESIS TABLE FROM PROJECTS SREENINGS**

- “STAND ALONE” MEASURES -

| **IMPACT** / **MEASURE** | **POLLUTANT EMISSIONS** CO | CO2 | C6H6 | HC | NOx | Particulate | **TRAFFIC INDICATORS** Vehicle km | Traffic volume | Average Speed | Fuel Consumption | Pass.km ton.km | Travel time | P.T use | Projects (or studies) & Location |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pedestrian and cycling | | | | | | | | | | -14% | | | | INESTENE (Strasbourg) |
| PT measures 1)Bus Priority | - .4%<br>-7% | - .3% | | | - .5% | - .4% | | | - .9%<br>+3%<br>-10% | -7%<br>-7% | - .11%(cars) | -14% | +5/10%<br>+18% | AUTO OIL II (Athens)<br>QUARTET PLUS (Athens)<br>INESTENE (France)<br>ERTICO (Turin)<br>ERTICO<br>ERTICO ITS (Gothemburg) |
| 2)Increased frequency | - .9% | | | | - .7% | | -1% | | | - .8% | | | | AIUTO (Como) |
| ITS/UTC measures (traffic lights) | +0,2 | -0,2 | | | -0,1<br>-6% | -0,1 | | | +1,1% | -2/3%<br>-14% | | | | AUTO OIL II (Athens)<br>OPTIONS TO REDUCE $NO_x$ AND…(Glasgow)<br>INESTENE (France urban area)<br>TRANSYT (Larisa – Greece) |
| Ramp metering | | | | | | | | | +20% | | | -20% | | ERTICO ITS |
| Staggered activity time | - 8% | | | | | | | | + 4,5% | | | -9% | | AIUTO (Geneva) |
| Taxes (on fuel, vehicle scrappage) | -.2%<br>-4,6%<br>-4,5% | +.4% | | | -.1%<br>-5,8% | +.1% | -15,5%<br>-7,8%<br>-14,6%<br>-2%<br>-4%<br>-6% | -5% (cars) | -.1% | -8,5% | + .5% | -3,6%<br>-0,4%<br>-7,0% | | SPARTACUS (Helsinki)<br>SPARTACUS (Bilbao)<br>SPARTACUS (Naples)<br>*DESGUPTA e al. (UK)*<br>*HELVI (Finland)*<br>AUTO OIL II (Athens)<br>AIUTO (Como)<br>AIUTO (Salerno) |
| Fleet & freight management -City Logistics | - .7% | - 2.5% | | | -3%<br>- 2.5%<br>-1%<br>-7%<br>-1% | -7%<br>- 5.1%<br>-5%<br>-8% | -10% | -6% (freight)<br>+1% | + .7% | -3%<br>-1%<br>-4/5%<br>-3%<br>-3% | +0.3% (car) | | | COST 321 (European average)<br>AUTO OIL II (Athens)<br>COST 321 (European average)<br>METAFORA<br>COST 321 (European average)<br>COST 321 (European average) |

## IMPACT OF NON TECHNICAL MEASURES – SYNTHESIS TABLE FROM PROJECTS SREENINGS
### - “STAND ALONE” MEASURES -

| **IMPACT** | **POLLUTANT EMISSIONS** | | | | | | **TRAFFIC INDICATORS** | | | | | | | Projects (or studies) & Location |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MEASURE** | CO | CO2 | C6H6 | HC | NOx | Particulate | Vehicle km | Traffic volume | Average Speed | Fuel Consumption | Pass.km ton.km | Travel time | P.T use | |
| Tele-working | | | | | | | -0,9%<br>-2,0% | +5% | +5% | | | -0,3%<br>-1,2%<br>-2,6% | | SPARTACUS (Helsinki)<br>SPARTACUS (Bilbao)<br>SPARTACUS (Naples) |
| Information to users | | -7% | | | | | | +3% | | -3%<br>-10%<br>-5/10% | | | | PROGNOS et al. (Germany)<br>OECD (the Netherlands) |

## IMPACT OF NON TECHNICAL MEASURES – SYNTHESIS TABLE FROM PROJECTS SREENINGS

- PACKAGE OF MEASURES -

| **IMPACT** / **PACKAGE** | **POLLUTANT EMISSIONS** | | | | **TRAFFIC INDICATORS** | | | | | Projects (or studies) & Location |
|---|---|---|---|---|---|---|---|---|---|---|
| | CO | CO2 | HC | NOx | Vehicle km | Traffic volume | Average Speed | Fuel Consumption | Travel Time | |
| Park & Ride | | | | | | | | | | |
| - Park & Ride & Bus-shuttle lines | -33,6% | | | | | -6% (cars) | | | | AIUTO (Salerno) |
| Road pricing | | | | | | | | | | |
| - Road pricing & New Tunnel | -4,8% | -4,7% | -4,8% | -4,5% | | | +2,5% (km/h) | -1,6% | -2,8% | AIUTO (Thessaloniki) |
| Parking pricing | | | | | | | | | | |
| - Park pricing & Dial-a-Ride | -5% | | | -4,1% | -5% | | | -0,13% | | AIUTO (Como) |
| - Park pricing & Car Pool | -5,7% | | | -4,7% | -5% | | | -8,3% | | AIUTO (Como) |
| - Park pricing & PT Increase | -6,7% | | | -5,4% | -6% | | | -9,2% | | AIUTO (Como) |
| - Park pricing & Management Measures | -4,4% | | | | | -3% (cars) | | | | AIUTO (Salerno) |
| Access control & limitation | | | | | | | | | | |
| - Access central area limitation & Park pricing | +13,7% (*) | | | | | -12% (cars) | | | | AIUTO (Salerno) |
| - Traffic calming & New Tunnel | -5,0% | -4,7% | -5,0% | -45% | | | +3,7% (km/h) | -1,6% | -3,0% | AIUTO (Thessaloniki) |
| - Access control residents/visitors & Park pricing | | | | | | -20% | | | | TRANSPRICE (Como) |
| Parking management | | | | | | | | | | |
| - Parking control & Access limitation | | | | | | -30% (veh.day) | -50% (km/h) | | | CAPTURE (Rome) |

## IMPACT OF NON TECHNICAL MEASURES – SYNTHESIS TABLE FROM PROJECTS SREENINGS

- PACKAGE OF MEASURES -

| **IMPACT** / **PACKAGE** | **POLLUTANT EMISSIONS** | | | | **TRAFFIC INDICATORS** | | | | | Projects (or studies) & Location |
|---|---|---|---|---|---|---|---|---|---|---|
| | CO | CO2 | HC | NOx | Vehicle km | Traffic volume | Average Speed | Fuel Consumption | Travel Time | |
| Pedestrian and cycling | | | | | | | | | | |
| - Pedestrianisation & New Tunnel arterial | -5% | -4,7% | -5,0% | -4,5% | | | +3,7% (km/h) | -1,6% | -3,0% | AIUTO (Thessaloniki) |
| - Pedestrianisation & New Tunnel arterial, PT bus lanes & traffic calming & parking management | -6,0% | -4,7% | -5,0% | -4,8% | | | +3,7% (km/h) | -1,6% | -2,9% | AIUTO (Thessaloniki) |
| | | | | | | | | | | |
| - Pedestrianisation & New Tunnel arterial & Metro | -6,1% | -4,9% | -5,1% | -4,6% | | | +3,9% (km/h) | -1,8% | -5,1% | AIUTO (Thessaloniki) |
| - Pedestrianisation & New Tunnel arterial & Metro & PT bus lanes & traffic calming | -5,2% | -4,9% | -5,1% | -4,6% | | | +3,9% (km/h) | -1,8% | -3,1% | AIUTO (Thessaloniki) |
| - Pedestrianisation & New Tunnel arterial & Metro & PT bus lanes, traffic calming & parking management | -5,1% | -4,8% | -5,0% | -4,6% | | | +3,9% (km/h) | -1,8% | -3,1% | AIUTO (Thessaloniki) |
| PT measures Priority | | | | | | | | | | |
| - Bus Priority & parking inf | | | | -8% | | | | | | CAPTURE (Brescia) |
| - Promote Public Urban Transports & Land Use Policies | -13% (g/veh*km) | | | | -9% | -9,5% | -7% | | | ESTEEM (Lyon) |

## IMPACT OF NON TECHNICAL MEASURES – SYNTHESIS TABLE FROM PROJECTS SREENINGS

### - PACKAGE OF MEASURES -

| **IMPACT** / **PACKAGE** | **POLLUTANT EMISSIONS** | | | | **TRAFFIC INDICATORS** | | | | | Projects (or studies) & Location |
|---|---|---|---|---|---|---|---|---|---|---|
| | CO | CO2 | HC | NOx | Vehicle km | Traffic volume | Average Speed | Fuel Consumption | Travel Time | |
| -Promote Public Urban Transports & Infrastructure measures | -1% (g/veh*km) | | | | -3,2% | -8,2% (cars) | | -4,1% g/veh*km | | ESTEEM (Brussels) |
| - Infrastructure measures (New metro line) | -5% | | | | -4% | -5% | +2% | -8% | | ESTEEM (Rome) |
| ITS/UTC measures | | | | | | | | | | |
| Multi-routing strategy | -2% | | | | | | | | -6% | CLEOPATRA TR 1012 (Turin) |
| In-vehicle route/ Guidance/information & Buses and Tram control | -2/4% | | | | | -9% | | | -3%(Bus) | INCOME (Gothenburg) |
| ITC (traffic routes,etc ) | +0,4% | +0,1% | | | | +1% | +7,5% | +0,1% | -4,4% | QUARTET PLUS II (Gothenburg) |
| PTS (Public Transport System ) | -2% | -2,2% | | -2,3% | -1,7% | -1,3% | +1% | -2,2% | -2,4% | QUARTET PLUS II (Gothenburg) |
| ITC & PTS (Pre-trip travel information, etc ) | | -5,3% | -6,1% | -4,2% | -3.5% | -4,5% | +3,5% | | -7,6% | QUARTET PLUS II (Stuttgart) |
| UTC & Public Transport Facilities | -6% | | | | | | | -8% | -14% | QUARTET PLUS II (Turin) |
| Traffic optimisation and reduction | | -20% | | | | | | -20% | | GERMAN AUTOMOBILE INDUSTRY (VDA), Koln |
| Regulation enforcement | | | | | | | | | | |
| - Regulatory Measure & Internalisation of external costs (Scenario R) | | -1,4% | | | -1,2% | | | | | EFFECTIVENESS OF ALTERNATIVES…. (West Germany) |

**IMPACT OF NON TECHNICAL MEASURES – SYNTHESIS TABLE FROM PROJECTS SREENINGS**

- PACKAGE OF MEASURES -

| IMPACT / PACKAGE | POLLUTANT EMISSIONS | | | | TRAFFIC INDICATORS | | | | | Projects (or studies) & Location |
|---|---|---|---|---|---|---|---|---|---|---|
| | CO | CO2 | HC | NOx | Vehicle km | Traffic volume | Average Speed | Fuel Consumption | Travel Time | |
| -Zoning- restricted access &Traffic Reduction Act | -8,3% | -8,4% | | -3,9% | | | | -7,2% | | ESTEEM (London) |
| -Restrictive traffic rules for heavy vehicles | | | | | | | -1,8% | +2,1% | | REFORM (Brussels) |
| Taxes (on fuel, incentives, etc) | | | | | | | | | | |
| - Financial Incentives & Awareness Campaigns (Scenario A) | | -.4% | | | +.3% | | | | | EFFECTIVENESS OF ALTERNATIVES … (West Germany) |
| - Financial Incentives & Awareness Campaigns (Scenario A) & Car cost increase | | -2,1% | | | -2,3% | | | | | EFFECTIVENESS OF ALTERNATIVES…. (West Germany) |
| Fleet & freight management | | | | | | | | | | |
| Implementation of Freight Platform & ban on Heavy Trucks | | | | | | +2,9% | -6,5% | +6,2% | | REFORM (Brussels) |
| Alternative Freight distribution | | | | -14% | -15% (trucks) | -1,3% (trips) | | | | REFORM (Rome) |

(*) Data are referred to the global area; for central area corresponding values are –82,4% (CO) and –68% (car traffic). The general conclusions that can be drawn from the TDM packages simulation is that, in the case of measures to limit Access to Central areas, in general the situation improves for the central and sub-central areas, while globally the situation becomes worse.

## 5. Analysis of Measure/Impact results

### 5.1 Introduction

In this section first conclusions are drawn on the assessment of the most cost-efficient non-technical measures.

As explained in the Cantique evaluation framework[1] cost and effectiveness information “will be combined in order to give for each non-technical measures the best single measure of cost-effectiveness based on available data”.

With the aim to facilitate the meaning of evaluation analysis and results, a preliminary issue has to be emphasised: the notion of costs and effectiveness adopted.

#### *5.1.1.Costs and benefit in the Cantique context*

The notion of costs adopted in the assessment exercise is quite “restrictive”, i.e. it doesn’t refer to generalised cost perceived by users (travellers, households and so on), but only to costs directly involved for its implementation, mainly related to infrastructure equipment, maintenance and personnel.

These are the costs actually available. We do not consider then social and environmental costs, as their inclusion would force us to analyse only a very limited number of studies.

The discussion of costs in the context of an impact assessment – and referring to the studies in the focus of CANTIQUE – could hence distinguish between:

- costs directly induced by a measure (investment, operation, maintenance,...);
- costs saving by changing traffic parameters, i. e. the monetary value of emissions and $CO_2$, including health damage, buildings and crops.

[1] Cantique Baseline Report, paragraph 5.5.3

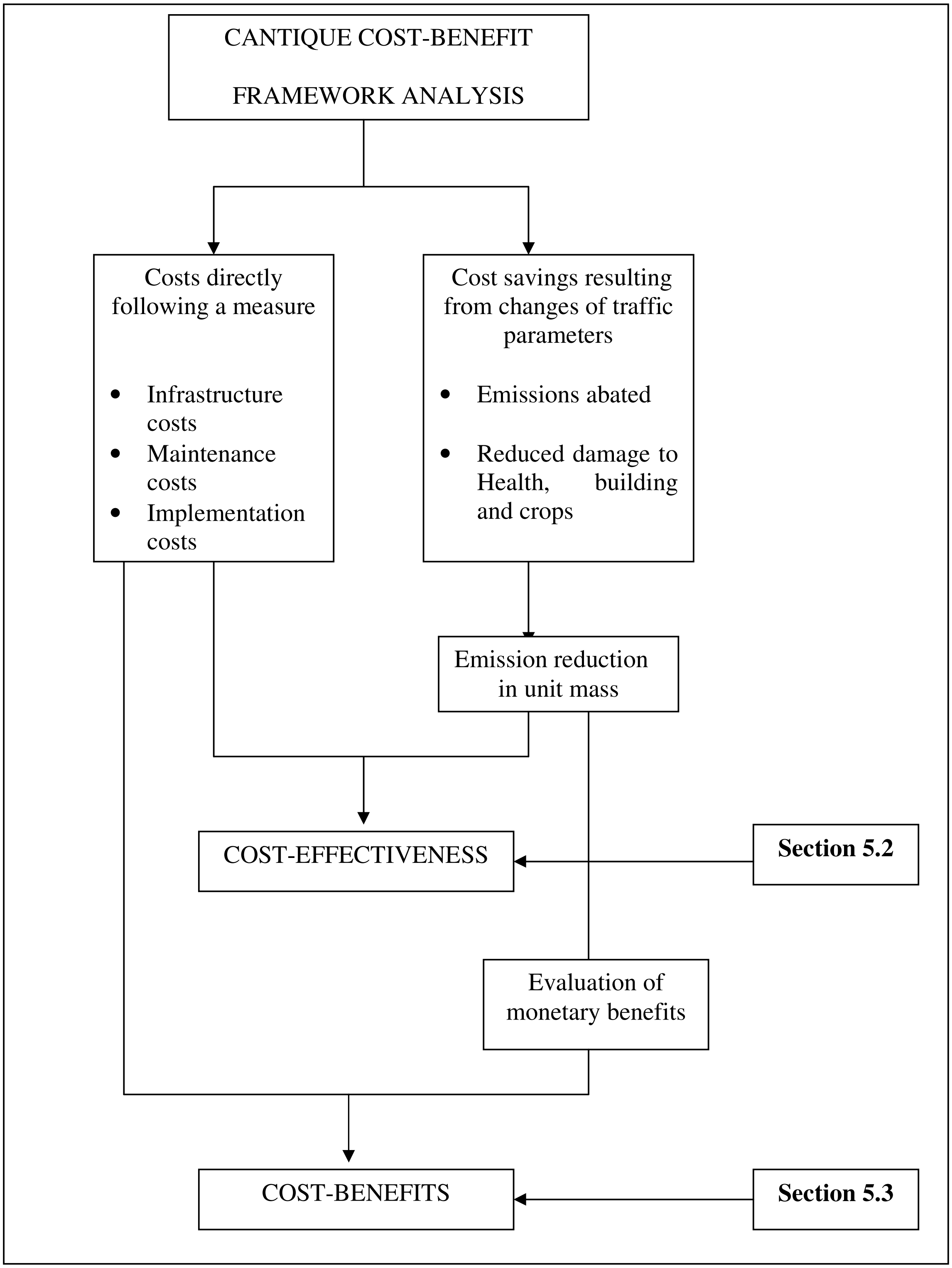
In general economic evaluations and especially in the Cantique context, the former are regarded as the costs of a measure, the latter as the benefits - reductions of environmental costs, with no accounting of accident costs and time costs due to lack of data.

However concerning benefits, we have the difficulty that in many cases their computation is incomplete since some pollutants are not considered in some studies. This detracts from the significance and comparability of monetary cost/benefit assessments. Therefore we have computed the benefits also in terms of abatements of (available) pollutants in physical terms and carried out a cost/benefit analysis in terms of cost per unit mass of abated pollutant.

This leads towards a two-level approach in the cost-benefit analysis:

- a first “cost-effectiveness” level, that analyses costs of measure with reference to each specific pollutant abated;
- a second level, that attempt to estimate a cost-benefit evaluation, based on more restricted measure, with a common spectrum of pollutant abated.

Consequently, a comprehensive cost-benefit scheme can be depicted as follows:


CANTIQUE COST-BENEFIT
FRAMEWORK ANALYSIS
Costs directly following a measure
Infrastructure costs
Maintenance costs
Implementation costs
Cost savings resulting from changes of traffic parameters
Emissions abated
Reduced damage to Health, building and crops
Emission reduction in unit mass
COST-EFFECTIVENESS
Section 5.2
Evaluation of monetary benefits
COST-BENEFITS
Section 5.3

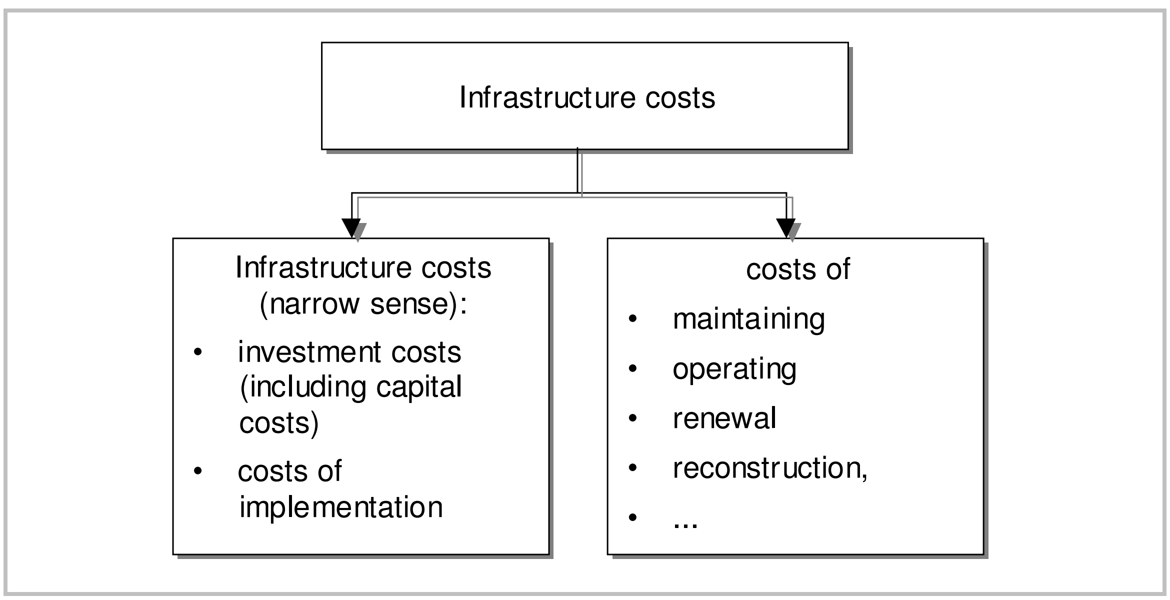
In order to gain a better clarification of such a cost-benefit assessment, two issues must be underlined, with reference to the costs and benefits side:

- the infrastructure costs, to the cost side;
- the allocation of costs (benefits) between pollutant, on the benefit side.

#### 5.1.1.1 Infrastructure costs

According to the targets of highlighting infrastructure costs in detail it is necessary to distinguish between cost accounting and charging. The latter is linked to the debate about pricing principles (full cost coverage, marginal pricing etc.) whereas cost accounting aspects are more relevant when addressing overall economic topics.

In the Cantique context, infrastructure costs are characterised as the costs of the measure. Infrastructure costs can be depicted in the following way:




Whereas cost expressions do not necessarily cause comparability problems within one harmonised frame (e. g. official transport planning procedures of a given country), a cross-country or "cross-methodological" examination has to consider some key questions. The critical point within Cantique is that most of this information remains unknown. In particular, two issues must be stressed:

1. The basic period a case study or a calculation refers to is essential to make cost expressions comparable. This is valid in case of a cross-country comparison as well as within one country. Monetary values need to be adjusted for inflation in order to make results transparent. Cantique deals with research work from the early 90s to the present time which comes up with alternating developments of the cost of living index across Europe (Table 1).

**Table 1: Cost of living index per country (1997, 1990=100)**

| | | | |
|---|---|---|---|
| Austria | 121.0 | Luxembourg | 118.0 |
| Belgium | 117.1 | Netherlands | 119.2 |
| Denmark | 115.0 | Portugal | 149.1 |
| Finland | 114.0 | Spain | 135.8 |
| France | 115.2 | Sweden | 126.3 |
| Germany | 122.9 | UK | 124.9 |
| Greece | 218.4 | EU-15 | 126.4 |
| Ireland | 116.8 | Switzerland | 118.4 |
| Italy | 136.0 | | |

2. The level of investment costs of a given implementation is strongly concerned to the depreciation period and the discount rate. To make things more complicated, the values applied in economic evaluations do not necessarily reflect real life observations. German Federal Transport Investment Planning, for instance, operates with an interest payment of 3 %. Table 2 shows that this is neither in line with the empirical long term interest rates observed in Germany nor to other selected countries.

**Table 2: Long-term interest rates per Country in % (1997)**

| | | | |
|---|---|---|---|
| Austria | 5.68 | Italy | 6.86 |
| Belgium | 5.59 | Luxembourg | 5.39 |
| Denmark | 6.23 | Netherlands | 5.55 |
| Finland | 4.85 | Portugal | 6,36 |
| France | 5.67 | Spain | 5.84 |
| Germany | 5.10 | Sweden | 6.61 |
| Greece | 9.92 | UK | 7.04 |
| Ireland | 6.49 | Switzerland | 3.36 |

Since case studies available are generally referred to mid 90s period, the empirical approach to overcome the above issue is to consider inflation rates in Europe in 1995 as to deflating annualised costs (Table 3).

**Table 3: Inflation rate in European Countries % (1995)**

| | |
|---|---|
| France | 1.7 |
| Germany | 1.7 |
| Greece | 6.9 |
| Italy | 4.6 |
| UK | 3.1 |

With reference to discount rate and depreciation period, it has been directly used the values indicated in the case studies, if available.

A reference to interest rates average values in 1997 (table 2) is adopted only if no other information is available.

#### 5.1.1.2 Evaluation of monetary impacts from emissions abatement

The aim of CANTIQUE is to inform local, regional and national transport policy and is therefore concerned with measures which improve air quality reducing emissions ($NO_x$, $PM_{10}$, HC, CO) as well as $CO_2$. The allocation of benefits deriving from these pollutants abatement should therefore reflect not only the relative quantities of the pollutants which are saved by a measure, but also their relative importance in terms of emissions/air quality impacts (e.g. on health, damage to buildings, crops).

In CANTIQUE, we are mainly concerned with urban air quality and the impacts of emissions on human health and the damage to buildings. In allocating benefits from the pollutants saved, the quantities of emissions saved have been given the following weighting, based on monetary impact values (including health, buildings and crops) from DG Environment's ExternE project and other sources.

The following monetary impact values are taken from DG Environment's ExternE project:

Relative weighting $W_p$ = Impact value $I_n$

| **Pollutant *p*** | **Impact value $I_p$** | Unit |
|---|---|---|
| CO | 500 | Euro/tonne |
| HC | 930 | Euro/tonne |
| $NO_x$ | 10000 | Euro/tonne |
| $PM_{10}$ | 20000 | Euro/tonne |
| $CO_2$ | 32 (range 18 - 46) | Euro/tonne |

### *5.1.2 Example of Cost-Benefit calculation*

In this section a practical example of cost-benefit assessment approach based on the above consideration is illustrated.

The following table gives Impact values (in Euro/tonne) for various pollutants according to ExternE and to values used by 37 USA agencies. Since the values are approximate and not very different from each other, the last column of the table gives intermediate values we are going to use in the present study. We stress here that these impact values are to be understood as rough first approximations, useful to express in quantitative fashion causal chains relevant to the air quality problem. No pretence of high accuracy is implied.

**Table of pollutants impacts in Euro/tonne**

| Pollutant | ExternE source | 37 USA agencies (*) | Value used here |
|---|---|---|---|
| CO | 500 | 662 | 600 |
| $NO_x$ | 10,000 | 6,454 | 8,000 |
| PM10 | 20,000 | - | 20,000 |
| $CO_2$ | 32 | 20 | 30 |
| HC | 930 | 256 ($CH_4$) | 650 |
| $H_2S$ | - | 1,415 | 1,400 |
| $N_2O$ | - | 3,050 | 3,000 |
| $SO_x$ | - | 3,153 | 3,100 |
| Voc (Volatile Organic Comp.) | - | 4,705 | 4,700 |

(*) PETS, D7 “Internalisation of externalities: Appendix”, July 1998

Now we fully recognise that impacts cannot be quantified in money terms in a final and significant way. Several social impacts having to do with quality of life considerations as well as with perceived effects, are, in fact, very difficult to measure in a reliable, repeatable way with some pretence of objectivity.

Another critical factor (already mentioned) is that implementation and operations costs have not been published by the authors of many studies considered here. Notwithstanding these snags, we are trying here to suggest a procedure for evaluating the cost/benefit ratio. It should be quite clear, then, that the Cost/Benefit calculations suggested here make no claim of representing a flawless scientific approach. On the contrary: we call attention to the naive simplicity of the calculations carried out.

At the same time, having made quite explicit the limits of accuracy achieved, we present the results obtained as an exemplification of improved analyses which will be obtainable after much wider experimentation and much more exhaustive data bases have been produced.

We will, then, compute the ratio between the positive impact of pollution reduction and the investment in non-technical measures aimed at reducing air pollution. The positive impact is computed as the sum total of the products of individual pollutants reduction (in tonnes) by the impact reduction given in the last column of the last table (in Euro/tonne). So both investment and benefit are expressed in Euros. The ratio expresses, then, the sum in Euros saved for each Euro invested in a measure.

In the following example, we take the pollutant mix recorded in Athens in 1995 and we apply a reduction in emissions due to implementation of parking charge policy[2].

| Pollutant | Percentages of reduction | Tonnes reduced (-) Tonnes emitted (+) (Annual average) | Impact in Euro/ tonne | Product of col. 2 by col.3 (Euros) |
|---|---|---|---|---|
| CO | -7.9 | -6,753.243 | 600 | 4,051,946 |
| $NO_x$ | -3.9 | -1,219.785 | 8,000 | 9,758,285 |
| PM10 | +0.6 | +8.639 | 20,000 | 172,792 |
| $CO_2$ | -13.2 | 404,021.319 | 30 | 12,120,640 |
| Voc | -4.0 | -842.974 | 4,700 | 3,961,978 |
| Total | | | | **29,720,056** |

It can be noted that in the final balance of total benefit, it must be subtracted the PM10 monetary evaluation, since it shows an increasing trend (+0.6%), and so it represents a damage to the society.

If we consider that the above reductions and impacts have been obtained after an investment of 3,100,000 Euros, then the benefit/cost ratio is

B/C = 29,720,056/3,100,000 = 9.58

so for every Euro invested damages are reduced by 9.58 Euros. The result is clearly understandable and significant -- but to be interpreted in view of the caveats and critical observations expressed above.

From a methodological point of view, in order to facilitate the analysis, the non-technical measure cost-benefit assessment will be carried out through the separation between single “stand alone” measure and the combination or packages of measures.

[2] Data reference: „Auto Oil II National Transport Base case“- Greece

## 5.2 List of measures analysed and their classification

According to available data a list of measures has been selected from the Deliverable 2 projects screening and further classified following the most common classes of solution and effects relevant at the city-level audience.

As outlined in Deliverable 2[3], measures for the city-level audience can be structured into three top-level categories, according to the means used to introduce/enforce them:

- **operational** measures, affecting the amount of pollutants emitted per vehicle-km;
- **strategic** measures, affecting the vehicle-kilometres driven per unit of demand (expressed in passenger*kilometres/tonne*kilometres);
- **demand** measures, directly affecting the demand for travel (expressed in passenger*kilometres/tonne*kilometres).

Two levels have broken down this top-level categorisation further. They include a 1st level category that classifies non-technical measures in broad categories, and a 2nd level that clarify the issues.

The 1st level categories considered here are:

- **Pricing policies**, which include road pricing and parking charges. Examples are measures of road cordon pricing, congestion pricing, corridor pricing.

[3] See Annex 6 „Structuring of Non-technical Measures for Local/Regional Level“

- **Regulation**, including policy instruments such as zone access control / environmental zoning, parking regulation, speed limits, eco-vignette programs, urban planning regulation, as well as more general policies of deregulation of public transport services and liberalisation of transport infrastructures (rail networks).

- **Infrastructure**, which cover all the investments made to enhance the transport system efficiency and sustainability, including new public transport services and infrastructure, modal interchanges, TEN infrastructures and high speed rail, cycle path and facilities, urban bypasses, high-occupancy and public transport lanes, rail freight freeways, traffic management systems and ITS applications.

The 2$^{nd}$ level categories specify the following sub-categories related to the first one:

- parking charges and road pricing relating to pricing policies;

- technology oriented investment and urban freight management investment relating to the infrastructure;

- air quality responsive traffic control and regulations strategies in urban and freight transport fields relating to regulation area.

A synoptic table follows with the indication of the non-technical measures analysed, the project reference, the top level categories at city level, location and further classifications.

At the bottom of the table, two packages of non-technical measures are listed , in the fields of Traffic Demand Management and Intelligent Transportation Systems.

| | PROJECT | MEASURE | TOP LEVEL CATEGORY | LOCATION |
|---|---|---|---|---|
| 1ST LEVEL CATEGORY **PRICING POLICIES**<br>2ND LEVEL SUBCATEGORY PARKING CHARGES | | | | |
| 1 | AUTO OIL II | Parking charges | Strategic measures | ATHENS |
| 2 | AUTO OIL II | Parking charges | Strategic measures | LYON |
| 3 | AIUTO | Parking charges | Strategic measures | COMO |
| 1ST LEVEL CATEGORY **PRICING POLICIES**<br>2ND LEVEL SUBCATEGORY ROAD PRICING | | | | |
| 4 | AUTO OIL II | Road Pricing | Strategic measures | ATHENS |
| 5 | NASQ | Road Pricing | Strategic measures | LONDON |
| 6 | EUROTOLL | Cordon Pricing | Strategic measures | STUTTGART |
| 7 | AIUTO | Road Pricing | Strategic measures | COMO |
| 1ST LEVEL CATEGORY **INFRASTRUCTURE**<br>2ND LEVEL SUBCATEGORY INVESTMENT | | | | |
| 8 | AIUTO | New lines, Public Transport Frequency Increase | Demand measures | COMO |
| 9 | OVERALL ECONOMIC.. | Integrated Telematic Systems | Demand measures | GERMANY-AREA WIDE - |
| 10 | AUTO OIL II | UTC-Improving traffic flow by increasing road capacity | Demand measures | ATHENS |
| 11 | AUTO OIL II | Bus lanes, priority | Demand measures | ATHENS |
| 12 | QUARTET PLUS | ITC | Demand measures | TURIN |
| 1ST LEVEL CATEGORY **INFRASTRUCTURE**<br>2ND LEVEL SUBCATEGORY URBAN FREIGHT MANAGEMENT | | | | |
| 13 | OVERALL ECONOMIC.. | Freight Distribution Center | Demand measures | GERMANY-AREA WIDE - |
| 14 | CITY LOGISTICS | Freight Distribution Center | Demand measures | COLOGNE |
| 15 | OVERALL ECONOMIC.. | Increased of payload | Strategic measures | GERMANY-AREA WIDE - |
| 16 | AUTO OIL II | City Logistics | Demand meas. | ATHENS |
| 1ST LEVEL CATEGORY **REGULATIONS**<br>2ND LEVEL SUBCATEGORY AIR QUALITY RESPONSIVE TRAFFIC CONTROL | | | | |
| 17 | NASQ | Parking management | Strategic measures | LONDON |
| 18 | OPTION TO REDUCE | Traffic restrictions | Strategic measures | NETHERLAND -AREA WIDE- |
| 19 | NASQ | Low emission zones | Strategic measures | LONDON |

| | PROJECT | MEASURE | TOP LEVEL CATEGORY | LOCATION |
|---|---|---|---|---|
| 1ST LEVEL CATEGORY **REGULATIONS**<br>2ND LEVEL SUBCATEGORY URBAN FREIGHT TRANSPORT | | | | |
| 20 | CITY LOGISTICS | Enlarging cons. | Strategic measures | COLOGNE |
| 21 | CITY LOGISTICS | Improvement supply condition | Strategic measures | COLOGNE |
| 22 | OVERALL ECONOMIC.. | Route planing | Strategic measures | GERMANY-AREA WIDE - |
| PACKAGES OF MEASURES<br>TRAFFIC DEMAND MANAGEMENT | | | | |
| 23 | AIUTO | Parking Pricing & Car Pool | Strategic measures | COMO |
| 24 | AIUTO | Parking Pricing & Dial a Ride | Strategic measures | COMO |
| 25 | AIUTO | Parking Pricing & Public transport | Strategic measures | COMO |
| PACKAGES OF MEASURES<br>ITS MEASURES | | | | |
| 26 | QUARTET PLUS | ITS- Packages | Strategic measures | STUTTGART |
| 27 | QUARTET PLUS | ITS- Packages | Strategic measures | GOTHENBURG |
| 28 | QUARTET PLUS | ITS- Packages & bus/tram priority | Strategic measures | STUTTGART |
| 29 | QUARTET PLUS | ITS- Packages & bus/tram priority | Strategic measures | GOTHENBURG |

Cost-benefit assessment follows for each cluster of policies.

## *5.2.1 Pricing Policies*

### 5.2.1.1. Parking charges: case studies specification

Parking charges are typical measures to encourage modal shifts and reduce congestion on urban roads. Usually, their implementation costs are lower than for road-pricing schemes[4].

Case studies examination are based on Auto Oil II Programme (for Athens and Lyon) and Aiuto Project, (for the city of Como).

In Athens and Lyon parking charges policies simulate the impact of an increase average parking charge of 3 Euro (average value that might be varied over the city area) for inhabitants and commuters at the urban destination of each trip.

Enforcement cost represents the main cost component: 3 M Euros per year in Athens and 2 M Euros in Lyon.

Implementation costs annualised over 20 years period using a discount rate equal to 9% in Greece and 5% in France, are approximately 106keuro in Athens and 60kEuro in Lyon.

In the city of Como, the charge will be 1,5 Euros for all the day (but only 1 Euro if the duration of the stay is 1 hour). This measure in the Como context is expected to determine switches on mode and parking destination (for all trips) and final destination.

The cost structure for the city of Como includes investments cost for new parking places in sub-central zones and infrastructure provision of 40 parking meters.

Hence, the annualised investment cost over 20 years period using a discount rate of 6% is equal to 1,200 kEuro, while operating costs, calculated on the basis of five man/year at 30kEuro per year, are equal to 150 kEuro.

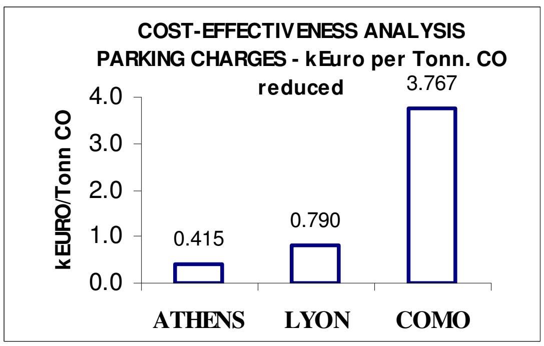
Total annualised costs in Euros for each case study at 1995 prices are approximately the following:

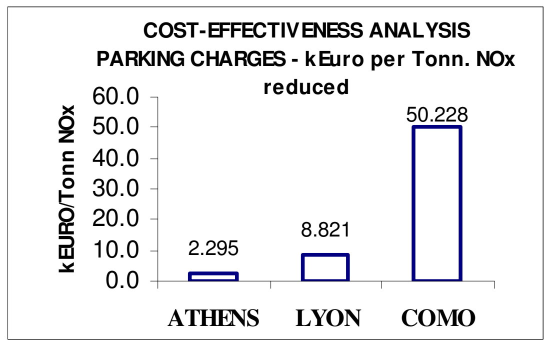
[4] Auto Oil II Programme „Non Technical Measures „ Draft final Report, page 40

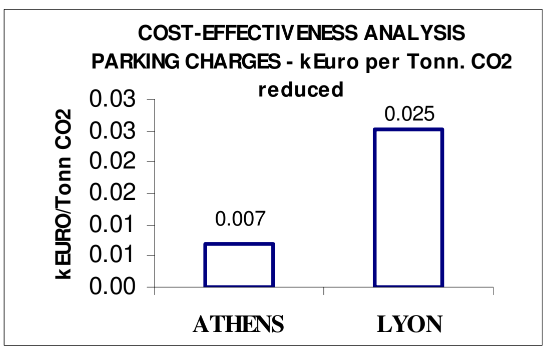
| ATHENS | LYON | COMO |
|---|---|---|
| 2,800,000 | 3,000,000 | 1,320,000 |

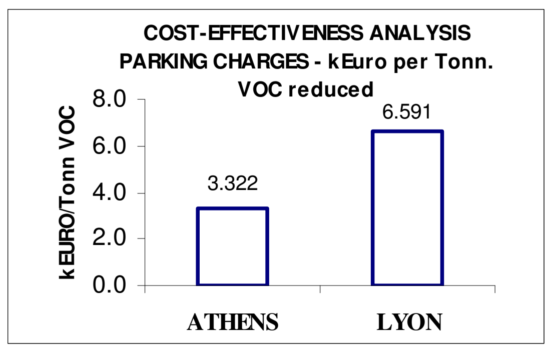
#### 5.2.1.2. Cost-effectiveness analysis

Case studies on parking charge clearly shows the peculiarity of Como case study. As shown in the graphs, cost-effectiveness evaluation for CO and NOx in Como gives values that exceed considerably the corresponding values for Athens and Lyon.




As mentioned above, the specific circumstances of Como case study do not depend on the cost structure level but on the absolute values of pollutant reduction.

In fact, the annual absolute values of emission saved in the city of Como are considerably lower than in Athens and Lyon, i.e. 350 tonnes for CO compared to 3,700 (Lyon) and 6,700 (Athens).

The annual value of emission saved in Como is probably underestimated due to the characteristics of environmental indicator evaluation in Como case study.

Since it provides only an average hourly emission saving (in kg), the equivalent value on an annual basis does not consider among other things the peak-emission level during the tourist season (crucial for the city of Como).

Leaving aside the influence of Como situation, the average cost-effectiveness for parking charges in reducing 1 tonne for pollutants are the follows:

-about 0.5kEuro for CO;

-about 4kEuros for NOx;

-about 5kEuros for VOC;

-about 20Euros for $CO_2$.

#### 5.2.1.3. Road pricing: case studies specification

Urban road pricing for access to certain areas has so far only been implemented in Singapore and Norway. Studies of road pricing schemes have been carried out in other cities, e.g. Stockholm, London, Oxford and Bristol[5].

Case studies analysed in Cantique cost-effectiveness assessment are related to four cities: Athens, London, Como and Stuttgart, respectively in the context of the Auto Oil II Programme (Athens), the National Air Quality Strategy Objectives (London), Aiuto project (Como), and Eurotoll project (Stuttgart).

In Athens, a toll time-differentiated for commuters as well as for inhabitants has been levied. Implementation costs annualised using a discount rate of 9% during 20 years are about 7 M Euro. Operating costs, including enforcement, are about 27 M Euro/year.

A study to estimate the effect of a road user-charging scheme has been tested in London, in the context of “The London Congestion Charging Research Programme”.

For the scheme selected, it is estimated that if this was operated using a transponder (an electronic base system) with smart cards, this would involve a capital costs of £335m, and annual operating costs of £155m.

Hence, costs estimates amount to 114M Euros[6] annualised over 30 year period using a discount rate of 6%.

In Como case study, car users will pay a fixed toll for each time they pass through a toll point (only when they enter into the city, not when they exit). The charge will be fixed not time dependent or distance dependent. The charge will be initially set at 2 ECU for each entrance during all the day.

Investment costs annualised over 20 years using a discount rate of 6% are equal to 335 kEuro, including operational costs of 2 man/year at 30kEuro/man year.

In Stuttgart, three scenarios differing in access price level and duration of high price period have been implemented.

[5] Auto Oil II Programme „Non Technical Measures „ Draft final Report, page 38

[6] Values in Euro are obtained using Ecu conversion rate for English Pound Sterling (year 1997)

A first scenario with a duration of 2x2 hours with a maximum of 4 DM; a second scenario with a duration of 2x0.5 hours with a maximum of 4 DM; and a third scenario with a duration of 1x1.5 hours with a maximum of 6 DM.

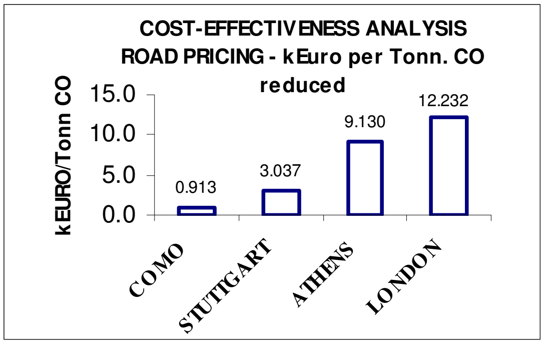
The first scenario with 2x2 hour with a maximum of 2Euro has been selected for cost-effectiveness assessment purpose. The estimated average investment costs annualised over 20 years using discount rates of 5% are about 2,7 M Euros.

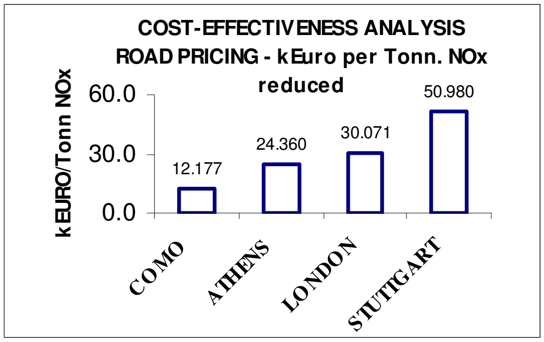
A summary yearly cost-table in Euros (1995 prices) for each case study selected follows:

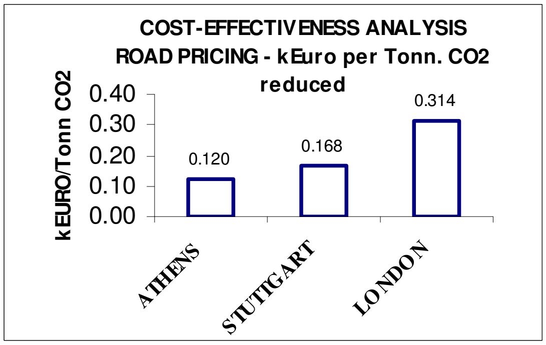
| ATHENS | LONDON | COMO | STUTTGART |
|---|---|---|---|
| 32,000,000 | 111,000,000 | 320,000 | 2,600,000 |

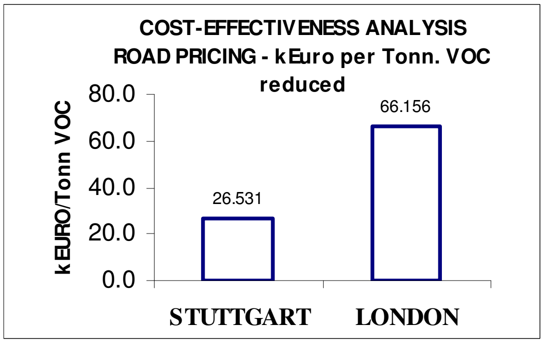
### 5.2.1.4. Cost-effectiveness analysis

The graph below shows cost-effectiveness evaluation for road pricing with reference to CO, NOx, CO2 and VOC.



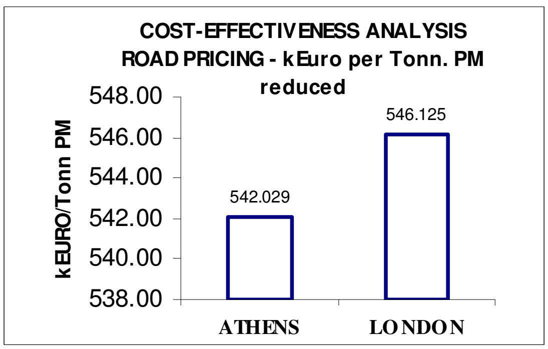



In evaluating cost-effectiveness results it must be considered that for the London case study it was assumed that the emissions reduction is proportional to the predicted average reduction in traffic volume, i.e. 10%, due to road pricing implementation.

This might lead to a rough evaluation for some pollutant reductions' (in particular NOx, VOC and CO2), that might affect cost-effectiveness results.

In spite of that, values for NOx and CO2 show a good fit to average values: about 30kEuros per tonne reduced for NOx and about 0.2 Euros for CO2.




A good was obtained also for PM, around the average value of 540 k Euros.

Cost-effectiveness values for CO show higher variations among case studies: from a minimum value of 0.9 kEuros per tonne in Como, 3.0 kEuro in Stuttgart, 9.1 kEuro in Athens and to 12.2 Euros in London. For VOC values go from 26 k Euros in Stuttgart to 66 k Euros in London.

In these cases average cost per tonne reduced presents large variations and should be used with great prudence:

1. for CO emissions, leaving aside the extreme values of Como and London, an average value should be fixed about 4 k Euro per tonne;

2. for VOC emissions the average cost-effectiveness values is about 40 k Euros.

## *5.2.2 Infrastructure*

### 5.2.2.1. Investments: case studies specification

Infrastructure investments include a set of measures with the purpose of improving urban road traffic flows, i.e. reducing inefficient and polluting stop-and-go traffic. This should be achieved using investment in telematics, e.g. route guidance and real time adaptive synchronisation of traffic lights, and variable message signs, and/or by improving infrastructure at bottlenecks, e.g. additional lanes and better design of intersections.[7]

The types of measures analysed by Cantique case studies are the following:

- investments in the field of urban traffic control (UTC) systems (Athens);
- investments in the field of Intelligent Transport Systems (ITS) and Integrated Telematics Systems (Turin and German -wide area-);
- investments in the field of Public Urban Transport (Athens, Como).

Investments in UTC systems that respond automatically in real time to traffic fluctuations can increase the capacity of an existing network.

In Athens, in the context of Auto Oil II Programme, increasing road-capacity by UTC systems involves annualised investment costs equal to 10 M Euros[8], including 4 M Euro/year in operating costs.

Simulation of an extended use of Integrated Telematics systems has been made across Germany assuming a 23% market penetration of RDS/TMC. Annualised investments costs are equal to 632 M Euros.

In Turin, in the context of Quartet Plus project, ITC measures have been tested by assigning to public transport priority at signalized intersections as an integral part of the area control provided by the UTC system (CALLED 5T). These apparatuses were

[7] See also “The Auto Oil II Programme, non-technical measures Draft Final Report, page57.
[8] Over 20 year using a discount rate of 9%,

connected to each other and then connected (by means of a connection every three SPOTs outward) with dedicated lines at the 5T traffic control center which make up the principal skeleton of the 5T telecommunications network.

Investment costs annualised over 15 year using discount rates of 5% is approximately 81 M Euros, including maintenance and operating costs.

Investments in the fields of Public Urban Transport include both infrastructure facilities and setting up of new lines and buses; in Athens, by dedicating lanes for buses and priority for public transport at signals, in the city of Como, by purchasing 150 new bus.

In the Athens case study, estimated annualised investment costs value over 20 years using a discount rates of 9% is 5,5 M Euros.

In the Como case study, annualised investments costs amount are approximately 7 M Euros, including 6,5 M Euros for operating and administrative costs (corresponding to 40 kEuro/man year – for 150 new drivers – and 30kEuro/man year – for 15 employees in administration -).

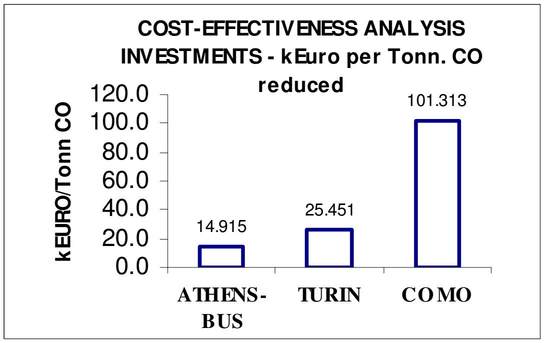
The yearly cost-table in Euros at 1995 prices for each case study considered is the following:

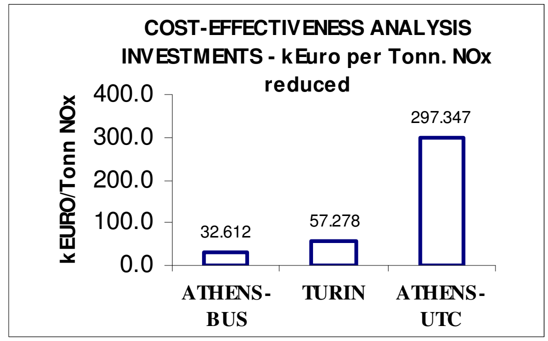
| ATHENS-UTC | GERMANY AREA WIDE | ATHENS-BUS LANES | COMO | TURIN |
|---|---|---|---|---|
| 9,300,000 | 620,000,000 | 5,100,000 | 7,100,000 | 78,000,000 |

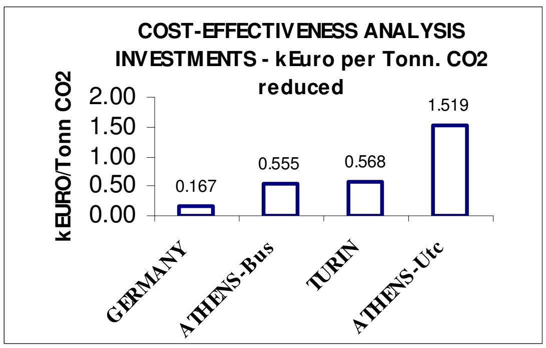
#### 5.2.2.2. Cost-effectiveness analysis

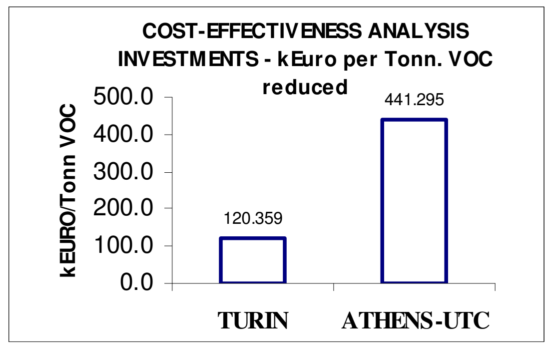
The following graph shows cost-effectiveness analysis for investment policies in the field of urban infrastructure.

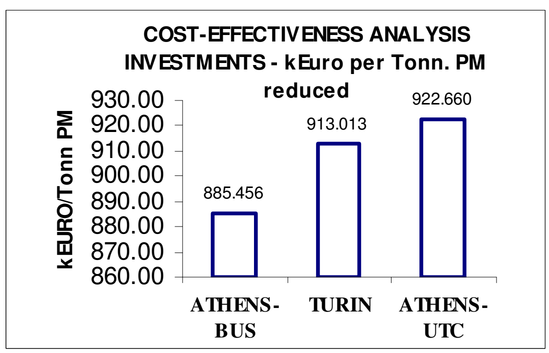
The pollutants analysed are CO, NOx, VOC, PM and CO2.




In the case of infrastructure investments, operating and capital costs could vary considerably among measures. A key variable in the determination of yearly total cost is the life cycle of the investment, the amount of which can hardly estimated in a credible way when reliable data are lacking.

This is true in particular for Athens-UTC, as regarding NOx, VOC and CO2 reductions, as cost-effectiveness values show a great variability from average cost-effectiveness values as UTC measures are simulated and include both a package of inexpressive traffic management measures and construction measures to remove bottlenecks[9].

The high cost-effectiveness value recorded for the city of Como, which clearly are outlier with respect to the average values for Athens and Turin, appear also to be influenced by a general underestimation of pollutant reduction due to particular Como case study reference data (see above, par. 5.2.1.2)

Keeping in mind the heterogeneous nature of investment policies analysed: from Intelligent Transport System to Public Urban Transport facilities; and leaving aside the “outlier”, an average cost-effectiveness value per pollutant can be defined as follows:

- 16 k Euros per 1 tonne CO reduced;
- 40 k Euros per 1 tonne NOx reduced;
- 0.5 k Euros per 1 tonne CO2 reduced;
- 910 k Euros per 1 tonne PM reduced.

[9] “The Auto Oil II Programme“, Non-technical Measures – Draft Final Report, page 58

### 5.2.2.3. Urban Freight Management: case studies specification

A survey of about 20 European cities showed that the share of freight transport on total mileage in urban areas varies between below 10% and about 20%, depending on the size and the local structure of a city[10].

There are strong indications that the growth of freight is expected to continue at a rate of approximately 2-3 % per year. The strong performance of road transport increased its market share (excluding maritime transport) to 73 % in 1997 (compared to 49 % in 1970)[11].

Therefore, the impact analysis of measures related to urban-freight transport should have play a strategic relevance towards implementation of urban clean air policies.

Investments in the field of urban freight management include the provision of interchange facilities, especially for combined rail transport, and a list of measures aiming to make urban road freight transport more efficient. These are often considered jointly under the heading of “city logistics”.

The measures analysed in the case studies includes:

- an increase of load factors by 10% (in Athens) and in Germany – area wide -;
- the establishing of freight distribution centres (FDC) in the city of Cologne and in Germany – area wide -.

In Athens, an increase of average load factors of 10% for HGV and LGV is simulated through the implementation of multi-modal infrastructure services.

Operating costs are equal to 50 M Euros/years in addition to annualised implementation costs of 5 MEuros over 30 years using a discount rate of 9.

Annualised estimated costs for increase of payload in Germany by 5% are equal to 130 M Euros[12].

[10] COST 321 „Urban Goods transport,, 1997
[11] „The Auto Oil II Programme“ Non-technical measures – Draft Final Report , page 36
[12] Cantique D2 „Overall economic evaluation of rationalizing measures in road transport“

Estimating annualised costs for establishing a Freight Distribution Centre dedicated to long-distance transport in the city of Cologne are about 782 M Euros, in Germany-area wide—are equal to 166 M Euros.

Consequently, the annualised cost-table in Euros at 1995 prices is the follows:

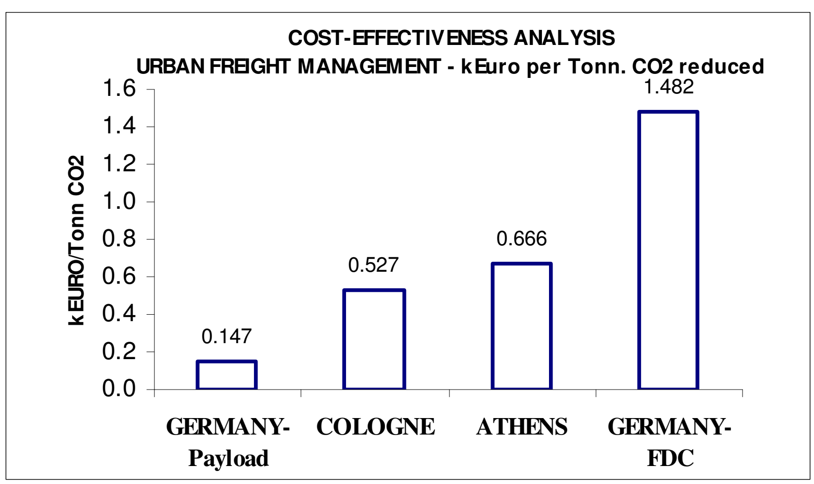
| COLOGNE FDC | GERMANY FDC | ATHENS PAYLOAD | GERMANY PAYLOAD |
|---|---|---|---|
| 769,000,000 | 163,000,000 | 51,000,000 | 128,000,000 |

The huge difference in the annualised investment costs of establishing a Freight Distribution Centre between the city of Cologne and Germany area wide, underlines how difficult it is to transfer cost component like price level, land property, availability and quality of infrastructure.

### 5.2.2.4. Cost-effectiveness analysis

Cost-effectiveness analysis for investments in urban freight management is available only for $CO_2$ emissions.

In fact, since emission reduction data for NOx, PM, VOC and CO, are available only for Athens, comparisons cannot be carried out.




With reference to $CO_2$ emissions, the average cost-effectiveness value is about 0.7 k Euros per tonne reduced.

### *5.2.3 Regulations*

#### **5.2.3.1. Air quality responsive traffic control: case studies specification**

Administrative and regulative measures are included in the more general traffic demand strategy, aiming at improving traffic flows or reducing the number of vehicle in specified areas.

Case studies analysed concerned :

- setting up of Low Emission Zones (London);
- providing of parking spaces (in London);
- applying traffic restrictions (the Netherlands).

Setting up a Low Emission Zone entails significant capital and operating costs; in particular if the costs of replacing old cars with new ones conforming to admitted standards are taken into account.

However, no direct estimates of these costs are available. The modelling Low Emission Zone for central London (Westminister and City) estimates financial costs of £30M (capital cost) and £15M (operating costs)[13] for implementing a road user charging cordon this does not include the additional resource costs to private individuals or firms for upgrading vehicles.

Corresponding annualised costs over 30 years using a discount rate of 6% are approximately 4,7 M Euros.

Parking restrictions involve removal of parking spaces on public roads, as distinct from parking charging, which allows parking at an (increased) cost[14].

Annualised capital costs of a parking restriction scheme are approximately 6,7 M Euros.

[13]Department of the Environment, Transport and the Regions, An economic Analysis of the National Air Quality Strategy Objectives, chapter 3

[14] Ibidem

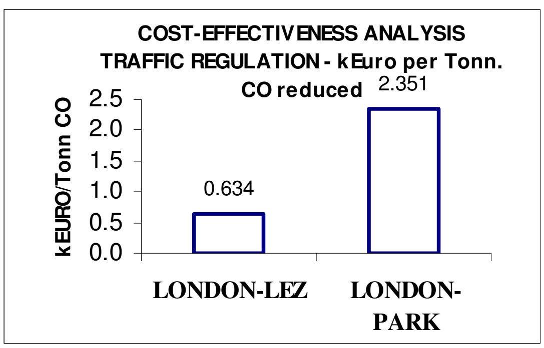
A traffic restriction scheme applied to petrol cars only in the Netherlands gives annualised total cost equal to approximately 5,7 M Euros (based on an average annualised total cost of 1.23 Euro/vehicle).

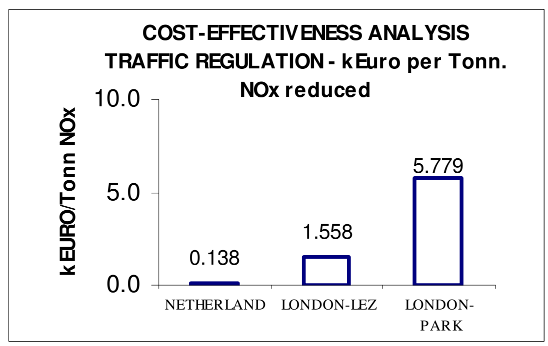
For each case study analysed, a summary cost-table in Euros at 1995 prices follows:

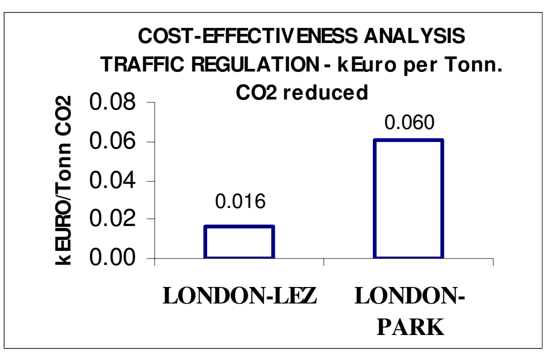
| LONDON -LEZ- | LONDON -PARKING- | THE NETHERLANDS |
|---|---|---|
| 4,600,000 | 6,400,000 | 5,600,000 |

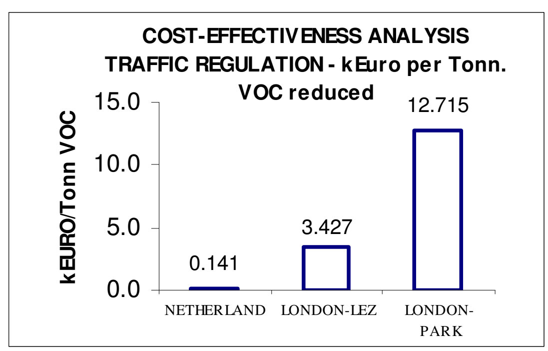
### 5.2.3.2. Cost-effectiveness analysis

The following graph shows cost-effectiveness values for CO, NOx, CO2 and VOC.



Although the case studies costs values' are similar, the range of cost-effectiveness values per pollutant appear to be very large.

This can be related to specific case studies characteristics; i.e. considering only London case studies, the cost-effectiveness values present lower variations.

For CO emissions, an average cost-effectiveness value can be set at about 1 kEuro per tonne abated; while for CO2, the corresponding value is about 0.03 kEuro per tonne reduced.

On the other hand, the Netherlands case study for NOx and VOC involves extremely simplified assumptions: i .e, total pollutant saved is considered equal to an average pollutant reduction potential per vehicle, with no information about the number of vehicle involved.

To estimate tonnes reduced for NOx and VOC in the Netherlands case study it was assumed that the total vehicle stock was identical to the total number of petrol cars (in 1995) in the Netherlands[15].

In view of the above, it is advisable to estimate an average value of cost-effectiveness for reducing NOx and VOC emission based only on the London case study.

For NOx we can approximately fix an average cost-effectiveness value equal to 3 k Euro per tonne reduced; for VOC the corresponding value is about 8 k Euro.

[15] Information taken from „Auto Oil II National Transport Base case for the Netherlands

#### 5.2.3.3. Urban freight transport: case studies specification

Among the administrative (planning) and regulatory measures, which do not use pricing signals as main tools and do not involve infrastructure investment, we consider here urban freight transport management.

Case studies analysed include

- increase in the size of consignments, in the city of Cologne;
- improvement of supply conditions, in the city of Cologne;
- route planning, in the Germany area wide.

The increase in the size of consignment is assumed to be of 10 % based on a company survey and might not be realistic today. Similar doubts can be mentioned concerning the expected decrease of 10 % v.km. The costs depend on specific components that are not transferable. Annualised values are estimated as 29 M Euros.

The improvement of supply conditions depends on the range of institutional regulation (e.g. access restrictions) at the starting point. Also labour market conditions (personnel needed outside regular working times) should play a crucial role. Estimated annualised costs are approximately 12 M Euros.

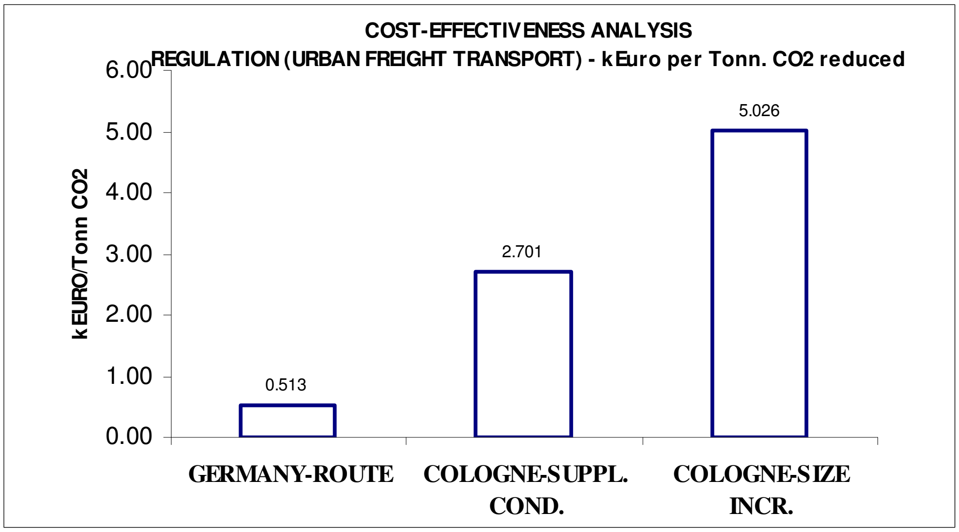
The practice of route planning, by the use of computers for planning and manufacturing purposes, is common standard today like in almost all other sectors. Annualised costs in Germany are approximately equal to 175 M Euros.

The summary cost-table in Euros at 1995 prices for each case study is the follows:

| COLOGNE<br><br>INCREASE IN THE SIZE OF CONSIGNMENTS | COLOGNE<br><br>SUPPLY CONDITION | GERMANY<br><br>ROUTE PLANNING |
|---|---|---|
| 29,000,000 | 12,000,000 | 173,000,000 |

#### 5.2.3.4. Cost-effectiveness analysis

The following graph shows cost-effectiveness evaluation for regulatory measures in the field of urban freight management.




Cost-effectiveness values are available only for CO2 emissions. Range of values goes from 0.5 k Euros for route planning in Germany, to 5 k Euros for increased size of consignments in the city of Cologne.

Consequently, average cost-effectiveness values due to improvements in the management of freight transport may be fixed approximately at 2 K Euros per tonne reduced.

## *5.2.4 Package of measures: Traffic Demand Management*

### 5.2.4.1. Case studies specification

Three packages of measures, which should be included in the family of traffic demand management policies, were simulated in the city of Como in the context of the Aiuto project. They are:

1. *Park Pricing with a time dependent charge plus increase in public transport frequency (PP&TFI)*. All the public parking spaces in the city centre will be charged through the installation of parking meters and three different zones are identified. An increase in the public transport frequency is simulated with a reduction of waiting time.

2. *Park Pricing with a time dependent charge plus Dial-a-Ride (PP&DAR)*. All the public parking spaces in the city centre will be charged through the installation of parking meters and three different zones are identified. A Dial-a-Ride scheme is simulated in the Convalle plus another zone on the east side.

3. *Park Pricing with a time dependent charge plus Car Pool (PP&CP)*. All the public parking spaces in the city centre will be charged through the installation of parking meters and three different zones are identified. A Car Pool scheme is simulated in the city centre (Città Murata). A Car Pool team is composed of at least three persons. The teams don’t pay the Park Pricing fees.

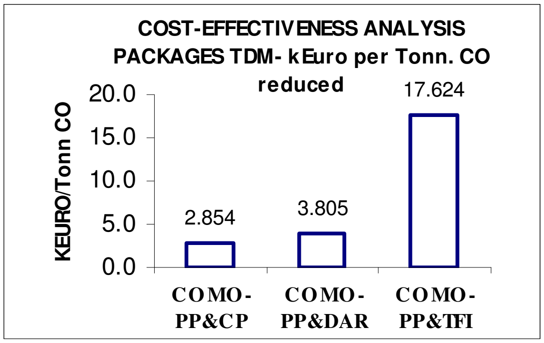
Costs evaluation is based on investments and operational costs (basically for employees’ salaries); costs are annualised over a 20 years period using a discount rate of 5%.

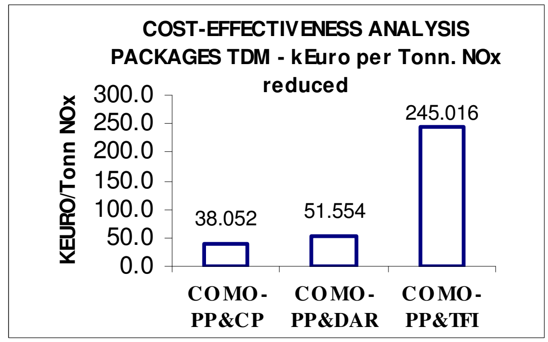
The following table summarises yearly costs in Euros at 1995 prices for each package :

| PP%TFI | PP&DAR | PP&CP |
|---|---|---|
| 8,800,000 | 1,400,000 | 1,200,000 |

#### 5.2.4.2. Cost-effectiveness analysis (TDM)

Cost-effectiveness analysis for CO and NOx reduction is depicted in the following graph.




Since the aim here is to evaluate packages of measures, their range with reference to an average value is obviously not meaningful. Moreover, each package could be evaluated considering indicators other than simple cost-effectiveness.

For example, values for Park Pricing and Public Transport Frequency clearly exceed the other ones. This is a direct consequence of high costs related to public transport frequency increases, which involved investments in the purchase of new buses and personnel.

Consequently, a mere cost-effectiveness analysis should lead to reduce public transport frequency in favour of Dial-a-Ride or Car Pool provisions. But, considering equity indicators, the benefits deriving from the increase of public transport probably exceed the Dial-a-Ride and car-pool ones.

With a strict reference to the costs of emission abated, the package with Park pricing and Car Pool is the most efficient, with 2.8 k Euros per tonne CO reduced and 38 k Euros per tonne NOx reduced.

### *5.2.5 Package of measures: ITS measures*

#### 5.2.5.1. Case studies specification

Case studies of packages of measures in the field of telematic applications are referred to Gothenburg and Stuttgart, in the context of the Quartet Plus Project.

In both cities, two different packages are simulated:

1. A package ”individually-based” (I) which assumes that current travel demand and any increase in demand between now and 2005 will be met chiefly by individual transport modes. In view of this, it is necessary to improve the individual transport system. A number of ITS measures were used to achieve this aim. The backbone of the system was the creation of special traffic routes where traffic flow is optimised and the disturbance from public transport, pedestrians and parking is limited. A policy of maximum penetration of vehicles was used where appropriate.

2. A package P is on the contrary ”public transport oriented”. It is anticipated that some of the current travel will move from cars to the bus/tram system and that the future increase in travel demand will be met by an improved public transport system. ITS measures can assist in different ways. Scenario P has as its central focus an integrated Public Transport system which links buses, trams and park-and-ride schemes.

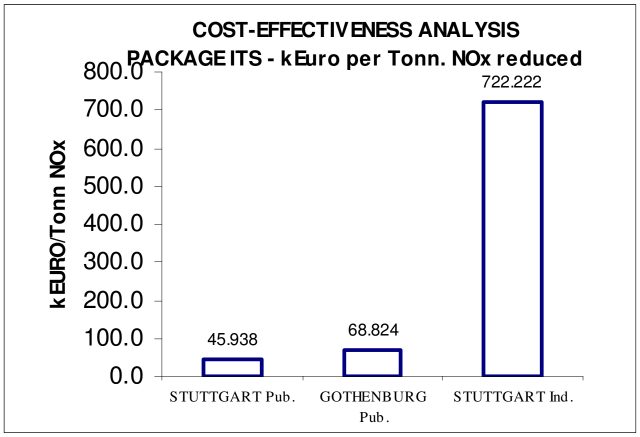
Costs structure for each package is composed of investment (capital) and maintenance and operation costs. Investment costs are annualised over 30 years using a discount rate of 5%.

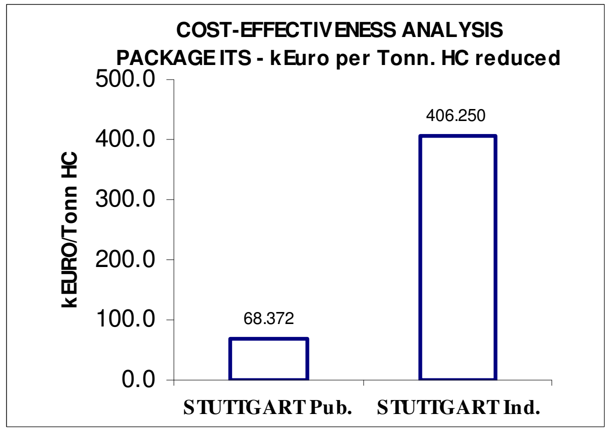
A summary yearly cost-table in Euros at 1995 prices follows:

| GOTHENBURG<br>Public | GOTHENBURG<br>Individual | STUTTGART<br>Public | STUTTGART<br>Individual |
|---|---|---|---|
| 11,700,000 | 25,000,000 | 31,000,000 | 33,000,000 |

### 5.2.5.2. Cost-effectiveness analysis (ITS)

The following graph depicts cost-effectiveness values per tonne NOx and HC reduced.




The evaluation of the two package results’ must consider that despite the similarities of the two strategic approaches, the differences between the packages termed “individual” adopted in Stuttgart and Gothenburg.

In fact, while both public transports oriented packages are comparable in all impact areas, the individual oriented packages present appreciable differences in the strategic approaches of the two sites.

The individual oriented scenario in Stuttgart does not assume a change in transport mode, i.e. a diversion of public transport trips to private vehicle. This effect leads in Stuttgart to a slight decrease in miles travelled for a given total volume of trips.

This appears to be the causal factor of the low level of emissions saved that, in association with high costs gives, in Stuttgart, a very high cost-effectiveness value: 722 k Euros per 1 tonne NOx reduced.

Where the packages are more homogeneous, like in “public” oriented case, cost-effectiveness values show a little range, with an average of about 60 k euro per tonne NOx reduced.

### *5.2.6 Main results*

In this section an attempt is made to show the main cost-effectiveness results in a concise way . The attention is focused on specific pollutants cost-effectiveness values, with the aim to analyse for each pollutant a specific range of values in order to identify which can serve as a yardstick to find the “outliers”.

The rationale that justifies this method of normalisation is that the impact of measures, and corresponding cost-effectiveness values, will inevitably differ in the manner in which they influence traffic level in different areas and at different scales.

We are also trying here to produce a ranking of most cost-efficient measures, considering that only the analysis of a sufficient number of occurrences, in different contexts, can partially overcome the uncertainties underlying such a ranking policy process.

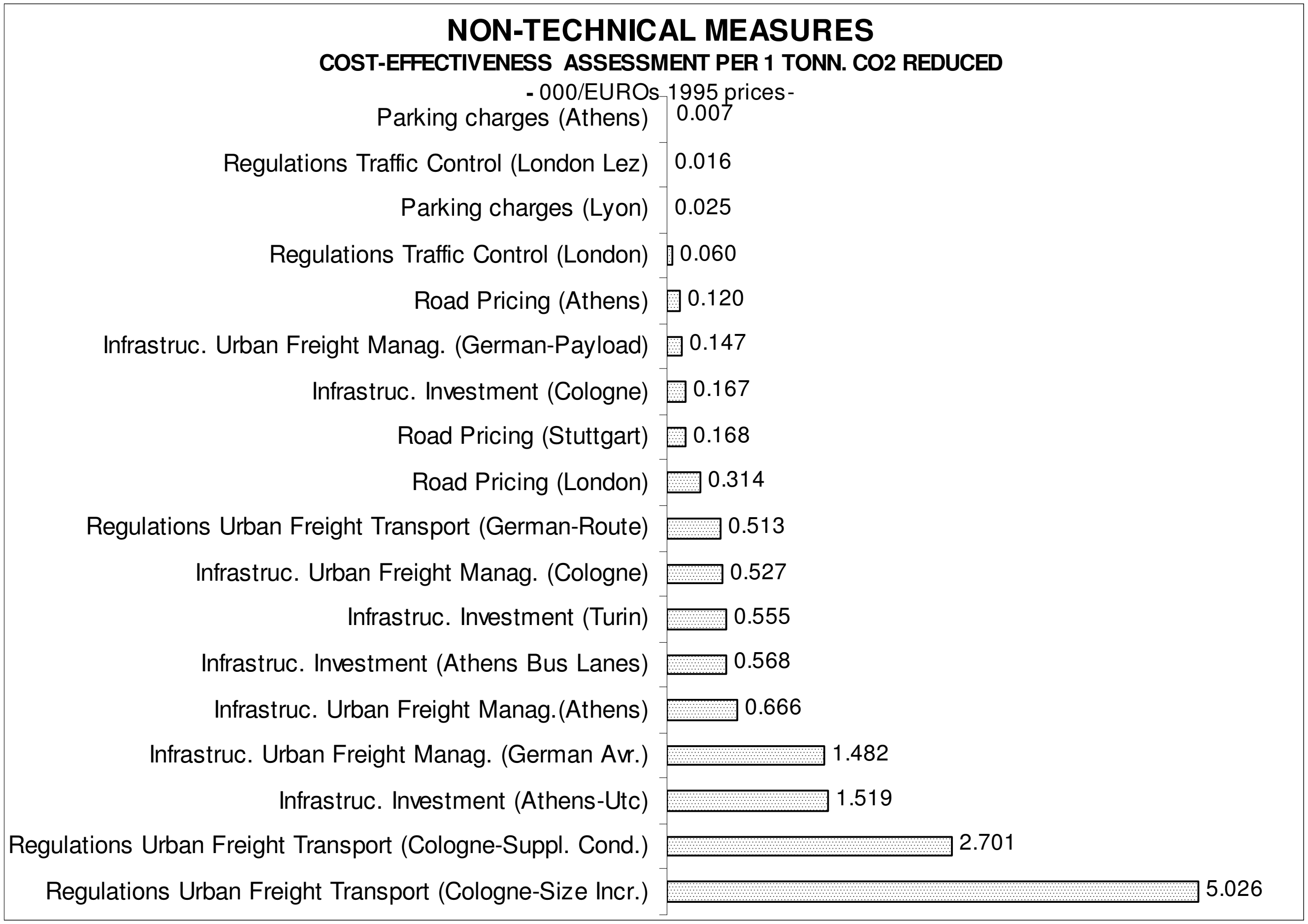
So we have undertaken the analysis only for pollutants for which a fair number of occurrences are available:

- Carbon dioxide ($CO_2$)
- Nitrogen oxides ($NO_x$)
- Carbon monoxide (CO).

#### 5.2.6.1 Carbon dioxide ($CO_2$)

The graph in the next page shows the range of cost-effectiveness evaluation, the values of which vary from 0.007 k Euros to 5 k Euros for 1 tonne $CO_2$ reduced.

High values in cost-effectiveness evaluation indicate a less-effective measure, which needs more resources for a unit-mass reduction of pollutant.


NON-TECHNICAL MEASURES
COST-EFFECTIVENESS ASSESSMENT PER 1 TONN. CO2 REDUCED
- 000/EUROs 1995 prices-
Parking charges (Athens) 0.007
Regulations Traffic Control (London Lez) 0.016
Parking charges (Lyon) 0.025
Regulations Traffic Control (London) 0.060
Road Pricing (Athens) 0.120
Infrastruc. Urban Freight Manag. (German-Payload) 0.147
Infrastruc. Investment (Cologne) 0.167
Road Pricing (Stuttgart) 0.168
Road Pricing (London) 0.314
Regulations Urban Freight Transport (German-Route) 0.513
Infrastruc. Urban Freight Manag. (Cologne) 0.527
Infrastruc. Investment (Turin) 0.555
Infrastruc. Investment (Athens Bus Lanes) 0.568
Infrastruc. Urban Freight Manag.(Athens) 0.666
Infrastruc. Urban Freight Manag. (German Avr.) 1.482
Infrastruc. Investment (Athens-Utc) 1.519
Regulations Urban Freight Transport (Cologne-Suppl. Cond.) 2.701
Regulations Urban Freight Transport (Cologne-Size Incr.) 5.026

The graph shows that higher values can be observed in the cases of urban freight transport management policies, both in the field of regulatory measures and in the field of infrastructure measures (Athens-Urban Traffic Control).

On the contrary, in the upper part of the graph, where more efficient measures are prevailing, parking charges and traffic regulation policies need less than 200 Euros per tonne reduced.

Due to site-specific variables effect and considering the large range of cost-effectiveness values recorded, the values less than 100 Euros and, in particular, more than 2000 should be considered out by the examination.

The middle section of the graph shows that the most-effective policies which cost-effectiveness values are comprised between less than 300 Euros per tonne and more than 100 Euros per tonne reduced, are prevailing in the field of **pricing.**

Infrastructure measures, owing to the higher implementation costs need approximately 800 Euros, on average, to reduce 1 tonne of $CO2$, and are prevailing in the lower side of the graph.

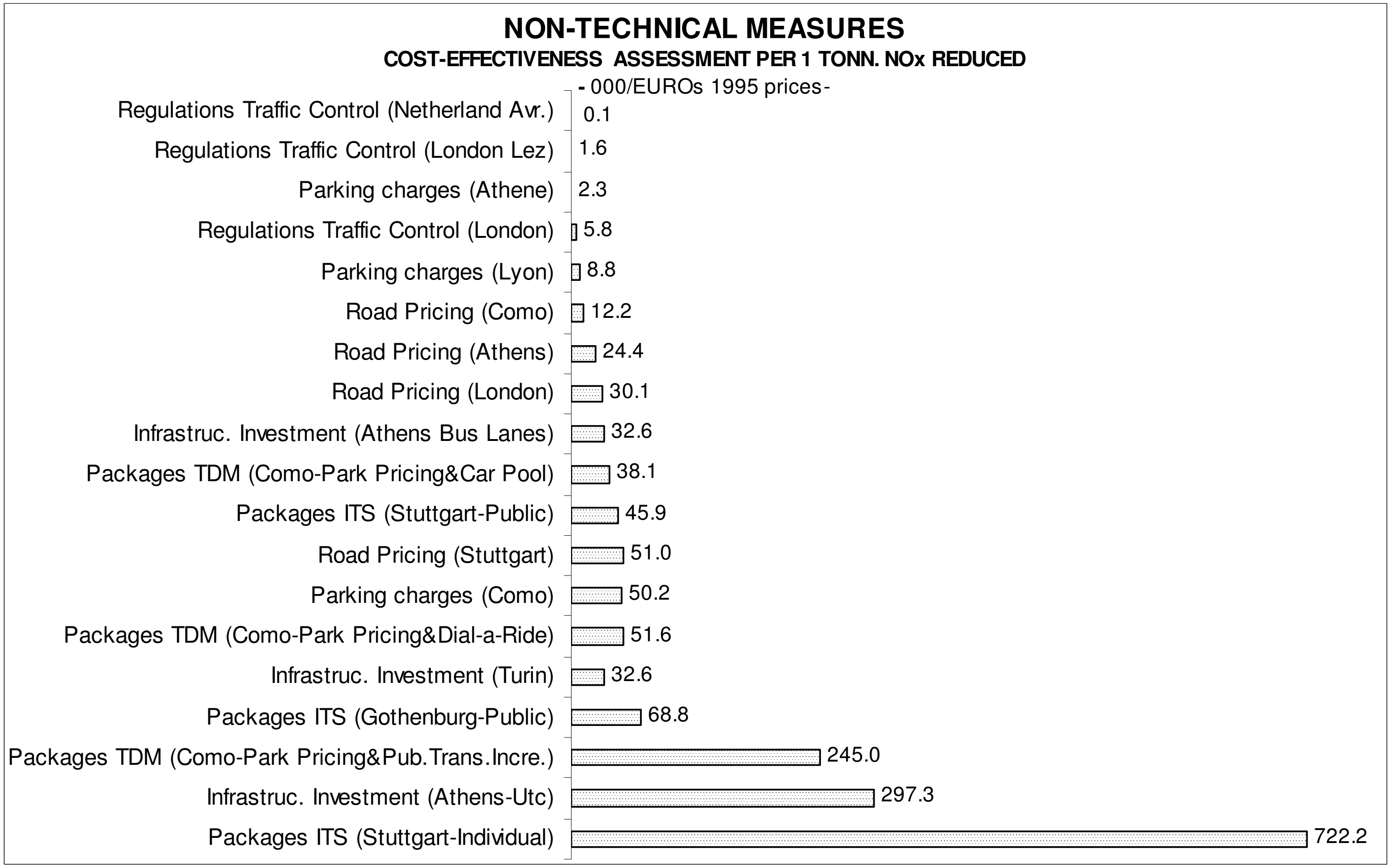
#### 5.2.6.2 Nitrogen oxides (NOx)

The range of cost-effectiveness values for NOx reduction can be observed in the graph on the next page.

It varies between 100 Euros (regulation traffic control, i.e. traffic restrictions) and 722 k Euros (Intelligent Traffic System package).

The distribution analysis of values clearly shows the presence of few “outliers” both on the upper and lower part of the graph.

In particular, the less cost-effective measures are mainly identified by packages of measures and infrastructure provision, which need more than 100 k Euros per tonne reduced.


NON-TECHNICAL MEASURES
COST-EFFECTIVENESS ASSESSMENT PER 1 TONN. NOx REDUCED
- 000/EUROs 1995 prices-
Regulations Traffic Control (Netherland Avr.)
0.1
Regulations Traffic Control (London Lez)
1.6
Parking charges (Athene)
2.3
Regulations Traffic Control (London)
5.8
Parking charges (Lyon)
8.8
Road Pricing (Como)
12.2
Road Pricing (Athens)
24.4
Road Pricing (London)
30.1
Infrastruc. Investment (Athens Bus Lanes)
32.6
Packages TDM (Como-Park Pricing&Car Pool)
38.1
Packages ITS (Stuttgart-Public)
45.9
Road Pricing (Stuttgart)
51.0
Parking charges (Como)
50.2
Packages TDM (Como-Park Pricing&Dial-a-Ride)
51.6
Infrastruc. Investment (Turin)
32.6
Packages ITS (Gothenburg-Public)
68.8
Packages TDM (Como-Park Pricing&Pub.Trans.Incre.)
245.0
Infrastruc. Investment (Athens-Utc)
297.3
Packages ITS (Stuttgart-Individual)
722.2

Nevertheless, to partially reinterpret their low effectiveness, it must be stressed that infrastructure investments and packages of measures that involve them, like public transport increase, reduce pollution for very extended periods of time (even without considering other benefits, i.e. equity).

The prevailing most-effective measures, considering with caution values too low, i.e. less than 100 Euros, are again in the **pricing** field, with an average of 10 k Euros per tonne reduced of NOx.

#### 5.2.6.3 Carbon monoxide (CO)

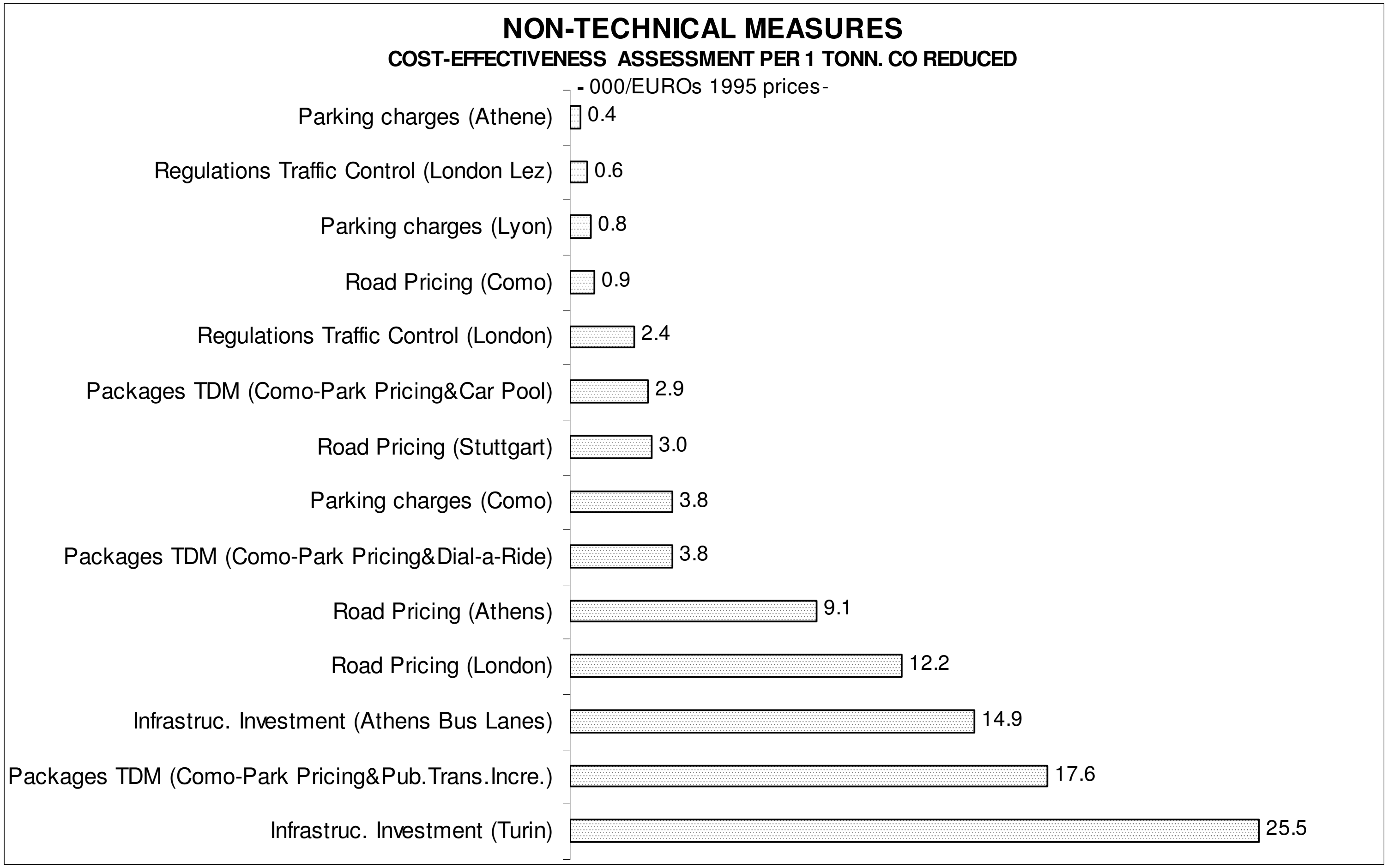
The range of cost-effectiveness values in the case of CO shows a distribution with less variability then CO2 and NOx, also due to the fact that the number of case studies is smaller.

Values range from 400 Euros (parking charges in Athens) to 26 k Euros (Infrastructure investments in Turin), with an average value of 7.4 k Euros per tonne CO reduced.

Specific cost-effectiveness values for each measure are shown in the graph on next page.

In the lower part of the graph, less effective measures are represented by infrastructure measures, respectively in the field of Intelligent Transport System (Turin) and Public Transport facilities (Bus Lanes and priority at signals in Athens), and package of measures (Park pricing and Public transport frequency increase in the city of Como). The average cost-effectiveness value in these cases is approximately 19 k Euros per tonne reduced

The most cost-efficient measures are represented by pricing **measures**, followed by regulatory measures (n the upper part of the graph).


NON-TECHNICAL MEASURES
COST-EFFECTIVENESS ASSESSMENT PER 1 TONN. CO REDUCED
- 000/EUROs 1995 prices-
Parking charges (Athene)
0.4
Regulations Traffic Control (London Lez)
0.6
Parking charges (Lyon)
0.8
Road Pricing (Como)
0.9
Regulations Traffic Control (London)
2.4
Packages TDM (Como-Park Pricing&Car Pool)
2.9
Road Pricing (Stuttgart)
3.0
Parking charges (Como)
3.8
Packages TDM (Como-Park Pricing&Dial-a-Ride)
3.8
Road Pricing (Athens)
9.1
Road Pricing (London)
12.2
Infrastruc. Investment (Athens Bus Lanes)
14.9
Packages TDM (Como-Park Pricing&Pub.Trans.Incre.)
17.6
Infrastruc. Investment (Turin)
25.5

### *5.3 Cost-benefit analysis*

As explained in the methodological section above[16], cost-benefit analysis is carried out in order to estimate the gains in terms of resource savings due to reduction of pollutant emissions and to compare them with the costs of abatement, i.e. the costs of measure implementation.

This is mainly achieved through the attribution of a monetary value per emission abated.

In order to compare studies, which have been analysed similar bundles of pollutants, the available case studies have been divided in two sets of measures with the same combination of emission saved:

1. a larger group (14 occurrences) considering CO and NOx together;
2. a more restricted group (7 occurrences) with CO, NOx, VOC and CO2.

#### *5.3.1 CO and NOx*

The following tables show detailed information about case studies available for cost-benefit assessment.

Basic information included in the tables is:

1. impacts of measure in terms of pollutant reduced, in percent and absolute value;
2. evaluation of benefits, i.e. monetary impact evaluating their relative importance in terms of emissions/air quality impacts (e.g. on health, damage to buildings, crops);
3. calculation of cost/benefit ratio, in terms of Euro gained per 1 Euro invested.

[16] Chapter 5, paragraph 5.1.1 „Cost and benefit in the Cantique context“

ATHENS CASE STUDY – PARKING CHARGES -

| **Pollutant** | **Percentages of reduction** | **Tonnes reduced (-) (Annual average)** (A) | **Impact in Euro/ tonne** (B) | **Benefit** (A)*(B) | **Total Costs** (Euro) 1995 prices (D) | **Benefit/ Costs** ratio (A)*(B)/ (D) |
|---|---|---|---|---|---|---|
| CO | -7.9 | -6,753.244 | 600 | 4,051,946 | | |
| $NO_x$ | -3,9 | -1,219.786 | 8,000 | 9,758,285 | | |
| Total | | | | **13,810,231** | **2,800,000** | **4.932** |

LYON CASE STUDY – PARKING CHARGES -

| **Pollutant** | **Percentages of reduction** | **Tonnes reduced (-) (Annual average)** (A) | **Impact in Euro/ tonne** (B) | **Benefit** (A)*(B) | **Total Costs** (Euro) 1995 prices (D) | **Benefit/ Costs** ratio (A)*(B)/ (D) |
|---|---|---|---|---|---|---|
| CO | -18.7 | -3,796.180 | 600 | 2,277,708 | | |
| $NO_x$ | -3 | -340.109 | 8,000 | 2,720,873 | | |
| Total | | | | **4,998,581** | **3,000,000** | **1.666** |

COMO CASE STUDY – PARKING CHARGES -

| **Pollutant** | **Percentages of reduction** | **Tonnes reduced (-) (Annual average)** (A) | **Impact in Euro/ tonne** (B) | **Benefit** (A)*(B) | **Total Costs** (Euro) 1995 prices (D) | **Benefit/ Costs** ratio (A)*(B)/ (D) |
|---|---|---|---|---|---|---|
| CO | -4.7 | -350.400 | 600 | 210,240 | | |
| $NO_x$ | -3.9 | -26.280 | 8,000 | 210,240 | | |
| Total | | | | **420,480** | **1,320,000** | **0.319** |

For Athens and Lyon, annual impacts on pollutant level in absolute values are based on National Transport Databases prepared by Standard & Poor’s DRI and K.U Leuven in the context of Auto Oil II Programme project. The reference year for calculation is 1995.

For Como case study, annual impacts on pollutant level (CO and NOx) are based on average-hour emission data evaluated through simulation model (Corinair model). Reference year, 1995.

COMO CASE STUDY – ROAD PRICING -

| **Pollutant** | **Percentages of reduction** | **Tonnes reduced (-) (Annual average)** (A) | **Impact in Euro/ tonne** (B) | **Benefit** (A)*(B) | **Total Costs** (Euro) 1995 prices (D) | **Benefit/ Costs** ratio (A)*(B)/ (D) |
|---|---|---|---|---|---|---|
| CO | -8.2 | -613.200 | 600 | 367,920 | | |
| $NO_x$ | -7.6 | -50.808 | 8,000 | 406,464 | | |
| Total | | | | **774,384** | **320,000** | **2.420** |

STUTTGART CASE STUDY – ROAD PRICING -

| **Pollutant** | **Percentages of reduction** | **Tonnes reduced (-) (Annual average)** (A) | **Impact in Euro/ tonne** (B) | **Benefit** (A)*(B) | **Total Costs** (Euro) 1995 prices (D) | **Benefit/ Costs** ratio (A)*(B)/ (D) |
|---|---|---|---|---|---|---|
| CO | -12.9 | -856.000 | 600 | 513,600 | | |
| $NO_x$ | -7.9 | -51.000 | 8,000 | 408,000 | | |
| Total | | | | **921,600** | **2,600,000** | **0.354** |

ATHENS CASE STUDY – ROAD PRICING -

| **Pollutant** | **Percentages of reduction** | **Tonnes reduced (-) (Annual average)**<br>(A) | **Impact in Euro/ tonne**<br>(B) | **Benefit**<br>(A)*(B) | **Total Costs** (Euro) 1995 prices (D) | **Benefit/ Costs** ratio (A)*(B)/ (D) |
|---|---|---|---|---|---|---|
| CO | -4.1 | -3,504.848 | 600 | 2,102,909 | | |
| $NO_x$ | -4.2 | -1,131.615 | 8,000 | 10,508,922 | | |
| Total | | | | **12,611,831** | **32,000,000** | **0.394** |

LONDON CASE STUDY – ROAD PRICING -

| **Pollutant** | **Percentages of reduction** | **Tonnes reduced (-) (Annual average)**<br>(A) | **Impact in Euro/ tonne**<br>(B) | **Benefit**<br>(A)*(B) | **Total Costs** (Euro) 1995 prices (D) | **Benefit/ Costs** ratio (A)*(B)/ (D) |
|---|---|---|---|---|---|---|
| CO | -10.0 | -9,074.479 | 600 | 5,444,687 | | |
| $NO_x$ | -10.0 | -3,691.248 | 8,000 | 29,529,982 | | |
| Total | | | | **34,974,670** | **111,000,000** | **0.315** |

In Athens and London, impacts in terms of emission reduction are based on the Greeke and English Transport Databases prepared by Standard & Poor’s DRI and K.U Leuven in the context of Auto Oil II Programme project.

For the city of London, impact values are estimated on the ground of an average reduction of 10% in vehicle*kilometer in London[17], with a corresponding reduction in pollutant emissions level.

Average-hours emissions level are used as reference for impact values in Como case study; while for Stuttgart case study emission effects have been calculated using the V-Emi model from user behaviour analysis.

[17] Specific valuesare -17% in central London; -11% in London;-3% outer London

ATHENS CASE STUDY – INFRASTRUCTURE INVESTMENT (BUS LANES) -

| **Pollutant** | **Percentages of reduction** | **Tonnes reduced (-) (Annual average)** (A) | **Impact in Euro/ tonne** (B) | **Benefit** (A)*(B) | **Total Costs** (Euro) 1995 prices (D) | **Benefit/ Costs** ratio (A)*(B)/ (D) |
|---|---|---|---|---|---|---|
| CO | -0.4 | -341.936 | 600 | 205,162 | | |
| $NO_x$ | -0.5 | -156.382 | 8,000 | 1,251,062 | | |
| Total | | | | **1,456,224** | **5,100,000** | **0.286** |

TURIN CASE STUDY – INFRASTRUCTURE INVESTMENT (ITS) -

| **Pollutant** | **Percentages of reduction** | **Tonnes reduced (-) (Annual average)** (A) | **Impact in Euro/ tonne** (B) | **Benefit** (A)*(B) | **Total Costs** (Euro) 1995 prices (D) | **Benefit/ Costs** ratio (A)*(B)/ (D) |
|---|---|---|---|---|---|---|
| CO | -5.0 | -3,064.694 | 600 | 1,838,816 | | |
| $NO_x$ | -5.0 | -1,361.776 | 8,000 | 10,894,212 | | |
| Total | | | | **12,733,028** | **78,000,000** | **0.163** |

For Athens and Turin infrastructure policies impact values in terms of emissions reduction are based on Greeke and Italian Transport Databases prepared by Standard & Poor’s DRI and K.U Leuven in the context of Auto Oil II Programme project.

In Italian case, an assumption has been made due to lack of data for the city of Turin. In fact, the average value of emission reduction (5%) in Turin case study[18] has been applied to Milan urban transport database (vehicle*kilometer) in order to obtain emissions reduction in absolute values.

The assumption is based on common characteristics between the two cities in terms of economic aspects and their regional relevance.

[18] See Quartet Plus, Deliverable 5.1 „Validation of Irte supported PT management“

LONDON CASE STUDY – REGULATIONS (PARKING SPACE RESTRICTION)

| Pollutant | Percentages of reduction | Tonnes reduced (-) (Annual average) (A) | Impact in Euro/ tonne (B) | Benefit (A)*(B) | Total Costs (Euro) 1995 prices (D) | Benefit/ Costs ratio (A)*(B)/ (D) |
|---|---|---|---|---|---|---|
| CO | -3.0 | -2,722.344 | 600 | 1,633,406 | | |
| $NO_x$ | -3.0 | -1,107.374 | 8,000 | 8,858,995 | | |
| Total | | | | **10,492,401** | **6,400,000** | **1.639** |

LONDON CASE STUDY – REGULATIONS (LOW EMISSION ZONES) -

| Pollutant | Percentages of reduction | Tonnes reduced (-) (Annual average) (A) | Impact in Euro/ tonne (B) | Benefit (A)*(B) | Total Costs (Euro) 1995 prices (D) | Benefit/ Costs ratio (A)*(B)/ (D) |
|---|---|---|---|---|---|---|
| CO | -8.0 | -7,259.583 | 600 | 4,355,750 | | |
| $NO_x$ | -8.0 | -2,952.998 | 8,000 | 23,623,986 | | |
| Total | | | | **27,979,736** | **4,600,000** | **6.083** |

For London case studies, the same pollutant reduction for Co and NOx has been estimated on the ground of an average pollutant reduction of 3% for parking space restrictions[19] and 8% for Low Emission Zones[20].

COMO CASE STUDY – PACKAGE (PARK PRICING AND PUBLIC TRANSPORT FREQUENCY INCREASES) -

| Pollutant | Percentages of reduction | Tonnes reduced (-) (Annual average) (A) | Impact in Euro/ tonne (B) | Benefit (A)*(B) | Total Costs (Euro) 1995 prices (D) | Benefit/ Costs ratio (A)*(B)/ (D) |
|---|---|---|---|---|---|---|
| CO | -6.7 | -499.320 | 600 | 299,592 | | |
| $NO_x$ | -5.4 | -35.916 | 8,000 | 287,328 | | |
| Total | | | | **586,920** | **8,800,000** | **0.067** |

[19] As average values between –3.7% (inner London) and-1.5% (outer London)
[20] As average values between –12% (inner London) and-4% (outer London)

COMO CASE STUDY – PACKAGE (PARK PRICING AND DIAL-A-RIDE) -

| **Pollutant** | **Percentages of reduction** | **Tonnes reduced (-) (Annual average)** (A) | **Impact in Euro/ tonne** (B) | **Benefit** (A)*(B) | **Total Costs** (Euro) 1995 prices (D) | **Benefit/ Costs** ratio (A)*(B)/ (D) |
|---|---|---|---|---|---|---|
| CO | -4.9 | -367.920 | 600 | 220,752 | | |
| $NO_x$ | -4.0 | -27.156 | 8,000 | 217,248 | | |
| Total | | | | **438,000** | **1,400,000** | **0.313** |

COMO CASE STUDY – PACKAGE (PARK PRICING AND CAR POOL) -

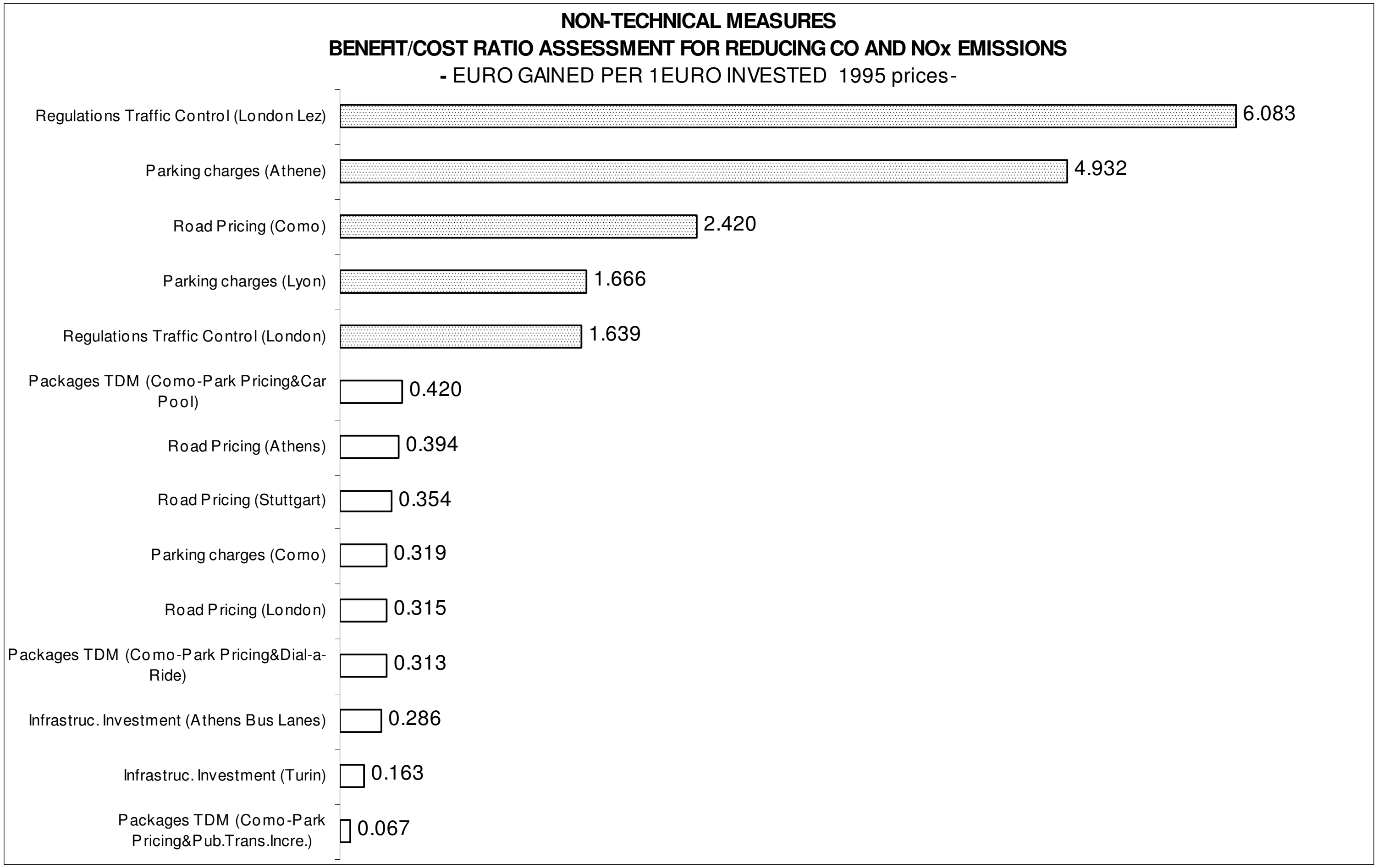
| **Pollutant** | **Percentages of reduction** | **Tonnes reduced (-) (Annual average)** (A) | **Impact in Euro/ tonne** (B) | **Benefit** (A)*(B) | **Total Costs** (Euro) 1995 prices (D) | **Benefit/ Costs** ratio (A)*(B)/ (D) |
|---|---|---|---|---|---|---|
| CO | -5.6 | -420.480 | 600 | 252,288 | | |
| $NO_x$ | -4.7 | -31.536 | 8,000 | 252,288 | | |
| Total | | | | **504,576** | **1,200,000** | **0.420** |

With reference to the measures analysed, the graph in the next page shows costs-benefit ratio for reducing Co and NOx emissions.

With a white colour are marked bars where cost-benefit ratio is less than one. In this case the economic meaning is that for 1 Euro invested the benefits are less than proportionate.

On the contrary, with a grey colour are marked the measures which implementation allows gaining benefits more than proportionate to costs.

In this group of measure are prevailing **pricing and regulative** measures.


NON-TECHNICAL MEASURES
BENEFIT/COST RATIO ASSESSMENT FOR REDUCING CO AND NOx EMISSIONS
- EURO GAINED PER 1EURO INVESTED 1995 prices-
Regulations Traffic Control (London Lez)
6.083
Parking charges (Athene)
4.932
Road Pricing (Como)
2.420
Parking charges (Lyon)
1.666
Regulations Traffic Control (London)
1.639
Packages TDM (Como-Park Pricing&Car Pool)
0.420
Road Pricing (Athens)
0.394
Road Pricing (Stuttgart)
0.354
Parking charges (Como)
0.319
Road Pricing (London)
0.315
Packages TDM (Como-Park Pricing&Dial-a-Ride)
0.313
Infrastruc. Investment (Athens Bus Lanes)
0.286
Infrastruc. Investment (Turin)
0.163
Packages TDM (Como-Park Pricing&Pub.Trans.Incre.)
0.067

### *5.3.2 CO, NOx, VOC and CO2*

This cluster of measures analyses the cost-benefit ratio for reducing four pollutants together:

- carbon monoxide (CO)

-carbon dioxide (CO2)

-volatile organic compound (VOC)

-nitrogen oxides (NOx).

Due to the inclusion of a major list of pollutants, case studies availability is reduced to 7 occurrences only.

Tables with crucial information follows:

ATHENS CASE STUDY – PARKING CHARGES -

| **Pollutant** | **Percentages of reduction** | **Tonnes reduced (-) (Annual average)** (A) | **Impact in Euro/ tonne** (B) | **Benefit** (A)*(B) | **Total Costs** (Euro) 1995 prices (D) | **Benefit/ Costs** ratio (A)*(B)/ (D) |
|---|---|---|---|---|---|---|
| CO | -7.9 | -6,753.244 | 600 | 4,051,946 | | |
| $NO_x$ | -3.9 | -1,219.786 | 8,000 | 9,758,285 | | |
| CO2 | -13.2 | -404,021.320 | 30 | 12,120,640 | | |
| VOC | -4.0 | 842.970 | 4,700 | 3,961,978 | | |
| Total | | | | **29,892,849** | **2,800,000** | **10.676** |

LYON CASE STUDY – PARKING CHARGES -

| Pollutant | Percentages of reduction | Tonnes reduced (-) (Annual average) (A) | Impact in Euro/ tonne (B) | Benefit (A)*(B) | Total Costs (Euro) 1995 prices (D) | Benefit/ Costs ratio (A)*(B)/ (D) |
|---|---|---|---|---|---|---|
| CO | -18.7 | -3,796.180 | 600 | 2,277,708 | | |
| $NO_x$ | -3.0 | -340.109 | 8,000 | 2,720,873 | | |
| CO2 | -11.1 | -119,404.880 | 30 | 3,582,146 | | |
| VOC | -9.3 | 455.170 | 4,700 | 2,139,296 | | |
| Total | | | | **10,720,024** | **3,000,000** | **3.573** |

STUTTGART CASE STUDY – ROAD PRICING -

| Pollutant | Percentages of reduction | Tonnes reduced (-) (Annual average) (A) | Impact in Euro/ tonne (B) | Benefit (A)*(B) | Total Costs (Euro) 1995 prices (D) | Benefit/ Costs ratio (A)*(B)/ (D) |
|---|---|---|---|---|---|---|
| CO | -12.9 | -856.000 | 600 | 513,600 | | |
| $NO_x$ | -7.9 | -51.000 | 8,000 | 408,000 | | |
| CO2 | -9.8 | -15,464.000 | 30 | 463,920 | | |
| VOC | -11.9 | -98.000 | 4,700 | 460,600 | | |
| Total | | | | **1,846,120** | **2,600,000** | **0.710** |

LONDON CASE STUDY – ROAD PRICING -

| Pollutant | Percentages of reduction | Tonnes reduced (-) (Annual average) (A) | Impact in Euro/ tonne (B) | Benefit (A)*(B) | Total Costs (Euro) 1995 prices (D) | Benefit/ Costs ratio (A)*(B)/ (D) |
|---|---|---|---|---|---|---|
| CO | -10.0 | -9,074.479 | 600 | 5,444,687 | | |
| $NO_x$ | -10.0 | -3,691.248 | 8,000 | 29,529,982 | | |
| CO2 | -10.0 | -353,788.510 | 30 | 10,613,655 | | |
| VOC | -10.0 | -1,677.860 | 4,700 | 7,885,933 | | |
| Total | | | | **53,474,258** | **111,000,000** | **0.482** |

TURIN CASE STUDY – INFRASTRUCTURE INVESTMENT (ITS) -

| **Pollutant** | **Percentages of reduction** | **Tonnes reduced (-) (Annual average)** (A) | **Impact in Euro/ tonne** (B) | **Benefit** (A)*(B) | **Total Costs** (Euro) 1995 prices (D) | **Benefit/ Costs** ratio (A)*(B)/ (D) |
|---|---|---|---|---|---|---|
| CO | -5.0 | -3,064.694 | 600 | 1,838,816 | | |
| $NO_x$ | -5.0 | -1,361.776 | 8,000 | 10,894,212 | | |
| CO2 | -5.0 | -137,396.240 | 30 | 4,121,887 | | |
| VOC | -5.0 | -648.060 | 4,700 | 3,045,897 | | |
| Total | | | | **19,900,812** | **78,000,000** | **0.255** |

LONDON CASE STUDY – REGULATIONS (PARKING SPACE RESTRICTION)

| **Pollutant** | **Percentages of reduction** | **Tonnes reduced (-) (Annual average)** (A) | **Impact in Euro/ tonne** (B) | **Benefit** (A)*(B) | **Total Costs** (Euro) 1995 prices (D) | **Benefit/ Costs** ratio (A)*(B)/ (D) |
|---|---|---|---|---|---|---|
| CO | -3.0 | -2,722.344 | 600 | 1,633,406 | | |
| $NO_x$ | -3.0 | -1,107.374 | 8,000 | 8,858,995 | | |
| CO2 | -3.0 | -106,136.550 | 30 | 3,184,097 | | |
| VOC | -3.0 | -503.360 | 4,700 | 2,365,780 | | |
| Total | | | | **16,042,277** | **6,400,000** | **2.506** |

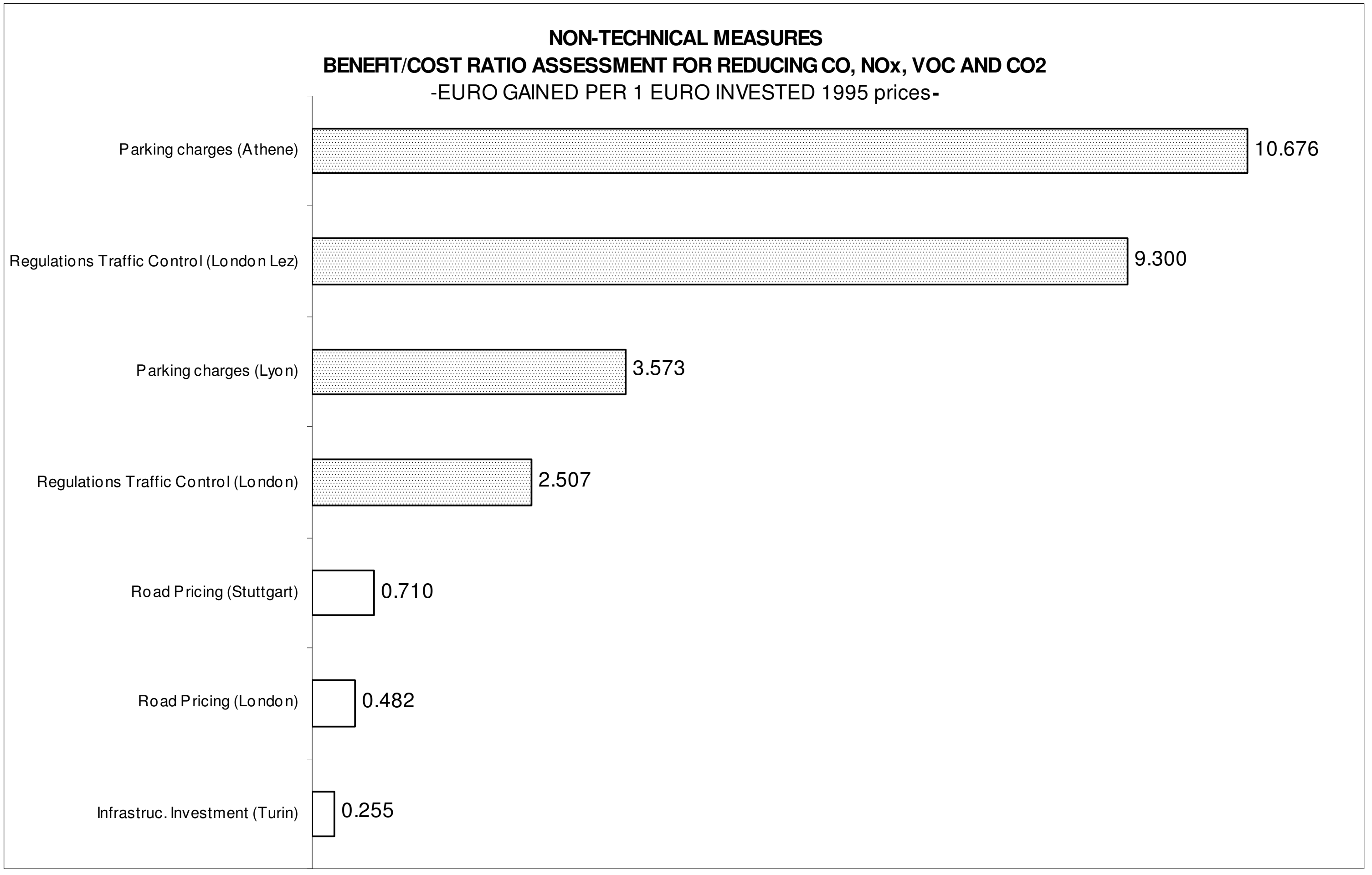
LONDON CASE STUDY – REGULATIONS (LOW EMISSION ZONES) -

| **Pollutant** | **Percentages of reduction** | **Tonnes reduced (-) (Annual average)** (A) | **Impact in Euro/ tonne** (B) | **Benefit** (A)*(B) | **Total Costs** (Euro) 1995 prices (D) | **Benefit/ Costs** ratio (A)*(B)/ (D) |
|---|---|---|---|---|---|---|
| CO | -8.0 | -7,259.583 | 600 | 4,355,750 | | |
| $NO_x$ | -8.0 | -2,952.998 | 8,000 | 23,623,986 | | |
| CO2 | -8.0 | -283,030.810 | 30 | 8,490,924 | | |
| VOC | -8.0 | -1,342.290 | 4,700 | 6,308,746 | | |
| Total | | | | **42,779,406** | **4,600,000** | **9.299** |

The graph in the next page shows cost-benefit values for reducing CO, NOx, VOC and CO2 together.

Due to lack of data with reference to this spectrum of pollutant, evaluation of measures must proceed with attention.

**Pricing and regulatory measures** show high cost-benefit values (marked in grey), while infrastructure investments show the lowest value (0.255 Euro gained per 1 Euro invested).


NON-TECHNICAL MEASURES
BENEFIT/COST RATIO ASSESSMENT FOR REDUCING CO, NOx, VOC AND CO2
-EURO GAINED PER 1 EURO INVESTED 1995 prices-
Parking charges (Athene)
10.676
Regulations Traffic Control (London Lez)
9.300
Parking charges (Lyon)
3.573
Regulations Traffic Control (London)
2.507
Road Pricing (Stuttgart)
0.710
Road Pricing (London)
0.482
Infrastruc. Investment (Turin)
0.255

## 6. Conclusions

As stated in Cantique Baseline Report[21], three main objectives are required from WP3 activity:

1. cost-effectiveness analysis and ranking of measures (subject to data availability)
2. assessment of most promising measures, individually and in bundles
3. indication of future research needs e.g. data collection, studies on implementation of measures

- The following table gives average cost-effectiveness values in kEuros per tonne reduced and shows that lowest cost-effectiveness values are mainly in relation **to pricing and regulatory measures**, with the notable exceptions of CO2 values, which are lower for pricing and infrastructure measures.

| POLICY | COST-EFFECTIVENESS VALUES 000/Tonn | | |
|---|---|---|---|
| | CO2 | NOx | CO |
| PRICING | 0.127 | 25.562 | 4.326 |
| INFRASTRUCTURE | 0.704 | 120.857 | 20.183 |
| REGULATIONS | 1.663 | 3.669 | 1.492 |
| PACKAGE-TDM | - | 111.541 | 8.094 |
| PACKAGE-ITS | - | 278.994 | - |

- Cost-benefit analysis, although it was based on a smaller number of measures, has substantially confirmed this finding.
- The most promising measures, individually or in bundles, appear to be expected from the association of **pricing and regulatory measures** . This statement is also confirmed by expert opinions’ emerging from the questionnaire answer analysis (see Annex II)

[21] D1 „Cantique Baseline Report“. Chap. 2.3

- At this stage, the indication of future needs must only stress the lack of “package of measures” information. In fact, based on available data, packages of measures analysed are too scarce to allow robust conclusions. In order to identify the best combinations of measures, additional work and research will be required.

Nevertheless, there are a number of uncertainties in the results presented above.

First , costs and impacts of local implementation measures are uncertain, being based on different methods and evaluation criteria.. This snag is balanced only in part by the large number of experiments and studies considered

Second , in few cases, in order to maintain more information, the impact of measures in terms of emission saved has been based on simplifying assumptions, i.e. the same percentage of emission saved for different pollutants. In this case the results should be only taken as illustrative of the potential impact of particular measures.

Third , the adoption of a more precise, but stringent cost-benefit approach is deemed to be useful in order to inform policy makers at city level about the relationship between cost of implementation of measures and their effectiveness, i.e. emission reduced and relative monetary impact. No information is provided on additional costs incurred , i.e. time costs, and benefit, including eventually side-effects.

## ANNEX I : CANTIQUE QUESTIONNAIRE FOR WORKSHOP

# CANTIQUE QUESTIONNAIRE FOR WORKSHOP

ROME, JANUARY 24/25, 2000

FILLED BY

**NAME** : ____________________

**SURNAME** : _____________________

**COMPANY** : ______________________

**E-MAIL** : _______________________

**Please, compile and forward this questionnaire via E-mail to:**

ISISROME@ISIS-IT.COM

**CANTIQUE QUESTIONNAIRE FOR WORKSHOP Jan. 24/25, 1999**

Reviews conducted so far suggest that 9 Non Technical Measures are the most efficient to reach urban air improvement goals. In the following table said measures are listed in an approximate ranking order starting with the most efficient. **Please fill the 2 right hand columns in the table indicating possible different ranking criteria based on**:

- measure of positive impact
- cost/benefit considerations.

**1. - Suggestions for new ranking**

| | Measure | Impact | Cost/Benefit |
|---|---|---|---|
| 1 | Road pricing | | |
| 2 | Access contr. & limitation | | |
| 3 | Parking management | | |
| 4 | Pedestrian and cycling | | |
| 5 | Public Transport Priority | | |
| 6 | Publ.Transp. Increased frequency | | |
| 7 | Traffic lights ITS/UTC | | |
| 8 | Lanes reserved for public transport & High Occup.Vehicles | | |
| 9 | Ecological regulations (e.g., stricter thresholds in pollutant concentration) | | |

**NOTE - Rank 1 is considered the most important/effective and importance decreases proceeding towards ranks labelled with higher numbers**

## 2. - Which do you consider more important among the following 3-pronged choices? (check one or give 1, 2, 3 preference)

| | | | | | |
|---|---|---|---|---|---|
| Enforcement | | Economic motivation | | Education | |
| Surveys of end users opinion | | Quantitative Measures of Effectiveness | | Experts' polls | |
| Use of Intelligent Traffic Systems | | Public transport enhancement | | Integrated reorga-nisation of work & leisure activities | |
| Land use planning by local government | | Infrastructure modernisation | | Modernisation of public transport vehicles & scrappage of old private ones | |
| Telematics as a basis for telework | | Dial-A-Ride schemes | | Park and Ride (with hubs for parking and general services) | |

## 2. -Preferred Combinations of Non Technical Measures

Based on the ranking you have suggested on the previous page, propose which ranking you consider to be the most advantageous among the following 21 combinations of measures:

| Measures combination | Proposed Ranking |
|---|---|
| 1) Road Pricing & Infrastructure measures | |
| 2) Park pricing & Dial-a-Ride | |
| 3) - Park pricing & Car Pool | |
| 4) Park pricing & Public Transport Increase | |
| 5) -Parking management & Infrastructure measures | |
| -Zoning- restricted access & Traffic Reduction Act | |
| 6) - Traffic calming & Infrastructure measures | |
| Pedestrian. & Infrastructure measures | |
| 7) - Promote Public Urban Transports & Land Use Policies | |
| 8) - Promote Public Urban Transports & Infrastructure measures | |
| 9) - New Transport Supply & Infrastructure measures | |
| 10) Regulatory measure & Internalisat. of external costs (Scenario R) | |
| Fuel taxes & Infrastructure Extension (Scenario P) | |
| Financial Incentives & Aware-ness Campaigns (Scenario A | |
| Bus Lanes & Infrastructure measures | |
| - Bus/HOV lanes, & Infrastructure measures | |
| 11) Bus lanes, Cycle lanes, etc | |
| 12) Substituting own account transport with commercial transport | |
| 13) - Freight Distribution Centre | |
| 14) Improvement Supply and Delivery conditions | |
| 21) Integrated Telematic System | |

## 3. - Suggestions and Comments

- Suggest other combinations which you consider appropriate and have been omitted.

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- Other comments and suggestions

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## 4. - Cost Inputs

- You noticed that cost data on the implementation of Non Technical Measures are scarce; please tick the measures or combinations of measures of which you feel able to suggest typical costs based on your experience and expertise.

**Single Measures**

- Road pricing
- Access contr. & limitation
- Parking management
- Pedestrian and cycling
- Public Transport measures : Priority
- Public Transport: Increased frequency
- Traffic lights ITS/UTC
- Lanes reserved for public transport and High Occupancy Vehicles
- Ecological regulations (e.g., adoption of thresholds in pollutant concentration)

**Combinations**

1) Road Pricing & Infrastructure measures
2) Park pricing & Dial-a-Ride
3) - Park pricing & Car Pool
4) Park pricing & Public Transport Increase
5) -Parking management & Infrastructure measures
6) -Zoning- restricted access & Traffic Reduction Act
7) - Traffic calming & Infrastructure measures
8) Pedestrian. & Infrastructure measures
9) Promote Public Urban Transports & Land Use Policies
10) Promote Public Urban Transports & Infrastructure measures
11) New Transport Supply & Infrastructure measures
12) Regulatory Measure & Internalisation of external costs (Scenario R)
13) Fuel taxes & Infrastructure Extension (Scenario P)
14) Financial Incentives & Awareness Campaigns (Scenario A
15) Bus Lanes & Infrastructure measures
16) Bus/HOV lanes, & Infrastructure measures
17) Bus lanes, Cycle lanes, etc
18) Substituting Own account transport through commercial transport
19) - Freight Distribution Centre
20) Improvement Supply and Delivery conditions
21) Integrated Telematic System

## ANNEX II : RESPONSES TO QUESTIONNAIRE

Nineteen experts in the working area of Governmental Agencies (36.8%), Companies and Associations (52.6%) and Universities (10.5%) have answered to questionnaire.

| GOVERNMENTAL AGENCIES | COMPANIES AND ASSOCIATIONS | UNIVERSITIES | TOTAL |
|---|---|---|---|
| 7 | 10 | 2 | 19 |
| 36.8 | 52.7 | 10.5 | 100.0 |

Their opinions assessing the ranking about most effective measures on the impact side are the follows:

**MOST IMPORTANT/EFFECTIVE (RANKING 1 AND 2)**

1 **32% (Road Pricing)**

2 **28% (Access limitation)**

3 **18% (Ecological Regulation)**

**LEAST IMPORTANT/EFFECTIVE (RANKING 8 AND 9)**

1 **24% (Ecological Regulation)**

2 **20% (Traffic lights ITS/UTC)**

3 **20% (Lanes reserved)**

Among the most effective non-technical measures, **pricing and regulatory measures** (access limitation) are indicated by about 60% of interviewees.

With reference to the non-technical measures with the most cost/benefit ratio, the experts’ evaluation substantially does not change.

**MOST EFFECTIVE (RANKING 1 AND 2)**

1 **30% (Access limitation)** 3 **16% (Parking management)**

2 **22% (Road Pricing)**

**LEAST EFFECTIVE (RANKING 8 AND 9)**

1 **23 % (Ecological Regulation)** 3 **16% (Lanes reserved)**

2 **20% (Traffic Lights ITS/UTC)**

Pricing policies and regulatory measure confirms your leadership in the experts' view.

About the preferred packages of measures, pricing polices associated with infrastructure measures are indicated by about 33% of interviewees.

**MOST IMPORTANT/EFFECTIVE (RANKING 1 AND 2)**

1 **22% (Road Pricing and Infrastructure Measures)**

2 **11% (Park Pricing & Public Transport Increase)**