PERIODICA POLYTECHNICA SER. TRANSP. ENG. VOL. 34, NO. 1–2, PP. 93–100 (2006)

ESTIMATION METHOD FOR EMISSION OF ROAD TRANSPORT

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Received: Oct. 24, 2005

Abstract

The sustainable development is a development, where the pace of technical development, the satiation of increasing supply and the raw materials and resources of Earth are poised so that the rate of living and opportunities of the next generations must not to be worse. Transportation cannot be replaced because it is part of the production chain. Societies are horizontally and vertically differential. The manpower, the stock, the semi finished and finished products must be transported. One of the most emphasized goals of the transport policy of the European Union is sustainable mobility. For this reason transportation systems must be developed and standardized, the effectiveness of transportation service must be increased, while the environmental pollution must be decreased or prevented. There are no harmonized guidelines for project assessment and transport costing at EU level yet. A critical issue when comparing appraisal practices across countries is to make sure the same definitions are being used. Theoretically, all benefits and costs should be accounted for in the cost-benefit analysis. In practice though, many effects are left out.

Keywords: environmental pollution, emission estimation, cost of pollution.

1. Introduction

In the last few thousand years nature gave humanity a stable base of living and gave almost infinite supply to reserve the biosphere. In early ages humanity made changes to the environment with limited technology, but the rate was infinitesimal compared to the size of the natural environment. Global changes were not detected.

In the last two or three hundred years there was an explosion in the development of industrial and technical sector, which gave people a multiplied set of tools to encroach nature. Motorization has been developed so dynamically that the air, soil, water pollutions are considerable to the amounts of air, soil, water of Earth.

The sustainable development is a development, where the pace of technical development, the satiation of increasing supply and the raw materials and resources of Earth are poised so that the rate of living and opportunities of the next generations must not to be worse.

Transportation cannot be replaced because it is part of the production chain. Societies are horizontally and vertically differential. The manpower, the stock, the semi finished and finished products must be transported.

The importance of the transportation sector is indicated by the sector production which is 10% of the European Union GDP and more than 10 million people are working in this sector. One of the most emphasized goals of the transport policy of the European Union is sustainable mobility. For this reason transportation systems must be developed and standardized, the effectiveness of transportation service must be increased, while the environmental pollution must be decreased or prevented.

The vehicles used nowadays are polluting. Most of them are converting fossils to mechanical energy and during the conversion 40% of the fossil energy is converted to garbage energy, thereby heating our environment. [1]

2. Importance of Environmental Pollution in Costing

There are no harmonized guidelines for project assessment and transport costing at EU level yet. A critical issue when comparing appraisal practices across countries is to make sure the same definitions are being used. In the proforma for country reports several references are made to the definitions used in the EUNET study. These are discussed in the relevant sections of this report. Different project analysis or combined ones are used nowadays:

- *Cost Benefit Analysis (CBA)*: The effects are assigned a monetary value, and included in an overall economic appraisal of the total value of the project in monetary terms.
- *Multi-Criteria Analysis (MCA)*: The effects are not assigned a monetary value, but are included in an overall project appraisal by assigning non-monetary weights to the individual effects.
- *Quantitative Measurements (QM)*: The effects are estimated in physical units or numbers (cardinal scale), but in contrast to the multi-criteria analysis (MCA) no specific weights are assigned to allow an aggregation of the effects to a single criterion.
- *Qualitative Assessment (QA)*: The effects are classified into one of several ranked categories (ordinal scale) based on well-defined standard criteria for each of the categories, which are invariant from project to project.

Theoretically, all benefits and costs should be accounted for in the cost-benefit analysis. In practice though, many effects are left out either due to difficulties of estimating a trustworthy money value, difficulties of quantifying the effects or because the effects are considered to be of minor importance.

For the analysis of how the main elements of a CBA are treated in the appraisal framework in the surveyed[1] countries, the effects have been grouped into 11 categories.

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[1] The EU 25 was surveyed in the HEATCO project (reference number: SSP8B/502481/2003) financed by EU 6^{th} Frameprogramme, by Department of Transport Economics TUB, Hungary, directed by Dr. Katalin Tánczos head of department

- Construction costs
- Disruption from construction
- System operating cost and maintenance
- Passenger transport time savings
- User charges and revenues
- Vehicle operating costs
- Benefits to goods traffic
- Safety
- Noise
- Air pollution - local/regional
- Climate change

The first rough indication on differences in current practice of project appraisal is how many of the main effects are included in the CBA and MCA [2].

One of the most emphasized goals of the transport policy of the European Union is sustainable mobility. For this reason transportation systems must be developed and standardised, the effectiveness of transportation service must be increased, while the environmental pollution must be decreased or prevented.

3. Marginal Cost Based Pricing in Cost of Emission

Externalities according to the EU guideline: ‚Users should pay the bill' should be internalized and indicated in the cost of transportation. The base of internalized cost is the marginal cost. So let us see the Total Social Cost as a base of the method of internalization.

$$\mathbf{TSC} = \mathbf{TSC}_{\text{infra}} + \mathbf{TSC}_{\text{service}} + \mathbf{TSC}_{\text{user}} + \mathbf{TSC}_{\text{accident}} + \mathbf{TSC}_{\text{env}} \tag{1}$$

TSC:	Total Social Costs
TSC_{infra} :	Total Social Costs of Infrastructure
$TSC_{service}$:	Total Social Costs of Service
TSC_{user}:	Total Social Costs of Users
$TSC_{accident}$:	Total Social Costs of Accidents
TSC_{env}:	Total Social Costs of Environmental Pollution

Total Social Cost of Users is nearly equal to the External Costs of Users, and Total Social Cost of Accidents is nearly equal to the External Costs of Accidents

$$\mathbf{TSC} = \mathbf{TSC}_{\text{infra}} + \mathbf{TSC}_{\text{service}} + \mathbf{EC}_{\text{user}} + \mathbf{EC}_{\text{accident}} + \mathbf{TSC}_{\text{env}} / \frac{d}{dx} \tag{2}$$

$$\mathbf{MSC} = \mathbf{TSC}_{\text{infra}} + \mathbf{MSC}_{\text{service}} + \mathbf{MEC}_{\text{user}} + \mathbf{MEC}_{\text{accident}} + \mathbf{MSC}_{\text{env}} [3] \tag{3}$$

4. Environmental Impacts

The environmental external effects of transport cover a wide range of different impacts, including for example noise, local/regional air pollution and climate change. Transport infrastructure projects often affect local and regional air pollution. Some of the countries take this into account in some form in the project appraisals. Some of them with a money value, whereas others include it in the project appraisal in form of a qualitative description, quantitative description and/or multicriteria analysis. (*Table 3* .)

There is no consensus on which elements should be included in the monetary valuation.

Table 1. Coverage - Air pollution Local/Regional

Approach	No. of countries	Countries
Included in CBA	14	*North/West*: Austria, Denmark, Finland, France, Germany, Netherlands, Sweden, Switzerland *East:* Czech Republic, Hungary, Lithuania *South*: Cyprus, Greece, Italy
Not included in CA, but covered by MCA, QM and/or QA	8	*North/West:* Belgium, Ireland, UK *East*: Latvia, Poland, Slovak Republic *South*: Portugal, Spain
Not covered / No information	3	*East*: Estonia, Spain *South*: Malta

The majority of countries which include *air pollution - local/regional* with a money value in the project appraisal include PM, NO_x, SO_2, HC and CO. Only *Pb* is not included in the appraisal in the majority of countries. The category *other* includes carcinogenic species (Germany) and polycyclic aromatic hydrocarbons (Hungary and Germany). The majority of the surveyed countries base their money value for *air pollution - local/regional* on the *impact pathway approach*. However, as can be seen many different approaches are used. Some countries use more than one approach for estimating the money value. There is no consensus, which effects to include in the money value for *air pollution - local/regional*. All countries, which include the effect on air pollution with a money value and for which the information is available, include *Human health – production loss by sickness and increased mortality.*

The money value for local and regional air pollution is constant over time.

Table 2. Selection of key figures for local/regional air pollution (costs per ton, kg – road and rail)

Region	Country	Differentiation	Unit	YEAR	CO	CH	NO_x	NO_x**-Eq.**	SO_2
	Austria	Urban Roads	Euro/t	1997	9,08	4454,84	3677,26		1555,20
Non-urban roads	Euro/t	1997	3,63	1725,98	736,06	327,03			
Rail	Euro/t	1998							
North/West	Denmark	Urban Roads	DKK/kg	2001	0,61	40,34	72,28		39,41
		Non-urban roads	DKK/kg	2001	0,20	13,45	24,09		13,14
		Rail	DKK/kg	2001	0,01	32,88	118,07		71,94
	Finland	Urban Roads	Euro/t	2000	24,00	67,00	1111		13421
		Non-urban roads	Euro/t	2000	1,00	67.00	435@	1994	
		Rail (diesel) urban	Euro/t	2000	15.00	236,00	1622		16757
		Rail (diesel) non-urban	2000	1,00	236.00	186		612	
		Rail (electric train)	Euro/t	2000			1536		1037
		Maritime (open sea)	Euro/t	2000	0.40	137.00	301		327
		Maritime (coast)	Euro/t	2000	2.00	153,00	397		547
		Maritime (inland)	Euro/t	2000	23,00	197,00	569		684
		Maritime (port)	Euro/t	2000	19.00	148,00	1062		2283
	Germany	Long-Range effects of emission (health damage, losses in forests; damage to water supply and distribution and to soil protection; loss of recreational facilities)	Euro/t	1998				365	
	Sweden	Regional effects	SEK/kg	2001		31,00 (VOC)	62		21
	Switzerland	Road	CHF/kg	2000			9		
		Road and rail (health costs) CHF/kg	2000			16,50			
		Road and rail (damage to vegetation)	CHF/kg	2000			1,50		
		Rail (damage to buildings)	CHF/kg	2000			12,50		
East	Lithuania	Roads transport	LTL/t	2004					
		Sea transport	LTL/t	2004					
South	Portugal	Value used in the Extension of Lisbo Metro assessment	ECU/t	1994	6230	6230	6230		
		Value used in the Extension of Lisbo Metro assessment (CO_2)	ECU/t	1995					

As it can be seen in *Table 2* there is a variation between countries in the numbers, price base and unit of account. This naturally complicates the comparison. However, it is clear that there is a significant range, e.g. in Finland a figure of 13421 EUR/ton is used for SO_2 compared to a figure of 1555 Euro/ton in Austria [2].

The amounts of emissions from road traffic have enough impact on the environment to be taken seriously. Many traffic emissions come only through the exhaust pipe. These are for example NOx and CO. They are easy to measure, in the sense that they can be sampled from the exhaust pipe and measured on-line in real traffic. Other techniques are to collect samples for later analysis or to measure the emissions while driving on a dynamometer. Even though the sampling and data collection seem easy, this will for practical reasons only be possible for small sets of cars and some traffic conditions and cannot easily be rescaled for a whole vehicle fleet or every possible driving situation. Other emissions may be evaporative; the major sources are hot soak losses and evaporation. Hot soak losses are caused by the heating of the fuel system when a hot engine is turned off and the system is no longer cooled by flowing fuel. Evaporation comes from the ventilation of the fuel tank when the temperature varies from day to night. The evaporative losses are harder to measure because there is no easy way to sample the evaporation. Different approaches have been tried for developing a model for evaporation emissions, and today there are competing models that give rather different results. Some emissions, like heavy metals, can be estimated by an indirect method, where the metal content in the fuel is determined separately and multiplied by the fuel consumption. Emissions from road traffic are a good example of a complex system with an output that cannot be completely measured. It is natural to analyse the emissions from a sample of vehicles under different driving conditions and other conditions (temperature, fuel content, road gradients, etc.) and to try to create an emission model for the traffic. Depending on what data are collected about the traffic, the model may be more or less detailed and complex. Traffic data are not collected in the same way and with the same level of detail in every country, and this is a problem if a model is meant to be used for calculations in many countries, or for comparisons between them [4].

5. Estimation Method

The EURO standards are based on the ECE-R15 driving cycle. Each vehicle category has its own limits. (For example the M1 category gasoline vehicle – *Table 3*)

The vehicle stock can be divided into groups by EURO standards and vehicle categories (*Fig. 2*), with their pollutant limits. Being aware of the vehicle numbers in each category multiplied by the limit they can be summarized. Now the pollutants can be calculated from the given vehicle flow and the given distance. Then the sum

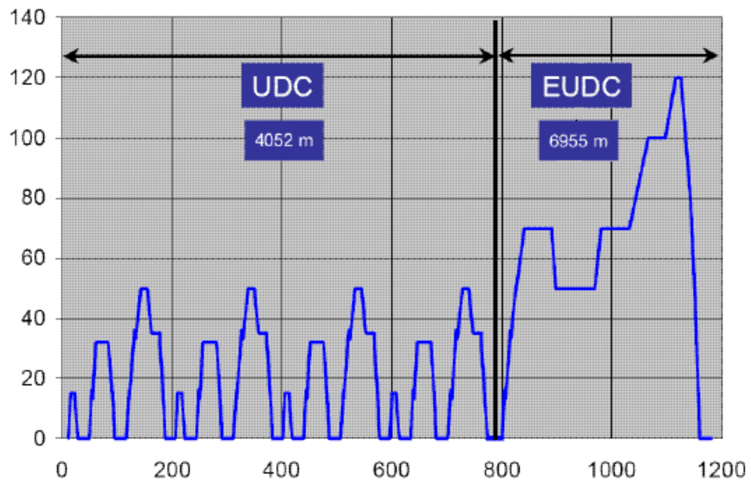

Fig. 1. ECE-R15 drive cycle [5]

Table 3. Example of EURO STANDARDS [5]

Gasoline	As From	CO	HC	NO_x
EURO 1	1/7/1992	4.05	0.66	0.49
EURO 2	1/1/1996	3.28	0.34	0.25
EURO 3	1/1/2000	2.30	0.20	0.15
EURO 4	1/1/2005	1.00	0.10	0.08

CO = carbon monoxide, g/km = gramm per kilometer, HC = hydrocarbons, NOx = nitrogen oxides

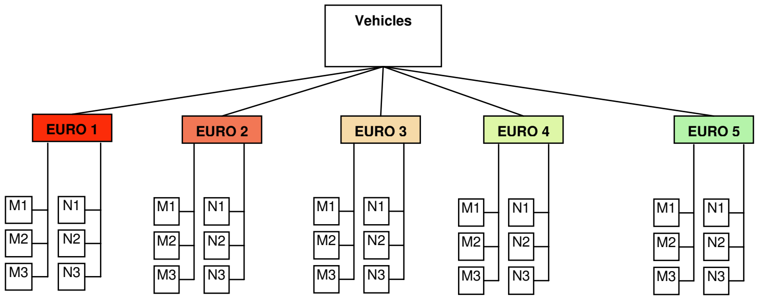

Fig. 2. Groups of Vehicles

pollutant can be monetarized by national ratio [6].

$$\mathbf{G} = \begin{matrix} g_{11} & \cdots & g_{i1} \\ \vdots & \ddots & \vdots \\ g_{1j} & \cdots & g_{ij} \end{matrix},$$

where: $\sum_{i=1}^{n} g_{ij} = \alpha_j j\mathit{=1, \ldots, m}$ emission of the vehicle of the EURO j standard

$\sum_{j=1}^{m} g_{ij} = \beta_i i\mathit{=1, \ldots, n} \begin{cases} M_i \mid i : 1..3 \\ N_{i-3} \mid i : 4..6 \end{cases}$ vehicle categories

$\sum_{i=1}^{n} \sum_{j=1}^{m} g_{ij} = \sum_{j=1}^{m} \alpha_j = \sum_{i=1}^{n} \beta_j$ sum of the domestic vehicles

6. Summary

Building of infrastructure and growing traffic cause environmental pollution. There is a justifiable demand by the society to moderate the environmental impacts caused by road transportation or building and maintenance of road infrastructure. CBA of building a new infrastructure element or managing the traffic is based on the costs. The external costs should be monetarized, implemented. My aim was to build a model that estimates the emission, caused by the vehicle flow. I grouped the vehicles by category and by the emission of the vehicle's EURO standards. With this classification the estimation can be done by the described process.

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