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Project: ***Serbian Strategy of Sustainable Development***

Economic activity and the status of the environment in Serbia

1st version

Introduction

Diverse and complex conditions of maintaining life on planet Earth, summed up under the name of the environment, may be under threat both by natural, geophysical, factors and by anthropogenic or social factors. There is much evidence that human economic activity is the major anthropogenic factor of contemporary environmental degradation on Earth. Since the middle of the XIX century, the anthropogenic impacts on environment have grown, and have become dominant. Of all types of economic activity, the greatest impact comes from activities related to production and use of energy in different sectors. Interrelations between the environment and economic activities are becoming the subject of separate scientific disciplines with have been growing rapidly since the middle of the XX century[1].

The links between economic activity and the environment in Serbia, in the period from the middle to the end of the XX century, do not differ significantly from the general, global trends in this domain. They have practically all features of these trends, in a manner characteristic of countries of South-East Europe and countries undergoing transition (Mnatsakanian 1996). When we state this, we rely on the following features:

1) The attitude that nature and its resources should primarily serve economic and social development,
2) The social imperative to master nature,
3) The dependence of economic development on available natural resources,
4) The lack of taking into account the full recovery costs of natural resources, which is the final consequence of full application of the theory of values (Papp 1977),
5) Imposing industrialization and urban way of living and abandoning traditional social forms,
6) Highly intensive use of natural resources and energy,

[1] The need to understand theoretically and reflect on the relations between the environment and economic activity resulted in the development of Environmental Economics; while the need to provide that the survival and the future of mankind is not restrained by the quantity and quality of natural resources resulted in the development of Economic of Natural Resources, two closely related and correlated disciplines.

7) Low efficiency of input transformation,
8) Low utilization of space and geographic advantages,
9) Intensive growth of big cities and depopulation of small settlements,
10) Inadequate control over waste generation and disposal, both municipal and industrial including hazardous waste,
11) Neglect of international, trans-boundary aspects of pollution and exploitation of natural resources,
12) Incomplete elaboration of property rights over natural resources,
13) Limited data and inadequate access to data regarding the state of the environment,
14) Inefficient public participation in decision-making processes regarding economic utilization of natural resources.

With respect to the second half of the XX century, the environmental impacts of economic development in Serbia may be assessed both by environmental media, for instance, impacts on air, water, soil, etc., and also chronologically, as impacts during different stages of development. We can differentiate three stages, which have left behind them three "layers" of environmental degradation in Serbia. These are:

I stage of socialist industrialization, beginning with the reconstruction era after the WWII and lasting until the disintegration of the SFRY. This stage is characterized by major damages, characteristic of ex-socialist countries, so there is practically no specific feature of Serbia, except perhaps in the concentrations of specific pollution. The major portion of environmental damages, resulting from this stage, is manifest today in form of pollution stocks, the problems related to the so-called environmental legacy, or historical pollution, an issue especially sensitive under the conditions of restructuring and privatization of former socially-owned enterprises;

II stage, from 1991 to 1999, covering the period from the disintegration of the SFRY and the wars in the neighborhood until the NATO bombing. This is the period of disintegration of the Yugoslav market, international sanctions, serious political and economic abuse, and one of the highest hyper-inflations in world history (Group G 17, 1999). This stage was characterized by drastic drop in economic efficiency, especially low efficiency in use of natural resources. The over-use of technical and natural capital, inadequate or no maintenance of treatment systems, general economic destruction, the growth of illegal economy and a devastation of the legal system resulted in huge damages, unparalleled in countries in transition. The situation in Serbia may only be compared with the situation in the Balkan countries and Caucasus countries (Mnatsakanian 1996), and this only partly. When speaking of the effects that this has had on the environment, we must not accept a light conclusion that thanks to economic depression the state of the environment spontaneously improved. Such an inadequate impression comes from inadequate application of environmental indicators, some of which may actually indicate certain positive changes, for instance absolute reduction of air pollution from industry and traffic, or reduction of chemical pollution of water streams. However, when the data on pollution emissions are placed in the context of actual outputs, the picture is tragic; indicating a drastic environmental degradation that would follow once the economic activity is normalized.

III stage, from 1999 to democratic changes in Serbia in 2000, is a period of NATO bombing and immediately afterwards. The damage caused to economic and infrastructure facilities was also accompanied by environmental damages. Radiological (depleted uranium), chemical (PCB) and physical (suspended matter) contamination, has environmental impacts. There are different opinions regarding the scope of economic damages, however there is no accurate quantified assessment[2]. It is beyond doubt that there were damages, that the NATO activities were relatively short term, and that the climatic and other natural conditions, upon the end of the NATO campaign were extremely favorable for regeneration of the damages caused to nature. Therefore, any attempt to present earlier environmental degradation as a consequence of the NATO campaign would be wrong and professionally not grounded.

Assessment of the Economic Value of Environmental Degradation in Serbia

Method

Since February to September 2004, within the development of the National Environmental Action Plan (NEAP), the European Agency for Reconstruction initiated, as a part of the Environmental Capacity Building Program 2003, the work on a study titled *Assessment of the Economic Value of Environmental Degradation in Serbia*. This study was the first attempt to assess the economic value of environmental damages in Serbia (Jantzen, J. and Pesic R. 2004). Having in mind the limited time and resources available, the authors decided to use the benefit transfer method, fully aware of its limitations (for more details on techniques and methods used for assessment of economic values of the environment, see the Appendix).

The Benefit Transfer method is based on results of earlier environmental assessment studies undertaken in other countries and regions and their transfer, with the necessary adjustments, to the conditions in the country to which the study refers. Most frequently used correction factors are the average income, calculated based on purchasing power, the size and characteristics of the population, geographical conditions, the scope of environmental impacts, the level of urbanization, historical states of the environment, etc. Relying on results of historical studies undertaken under different geo-physical and socio-economic conditions is not always adequate. The described procedure gives better results if local impacts are weaker. However, in terms of global impacts, the results may be considered valid to a higher degree.

The said Study used the results of similar studies undertaken elsewhere in Western Europe (EFTEC/RIVM 2000) and in Central and East Europe (Ecotec 2001). At the beginning of 2004, these were considered the best European technical studies in this domain. The adjustment to the national specific conditions in Serbia was done **a**) by application of exchange rates based on purchasing power, according to data of OECD (www.oecd.org/statsportal) and CIA World Factbook (2003), **b**) corrected by consumer price indices, CPI, to take care of inflation.

Having in mind that there were no earlier studies of this type in Serbia, and the fact that there was not even one study done by conditional assessment, the authors used the benefit transfer method in a rather simplified manner. It consisted of **a**) assessment of pollution

[2] The attempt made by two experts of the Institute for Nature Protection (Jakšić, P and Mandić, R. 1999) is theoretically unsound, based on rough approximations and suffers from serious technical errors. The results can not be considered even as approximate, while the text itself is a shame not only to authors and editors, but also a demonstration of the tragic state of scientific thinking in Serbia at the end of the XX century.

emissions **b**) application of unit value per ton of pollution adjusted to Serbia, and **c**) settling minimum and maximum values. **Figure 1**

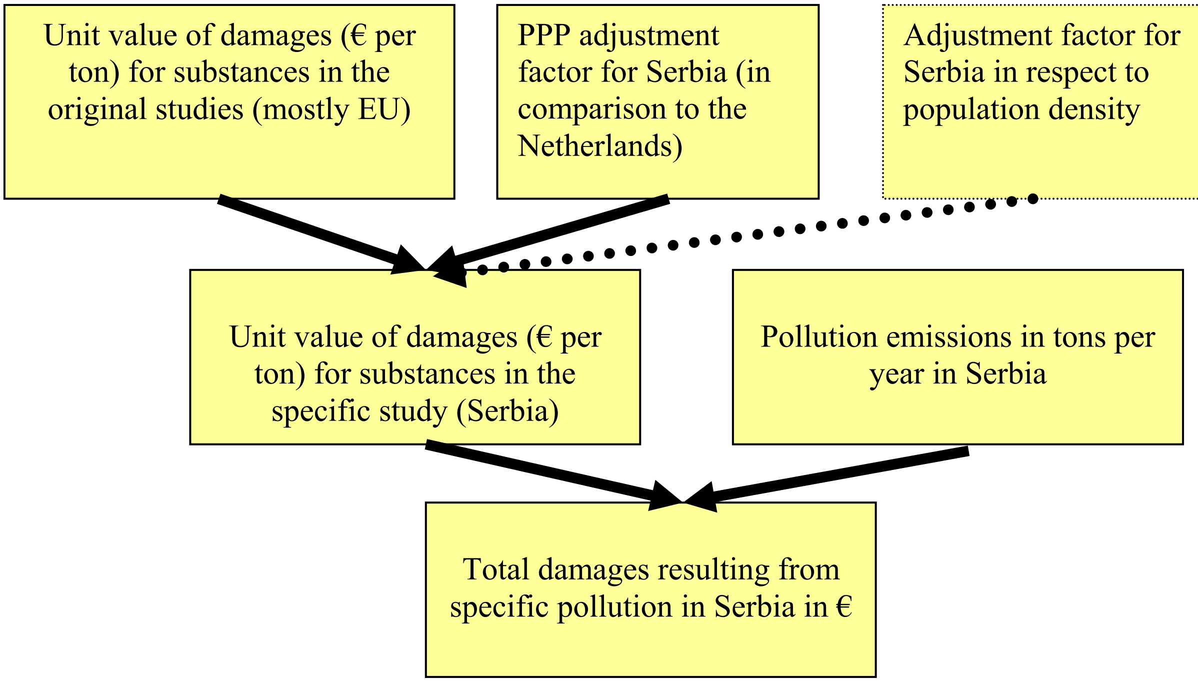

Figure 1

Wherever possible, the assessment of unit value of damages combined **a)** the *demand side* approach (see the Appendix), starting from the analysis of demand for healthy environment, and **b)** the *supply side* approach, based on limit expenditures (applied technologies) for reducing pollution to allowable level. Unfortunately, for several types of pollution it was not possible to determine with certainty either the technologies available or the limit expenditures needed for their application. There were also no accurate data available on social demand for high quality environment and it was therefore impossible to develop an aggregate demand curve for it. It was also not possible to identify the physical volume of damages (damage to crops, forests, mortality and morbidity of humans and animals), to be accompanied by assessment of monetary value of such damages.

However, a much greater methodological problem was the fact that the study covers mostly the flows of pollution and environmental degradation (pollution flows), and not pollution stocks accumulated in water, air and soil over time[3]. Also missing is the assessment of environmental damages in Serbia resulting from the third stage of development. With respect to the assessment of the value of environmental damages from the period of the NATO campaign, it should be noted that the method described here and used in the study (Jantzen, Pesic 2004) gives a picture of economic value of pollution flows and not of pollution stocks. It is a fact that the environmental damage from the third stage at present have predominantly the character of stocks and that they should be studied further.

[3] Regarding the relation between pollution flows and stocks see (Pešić, R. 2002; 81-114)

Results

In the Study (Jantzen, Pesic 2004) the environmental damages were analyzed by segments (environmental media). The chapter dealing with assessment of economic value of damages to air analyzed: a) emissions of greenhouse gases, causing global climate changes, b) acidification, resulting from emissions of sulphur-dioxide, nitrogen oxides and ammonia, c) tropospheric oxygen, emissions of VOC (volatile organic compounds), d) emissions of particles PM-10, and e) emissions of lead from fuel. By applying adjusted unit values of damages, the minimum and maximum levels of damages were identified at annual level and are presented in **Table 1.**

Emission CO_2 annually	45,592,200 tons		
Unit damage €/t		1,31	10,0
Total damage		**59,6 million €**	**455,9 million €**
Emission SO_2 annually	525,000 tons		
Unit damage €/t		541	1,341
Total damage		**284 million €**	**703,8 million €**
Emissions NO_x annually	161,000 tons		
Unit damage €/t		87	145
Total damage		**14 million €**	**23,3 million €**
Emission NH_3 annually	90,000 tons		
Unit damage €/t		39	332
Total damage		**3,5 million €**	**29,8 million €**
Emissions VOC annually	97,000 tons		
Unit damage €/t		7,6	15,5
Total damage		**0,74 million €**	**1,5 million €**
Emission PM-10 annually	60,000 tons		
Unit damage €/t		1,174	2,126
Total damage		**70,5 million €**	**127,5 million €**
Emission Pb annually	351 tons		
Unit damage €/t		40,147	80,294
Total damage		**14,1 million €**	**28,2 million €**
TOTAL AMOUNT	**DAMAGE: AIR**	**447,2 million €**	**1,370,1 million €**

Table 1. ***Total damage (minimum and maximum level) of air pollution in Serbia in the year 2003(Jantzen, Pesic 2004)***

In terms of water, the assessment of damages was limited to discharge of municipal and industrial waste water, discharge of nutrients from livestock farms, excessive exploitation of ground water resources, especially in Vojvodina. The results range from about 180 million € to 575 million € annually. If heavy metals in rivers are included, primarily in sediments, the amount of damages increases significantly and ranges from 640 million € to 2,800 million € annually. Such a drastic increase of total damages is not only a result of high unit values for specific heavy metals (lead from 832 to 43,449 €/t, cadmium from 43,449 to 103,491 €/t, arsenic from 43,450 to 51,250 €/t, zinc from 166 to 43,500 €/t), but also of high concentrations of heavy metals in river courses, especially the Ibar river. However, we do believe that the assessment of the value of damages to water should be repeated by use of another method in order to arrive at a more realistic picture.

In respect to waste and waste handling, the situation in Serbia is far from satisfactory. Inadequate disposal of municipal and hazardous waste, including medical waste, is a big environmental pressure. This pressure manifests itself through emissions of methane from dumpsites, and leakage of leachete from inadequate landfills, fly ash as a result of spontaneous garbage burning, soil pollution and occupation by illegal dumpsites, etc. All of this results in total damages of approximately 100 to 275 million € annually. However, this analysis did not include industrial waste, as it was not possible to receive full information on locations and volumes of industrial waste, nor accurate data on categorization and contents of such waste, so assessment of damages was impossible. If damages resulting from industrial waste were included, and if damages due to soil pollution due to gas-filling stations were included, this amount would be much higher.

In order to make the analysis of environmental damages due to economic activity complete, and comparable to similar studies in EU countries, the authors also included noise, primarily in towns, traffic and industrial facilities. Noise exceeding 50 dB(A) is considered to be environmentally unacceptable. The assessed damages range from 57 million to 181 million € annually. We believe that this result needs to be reconsidered, especially in terms of adjustment factors used in the benefit transfer (the impact of noise on the price of real estate in towns).

The study includes a separate chapter on wind-caused (eolic) erosion in Vojvodina, caused by inadequate agricultural practices. Erosion results loss of top-soil, which in turn reduces soil fertility, and loss of crops and income from agriculture. This segment of damages was assessed at approximately 80 million € annually. However, in order to have a more complete picture, there is need also to include damages of other forms of erosion in Central Serbia, and damages from inadequate use of fertilizers and pesticides in Serbian agriculture. Unfortunately, the authors did not have access to data regarding the intensity of such damages.

In summarizing the assessed damages, according to data available mostly for the year 2003, the authors came up with an aggregate value of damages ranging from 861 million € to 2,500 million € annually.

If damages from heavy metals in rivers are included, the damages range from 1,300 million € to 4,700 million €. However, this should be considered with certain reserve, as damages due to heavy metals in river sediments have the character of pollution stocks and not of pollution flows, as other values determined in the study. Also, if damages due to industrial waste disposal, soil pollution caused by inadequate fertilizer and pesticide use, were included,[4] this would also refer to the value of damages expressed as pollution stocks, and it would not be

[4] We are free to make an intuitive assessment that in such a case the minimum level of environmental damages would exceed 10 billion €.

adequate to compare them with the level of GDP for a specific year. The assessed value of pollution stocks should be considered in the context of assessed national wealth, which has a character of a stock. We are not aware that there is an assessment of the national wealth of Serbia for the year 2003, so we will not consider this greater range of damages either in the context of GDP as it would be theoretically inconsistent, or with the national wealth whose value is not available to us.

The value of environmental pollution flows in 2003, ranging from 861 million € to 2,500 million € should be considered in the context of the actual gross domestic product for that year, which also has the nature of a flow. Since the assessed GDP of the Republic of Serbia in the year 2003 was 16,838 million €, or 2235.4 € per capita (The Republic Statistical Office, RSO, 2004), we may conclude that the value of damages varies from 5.11% of GDP (lower level) to 14.85% of GDP (higher level). The said Study (Jantzen, Pesic 2004) arrived at a lower share, ranging from 3,5% to 10,3% as it considered a GDP of about 25 billion €, arrived at by adjusting the nominal value by standard purchase power parity, PPP.[5] In order to avoid any arbitrary approach to GDP, either through application of exchange rate (RSO 2004) or by application of PPP standards (Jantzen, Pesic 2004), we decided to view the annual value of environmental pollution flows in Serbia on a per capita basis. In the year 2003 on a per capita basis it ranged from 115 € to 334 € .

Assessing the future value of environmental damages in Serbia, authors Jantzen and Pešić (2004) have worked out nine possible scenarios for a period of ten years. From the aspect of economic growth three options were considered: **A**) slow growth, with an average annual rate of 1.8%, which is somewhat higher than demographic growth, **B**) average growth rate at 4.73%, based on the current growth of Poland, Hungary and the Check Republic (Economist 2004) and **C**) a rapid growth of 8%, as for instance in Russia (Economist 2004).

From the point of view of damages growth, three options were considered as well: **A**) the option *ceteris paribus,* implying that the growth of damages is parallel to economic growth, meaning that there is no technological nor structural change; **B**) the option with autonomic technological progress and structural changes leading to reduced pollution per unit of GDP of 2%; **C**) the option with application of environmental pollution abatement technologies, in the context of accession and harmonization with the EU, accompanied with reduced damage per unit of GDP of 5%.

Starting from the lower value of assessed damages in the year 2003 of approximately 860 million €, nine possible scenarios were developed; of which three (green) imply an improvement in the status of the environment in Serbia. Other scenarios indicate a higher or lower increase of damages. **Table 2**

		Environmental policy scenario		
Economic growth		0%	Technological progress -2%	EU policy -5%
Low	1.80%	€ 1,027,960,000	€ 842,800,000	€ 621,230,000
Medium	4.73%	€ 1,365,250,000	€ 1,125,830,000	€ 837,060,000
High	8%	€ 1,856,670,000	€ 1,540,130,000	€ 1,155,770,000

Table 2 ***Projections of environmental damages (lower) in Serbia in the year 2013. (Jantzen, Pesic 2004)***

[5] Specifically, the GDP assessed by PPP standard was 24,931 million € (Jantzen, Pesic 2004; 68).

If we assumed the higher value of environmental damages, of about 2,500 million €, we would arrive at the following damages in 2013 (**Table 3**), of which only three indicate a better status of the environment.

		Environmental policy scenario		
Economic growth		0%	Technological progress -2%	EU policy -5%
Low	1.80%	€ 2,988,250,000	€ 2,450,000,000	€ 1,805,900,000
Medium	4.73%	€ 3,968,750,000	€ 3,272,750,000	€ 2,433,310,000
High	8%	€ 5,397,310,000	€ 4,477,000,000	€3,359,800,000

Table 3 ***Projections of environmental damages (higher) in Serbia in the year 2013. (Jantzen, Pesic 2004)***

In case of the scenario with low economic growth, the effect of autonomous technical progress could lead to mild decrease of damages. Higher reduction of damages could be expected in case of active measures of environmental policy, in line with EU principles and standards. However, low economic growth, by all considerations, would not allow a more active or ambitious environmental policy needed for accession to EU. A medium economic growth would, after ten years, lead to a more favorable situation only if accompanied with consequent application of EU standards. High rates of economic growth would certainly lead to additional environmental pressures; however, a consistent implementation of EU regulation would make such pressures bearable. In that case a rapid economic growth would not be detrimental to the environment. It would also generate the much needed investment potential for more ambitious environmental protection and increased standard of living in the future.

Assessment of environmental expenditures in Serbia

In order to arrive at a more complete picture of the scenario options regarding the implementation of protecting measures for environmental protection, in the context of accession to EU, the authors of the above Study had an objective to consider the required investment expenditures within the NEAP and the National Environmental Strategy (NES). Although there were on one side certain doubts about the assessment of the economic value of environmental damages, these doubts were less present in choosing the method for projections of the necessary environmental investment expenditures in Serbia. Having in mind the EU environmental *Acquis Communautaire*, including all directives, regulations and guidelines referring directly or indirectly to the environment in the EU, and the approach identified within the activities of the NEAP Forum, authors Jantzen and Pešić developed an overview of financing needs for the implementation of the NES National Environmental Strategy.

Method

The starting point in evaluating the level of environmental investment expenditures was the degree to which the present status by individual environmental media (water, air, soil, etc.) differed from the status acceptable according to the EU environmental *Acquis Communautaire*. Some of these discrepancies require investments which were identified on the basis of expenditures required for the introduction and implementation of the presently best available technologies. Under best available technologies, we mean the most cost-effective technologies available today. If it happens that in the future there are, for instance, new abatement technologies for removal of sulphur-dioxide from the air, which would be more efficient and more cost-effective than those presently available (in terms of lower expenditures per removal of one ton of SO_2 from emission by polluters) the total expenditures would certainly change accordingly. So, the level of required investment expenditures was identified, based on the scope and type of needs and based on the best available technologies at present. This was then used to identify the projections of operating and maintenance costs for the new installed systems.

This was done by using the MOSES model (**M**odel **O**n **S**ustainable **E**nvironmental **E**conomic **S**cenarios), developed for the needs of the World Bank by Jochem Jantzen and his associates in the period from 1989 to 1992 in the TME Institute (Institute for Applied Environmental Economics) from the Hague[6]. For all types of environmental pressures, relevant marginal abatement cost functions were developed, and based on them and the available abatement technologies, as well as standard costs of specific technologies, the investment and operations expenditures for environmental investments in Serbia were determined.

The analyzed time horizon of ten years is divided in two periods, the first from beginning of 2005 until the end of 2009, and the second from beginning of 2010 to end of 2014.

Total environmental expenditures, investment and operational, range around 4 billion € for the ten year period.

In this, it is worth noting that the expenditures for the existing infrastructure (for instance in the field of waste management, waste water collection, air, etc.) and the existing institutions (environmental monitoring and supervision, administration at all levels, etc.) have not been included in the analysis. This, therefore, refers only to additional funding needed for improving the existing system and harmonizing it with the EU standards. Also, no part of the analyzed investments was exclusively of environmental nature, but has numerous other benefits as well. However, expenditures that are not strictly of environmental nature were not considered in this analysis.

Results

According to the projections (**Table 4**) total expenditures range from 26 million € annually, at the beginning, to 720 million € annually at the end of the period under consideration.

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	**Total**
Waste	€ 6	€ 36	€ 52	€ 70	€ 138	€ 138	€ 133	€ 139	€ 144	€ 150	€ 1006
Energy	€ 4	€ 2	€ 54	€ 47	€ 51	€ 141	€ 192	€ 243	€ 227	€ 244	€ 1.205
Mining		€ 2	€ 0.3	€ 10	€ 12	€ 2					€ 26

[6] For more information on the MOSES model please look at the web page of the TME instituta www.tme.nu

Industry	€ 0.8	€ 22	€ 36	€ 26	€ 23	€ 23	€ 26	€ 30	€ 33	€ 38	€ 258
Transport	€ 0.1	€ 1	€ 15	€ 12	€ 12	€ 68	€ 79	€ 94	€ 107	€ 127	€ 515
Agriculture	€ 1	€ 12	€ 14	€ 15	€ 15	€ 11	€ 12	€ 13	€ 15	€ 16	€ 124
Soil	€ 0.1	€ 2	€ 2	€ 2	€ 3	€ 3	€ 3	€ 3	€ 3	€ 3	€ 24
Air	€ 0.4	€ 5	€ 17	€18	€14	€ 80					€ 135
Water	€ 11	€ 14	€ 14	€ 16	€ 22	€ 108	€ 115	€ 121	€ 127	€ 134	€ 682
Nature	€ 2	€ 2	€ 3	€ 1	€ 4	€ 3	€ 3	€ 3	€ 3	€3	€ 27
Noise	€ 0.3	€ 0.5	€ 1	€ 0.9	€ 1	€ 1	€ 2	€ 3	€ 4	€ 5	€ 19
Radiation	€ 1	€ 1	€ 1	€ 1	€ 3	€ 18	€ 18	€ 18	€ 1	€ 1	€ 63
TOTAL	€ 26	€ 99	€ 213	€ 219	€ 298	€ 595	€ 583	€ 667	€ 664	€ 720	€ 4085

Table 4 ***Total and annual expenditures of direct actions at improving the environment in Serbia (not including expenditures for indirect actions) in millions of € (calculated by authors)***

Along with this, it is worthwhile to consider also expenditures that are not directed primarily at the environment, but which do have indirect effects, such as construction of traffic infrastructure (road and railway bypass roads, drinking water treatment plants, district heating system improvements, modernization of aviation fleet, modernization of road traffic). We estimate that these expenditures are approximately 4 billion €. These expenditures are not considered as environmental expenditures, but they shall have positive indirect effects.

With respect to direct expenditures, they increase gradually over time, as a consequence of economic growth and increased potential for own investments. At the beginning, these are mostly modest expenditures for building an adequate institutional infrastructure, developing an adequate legal and regulatory framework, improved monitoring and supervision, which altogether is not a capital-intensive activity. At a later stage, there will be an increased share of capital-intensive investments, while the ratio of investment and operating expenditures will vary. At the beginning, there will certainly be a predominant share of investment expenditures (waste water treatment plants, sanitary landfills, air filters, recycling projects, etc.) while at a later stage the share of management and maintenance expenditure for the existing systems, i.e. operational expenditures, will increase. **Figure 2**

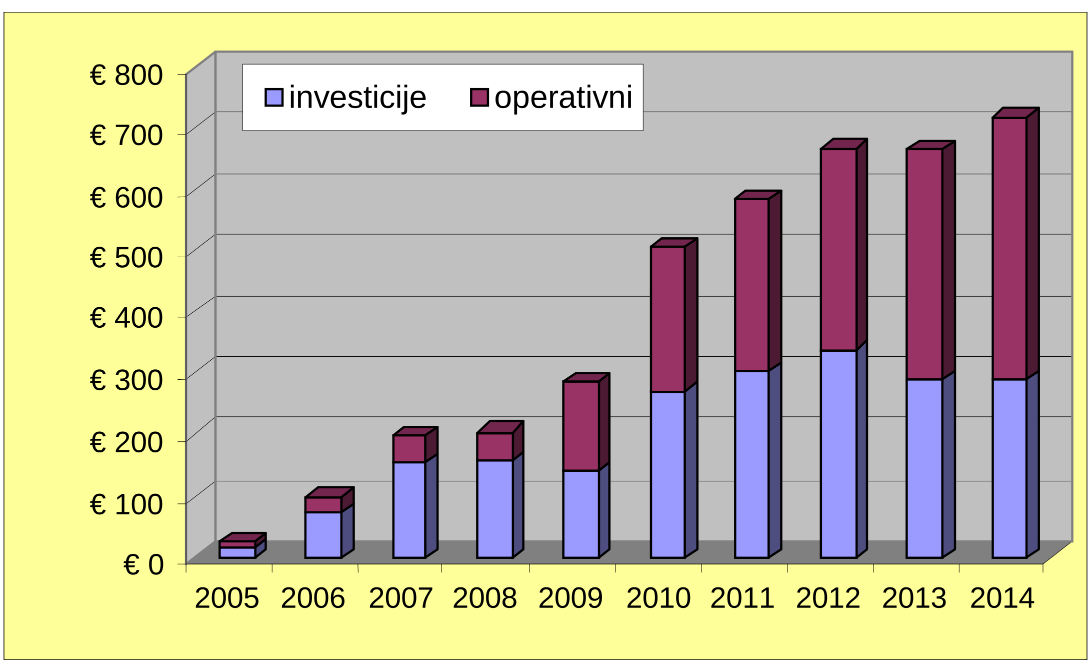

Figure ***2 Dynamics and structure of total environmental expenditures in Serbia (calculation by J. Jantzen)***

It is possible to conclude that the expenditures will be the highest in the energy sector, with about 30%, waste management with about 25%, water with 17%, transport with about 13%, industry with about 6% and agriculture with about 3%. With respect to expenditures related to air, the stated expenditures refer exclusively to expenditures that have not already been included in the expenditures of the energy sector, transport and industry. If these expenditures were included as well, the expenditures relevant to air quality in Serbia would be about 1.7 billion € or about 41.5%.

Significant investments are expected in the field of waste management, on the average about 15 million € annually[7]. Operating and management costs for sanitary landfills will be increasing and at the end of the stated period will reach about 20 million €. The expenditures relevant to recultivation of existing dumpsites shall begin to appear since the year 2009, with a minimum amount of 2.5 million € annually. Operating expenditures for waste collection systems will increase to the level of about 70 million € annually at the end of the period under consideration. Investment expenditures for recycling and composting, planned in the second stage, shall amount to the average of about 14 million annually, while operating expenditures shall increase to the level of about 15 million €, at which level they would become stable. With respect to investment expenditures for medical and hazardous waste, it is planned that a total of about 40 million € will be needed, while the annual expenditures for treatment and transport of hazardous waste would be annually around 17 million €[8]. When all the required facilities are constructed, operating expenditures for handling of hazardous waste shall increase to about 14 million annually in 2014[9].

It is estimated that total investment expenditures in the energy sector will exceed 800 million €, of which about 50 million refers to refineries and the rest to power plants[10]. Operating expenditures will increase to the level of about 100 million in 2014, of which about 10% of operating costs will be covered by refineries and the remaining by power plants.

In order to achieve the objective of treating 50% of industrial waste waters by 2014, it will require about 10 million € annually in form of new investments, while the operating expenditures would increase to the level of 17.5 million € in 2014. It is projected that after 2010, about 2 million € will be invested annually to clean up industrial pollution zones and inadequate industrial waste disposal sites. Establishing a chemicals handling system[11] will require investments of about 9 million € annually, half from the public and half from the private sector. Since the year 2010 the operating costs of this system will be about 5 million, of which 1 million will be covered by the public sector and the remaining part by the private sector. The introduction

[7] The reason for this is compliance with the Directive 75/442 EEC, amended in Directive 91/156 EC

[8] The reason for this is compliance with the Directive 91/689 EC on hazardous waste, amended in Directive 94/31 EC.

[9] Directive 96/61 EC, the so-called IPPC Directive, and Directive 96/82 EC

[10] This refers to full compliance with the Directive 96/62 EC.

[11] Directive 67/548 EC I Directive 76/769 EC

of the EMS (**E**nvironmental **Ma**nagement **S**ystem) at least in the biggest enterprises in Serbia will require about 1.5 million € annually (approximately about 50,000 € per enterprise).

Increased use of unleaded petrol will require expenditures of about 5 million € annually, supposing that fuel consumption will increase at the rate of 5%, while the transfer to diesel fuel with low sulphur content will require between 15 and 18 million € annually[12]. If assumed that the number of vehicles will be increasing at the rate of 5% annually and that the share of second-hand vehicles will reduce to about 50% by 2014, it is expected that the expenditures for new vehicles according to EU standards will be 36 million in 2010, and will increase in 2014 to 87 million €. To this, we should add expenditures for rigorous technical control including also emission control, in an amount starting with 10 million € in 2007 and reaching 15 million € in 2014.

The policy objective to construct municipal waste water treatment plants in settlements exceeding 100,000 equivalent-inhabitants[13] will require about 215 million € additional investment expenditures, or about 45 million annually, starting in 2010. Operating expenditures of these systems will stabilize at 25 million € annually in 2014. It is estimated that by 2014 another 1 million inhabitants will be connected to the sewerage collection systems, which will require about 342 million € additional investment expenditures, or 75 million annually starting from 2010. It is also expected that operating expenditures for sewerage systems will increase to 17 million by end of 2014. The required annual investment expenditures for modernization of water supply systems are 10 million €. It is estimated that investments in repairs of water supply networks will require about 2 million annually.

In order to make the picture of required environmental investment expenditures complete, there is need to add investments in noise reduction, in an amount of 1 to 5 million € annually, and investment expenditures for radioactive waste disposal, at a level of 50 million €.

Conclusions

Total environmental expenditures, investment and operating, in the ten year period will be about 4 billion €, or about 545 € per capita in Serbia. Although at first sight these expenditures may seem high, when compared with the assessed environmental damages of 115 € to 334 € per capita <u>annually,</u> they are more than acceptable. Thus, for the ten year period, the environmental damages, resulting only from pollution flows (the pressure of environmental stocks has, for reasons of methodology, been excluded) range from 1150 € to 3340 € per capita. With the expenditures of 545 € per capita, these damages would be reduced in an amount that would depend on the speed of economic growth and pressures of the economy on natural resources. However, even under very rapid economic growth of 8 %, the measures implemented, in accordance with EU standards, would significantly reduce the environmental problems in Serbia.

A comprehensive study (Ecotec et al. 2001) performed in 13 countries of Central and Eastern Europe indicates that annual benefits (including the benefits in the field of health care, resources and eco-systems) resulting from the implementation of EU environmental regulations are on the average 2.6 % of the GDP of the countries under review in the period 1999-2020. These benefits are especially strong in the Check Republic at 4.8% GDP and Romania at 4.0%

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[12] International studies indicate that the use of vehicles with engines Euro 3 and Euro 4 are by about 310 € annually more expensive that vehicles with old types of engines, while in case of trucks this difference is 2745 €.

[13] Directive 91/271 EC on municipal waste water treatment.

GDP, which is a consequence of many years of environmental pollution and exploitation of resources in the period of socialist industrialization.

The benefits of implementing EU environmental standards are difficult to quantify without accurate projections of economic growth or the speed and structure of the economy in a period of at least twenty years. We are not aware of such macroeconomic projections being available in Serbia and therefore we cannot analyze the relation between expenditures and benefits of implementation of EU standards as percentage of future GDP.

If we attempted, however, to look at the ratio between economic activity and the environment in a per capita dimension, with the assumption that the population of Serbia will not change drastically over the next decades, and the assumption that the implementation of EU standards in this area could result in a reduction of damages of at least 50%, we could then conclude that the cost/benefit ratio would be achieved of between 1.1 to 3.1 after the first decade of implementation. Such a cost/benefit ratio could be even better after the second decade from 2014 to 2024, because the investment expenditures would then reduce both in absolute and in relative terms, making room for operating expenditures, technical systems and public institutions intended for environmental protection. The actual cost-benefit ratio will depend not only on environmental policy but also on the speed and nature of sustainability of economic development of Serbia.

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Appendix

Techniques for valuation of the environment and environmental resources

Economic approach to valuation of environmental changes is based on assessing people's preferences with respect to changes in the environment in which they live. Environmental resources produce goods and services, very important for welfare of people, and for which very often there are no markets or they function in very imperfect ways. Examples of this are numerous, starting from air quality which impacts human health, yields of crops, damages to buildings, damage to forests due to acid rains, and drinking water. Whether there is no market or it is imperfect, the result is that there are no prices for environmental resources; therefore there is no awareness of direct monetary value of the environment. In order to introduce economic valuation of the environment, we must start from the same principles that apply to valuation of products of human activity, these being the principles of ″willingness to pay″ (WTP) and the principle of ″willingness to accept compensation″ (WTA) for environmental damage or degradation. When these parameters are measurable, then economic assessment enables environmental damages and benefits to be financially expressed, for instance as the value of different scenarios of pollution control. Than, it is also possible to assess net environmental benefits and damages to society as a whole.

Lack of market and prices for environmental goods and services is a twofold challenge for economists. The first challenge is identification of how environmental damages affect welfare. The second challenge is the assessment of monetary value of such changes, by using a series of direct and indirect techniques.

Total environmental value

The monetary expression of changes in the level of social welfare, caused by changes in the quantity and quality of environmental resources is termed ″total environmental value″ (TEV). As some environmental resources offer a series of useful services to society, TEV could be decomposed so as to better cover all aspects of impacts on social welfare. TEV consists of the ″the use value″ and the ″non-use value″, or ″ value of passive use of environmental resources″.
The use value includes a) direct use value, when individuals actually use the resources, either for commercial purpose (logging timber, fishing), or for recreation purposes (swimming in the lake, walking in a forest); b) indict use value, when the society has direct benefits of functional eco-systems (water purification in swamps, carbon sequestration in forests); c) option value, when individuals are willing to pay for the future potential to use the resource (future visits to national parks).

Non-use value takes the form of: a) existence value, which is reflected in valuing the nature from ethical or philosophical perspective, irrespective of present of future benefits; b) bequest value of heritage, which represents what the people of the present are willing to pay, or to take the costs of, so that the future generations may also enjoy the use of environmental resources.

In practice, it is often difficult to differentiate among these categories of valuation, so we use total environmental value as a sum of all of these forms.

TEV = use value + non-use value

TEV = direct use value + indirect use value + option value + existence value + bequest value

TOTAL ENVIRONMENTAL VALUE (TEV)				
USE VALUE			NON-USE VALUE	
Direct use value	***Indirect use value***	***Option value***	***Bequest value***	***Existence value***
Directly consumable outputs	Functional use	Future direct and indirect use	Use and non-use value of eco-heritage	Value of awareness of continued existence
Food *Biomass* *Recreation*	*Flood prevention* *Accidents protection*	*Bio-diversity* *Habitat preservation*	*Habitats* *Prevention of irreversible change*	*Genetic funds* *Eco-systems* *Living species*

The first step in determining any components of TEV is identifying and measuring environmental impacts, which often implies a high level of scientific uncertainty. For this reason, the accuracy of economic valuation depends, primarily, on the accuracy of scientific identification and quantification of both environmental changes and people's preferences for environmental goods and services.

Valuation techniques

One of the fundamental practical problems in economic valuation of the environment is to identify people's preferences in conditions where there is no market, or when it is imperfect. With respect to goods and services that are subject to market transactions, the market price is an expression of consumer preferences and willingness to pay a certain sum to get the desired goods. However, in non-market transactions, we have to use other techniques. There are two principal groups of techniques for non-market valuation, specifically:

A) *Revealed preference technique,* which derives preferences from actual market based information. In this case preferences are derived indirectly from market information, when consumers in the market buy goods and services which in some manner are related to environmental goods.
B) *Stated preference techniques* which determine preferences directly from consumers, by using various types of questionnaires. This approach is especially useful in valuation of non-use value.

Revealed preference techniques

This group of techniques derives the value of environmental goods from market transactions to which environmental factors have a significant influence. These transactions, for instance, include transactions involving goods and services related to the environment, either related to market goods for which environmental goods are services are substitutes, or if they are complementary to them. In such cases, the consumer behavior in existing markets is a result of their preferences for environmental goods. This group of techniques includes:

A) Averting behavior;
B) Hedonic pricing (of real estate or labor);
C) Travel cost method;
D) Random utility or discrete choice models;

Averting behavior technique

The averting behavior technique is based on the assumption that market goods can, to some extent, act as substitutes for environmental goods and services. When the quality of the environment deteriorates, people undertake certain activities to prevent the consequences and protect the level of personal or collective welfare. For example, expenditures for sound insulation may be a signal of the value of noise level, expenditures for home water filters indicate the value of clean water, expenditures for exhaust gases filters indicate the economic value of clean air.

This method is applicable when people spend money to reduce the effects of pollution or environmental damages. It requires data both on environmental changes and the substitution effects caused by them. Simple comparison of the level of expenditures may provide rough estimates of the economic value of environmental changes. The advantage of this method is that it does not require a lot of data, can be applied quickly, and may give relatively accurate value that reflects the reality. However, it is not always reliable, especially if it neglects all other important aspects of behavior accompanying the decision. Also, this method does not take into consideration the accompanying, or additional, effects of protecting expenditures, for instance, sound insulation may have also positive effects on heat, or lead to energy saving. Also, averting behavior is not always a continued activity, but is most often a discrete decision, happening at one moment, like for instance purchasing a smoke detector. As this is not a continued expenditure, there is a risk of overestimating the value of environmental goods.

Hedonic pricing

Hedonic pricing includes an analysis of such markets in which environmental factors have a greater or lower effect on price. Sometimes, such an effect may be dominant. This is often illustrated by the real estate market, in which environmental factors may have a strong effect on prices. For instance, the vicinity of an airport and noise caused by it may drastically reduce the real estate prices for the otherwise same quality of real estate. The same applies to air quality. The difference in the price of square meter of housing, provided that all other factors are the same, reveals the value of clean air to residents. This difference is expressed through readiness to pay (WTP) for a specific environmental good.

The described method may be used successfully also when the prices of real estate differ for other reasons, not only environmental. By application of different statistical methods, the hedonic approach may: **a)** identify the share of the difference in price that is attributed to environmental factors, and **b)** the willingness to pay to improve the environment, or the social value of improved environment. The main disadvantages of this method are in the high data requirements and that it requires a well functioning real estate market (no monopoly, high transparency and balance, etc.).

A similar approach may be implemented on labor markets, by looking at differences in the price of rentals for the same type of activity under different conditions. Identification of the differences in the rent levels, due to different health risks, gives an indication of the willingness to accept compensation (WTA) for environmental risk, which could be a measure of the value of activities aimed at improving the environmental conditions.

Travel cost method

Many natural resources are used for recreation purposes. It is often very difficult to determine the value of such resources as they usually have no price tags attached. The travel cost method starts from the assumption that the value of such resources may be considered also through the costs of traveling, entry and stay in nature, in certain recreation zones, picnic sites and national parks. The expenditures resulting from the need to use environmental resources are used as an approximate indicator of the value of the recreation zone.

However, since the models of observing travel costs are linked exclusively to active use of environmental resources, this method may measures only the use-value of resources. This method is at present used mainly for valuing the non-market benefits of recreational zones. It advantage is that it is based on actually observed behavior, although it is very demanding in terms of the data required.

Random Utility or Discrete Choice Models

The previous method is useful in identifying total valuation of demand or willingness to pay for recreational zones, but is not so useful in identifying the partial value of specific segments of nature, or components of environmental resources. For this purpose the Random Utility or Discrete Choice Models are developed. The essence of random utility or discrete choice models lays in explanation of the choice between two or more goods with varying environmental attributes as a function of their characteristics. For example, polluting activity (industrial waste water discharge in the upstream parts of a river) creates damage to some features of a recreational site (the fishing area) but not to others which may remain intact (mountainous areas and forests). The data indicating the number of visitors lost to this recreational zone, or the reduced revenue by the management of the recreational zone, may indicate the value of the river as a component of nature. The essence of this method may be illustrated by a simple example of the choice of transportation. Supposing that an individual may choose between transport from place A to place B by taxi at a cost of 10 $ lasting for 20 minutes and public transport at a cost of 2 $ lasting for one hour. If the individual chooses the taxi, we can conclude that the 40 minutes time difference for him has a value of at least 8 $. In other words, the value of one hour for him is at least 12 $. Another example is the choice between bottled drinking water and water from the water supply system. Bottled water is certainly more expensive, and the difference in price indicates the difference in value related to the use of drinking water supply system.

Stated Preference Techniques

The stated preference techniques enable economic value estimations to be determined for a wide scope of non-traded goods. They are the only way of identifying the non-use value of environmental resources. These methods include:

A) Contingent Valuation Method, and
B) Hypothetic choice modeling.

Contingent Valuation Method

In contingent valuation research, individuals are questioned directly of their willingness or readiness to pay for some benefit of using environmental resources, and on how much they are willing to pay to avoid a certain damage due to environmental degradation. Contingent valuation method starts from the identification of the environmental resource as such, identification of the institutional conditions of consumption, and the way of paying for it. This situation is hypothetical, and therefore it is called "contingent", but the respondents are expected to answer as though they were in a real market. The respondents are therefore asked structured questions, most often in a form of bidding game, or auction, with the aim of getting the information of the willingness to pay for a specific resource. Such questionnaire results are then subject to econometric techniques, by which the average offered price is determined, or the average WTP.

The questionnaires used in this technique most often consist of three parts. The first part, which is a hypothetical description of the situation in which the environmental resource is offered, consists of information on quality, reliability, certainty and time of use of the environmental resource. The second part includes questions on how much the respondent is willing to pay for such resource, provided that he is in a position to procure it under the stated conditions. The results then undergo econometric processing, in order to determine the WTP or WTA. Finally, there are questions regarding the socio-economic and demographic characteristics of respondents aimed at clearly identifying the position of the respondent within the observed population, in order to evaluate also the accompanying aspects of his answers.

Since the accuracy of results greatly depends on the right formulation of questions, it is of special importance to word the questions correctly. For this purpose there are several handbooks, such as the guidelines of the US National Oceanic and Atmospheric Administration Panel (Arrow et al, 1993). An updated and improved version of this handbook was also prepared for the UK Department of Environment, Transport and the Regions in 2000. A very instructive example is given in the book *Environmental Economics Policy in Transition* (Kaderjak and Powel 1997).

Hypothetic choice modeling

Hypothetic choice modeling implies a specter of several different observation techniques which, instead of asking the respondents to accurately express the WTP or the WTA, asks them to rank the offered options. Including prices as one of the attributes of each alternative enables monetary valuation. In all other aspects these techniques resemble contingent valuation and are used mainly in analyzing health implications of environmental changes.

Dose-response and Exposure-response functions

The dose-response function (DRF) measures the relationship between a unit concentration of a pollutant and its impact on the relevant receptor. Exposure–response functions are based on the same principle, but measure the response with respect to exposure. Exposure is a measure of the levels of a pollutant in the environment surrounding the receptor in question. For example, an individual may be exposed to a certain concentration of pollution in the air, but the applied concentration depends on the inhaled quantity which is greater when the individual is moving, or making effort, than when he is at peace. Generally, effects of pollution are more closely related to doses but exposures are easier to measure. It is therefore important to remember that almost every dose-response function may be approximately demonstrated by an exposure-response function.

The dose-response function is widely used in all cases when the physical relation between the cause of damage (the pollution level) and the environmental effects or responses is known, and when such relation is measurable (ex. the relation between ash emission from power plants in tons per week and the number of reported respiratory diseases in a certain region). When this relation is established, the WTP is applied, which may be derived from actual market prices, provided that it is possible to identify them, or otherwise from conditionally expressed prices. Namely, the physical damage determined based on the function FDO/ERF is multiplied by WTP, i.e. the value of unit damage, in order to determine the monetary function of damage.

This approach can be used always when the relation between pollution and its effects is known. The choice of a specific form of function is crucial for the accuracy of the resulting monetary value of damage and is the main reason for theoretical disagreements.

Difficulties and uncertainties related to the use of this approach may also arise with respect to: identification of type of pollution responsible for the damage; isolated effects of different factors in order to determine the effects on specific receptor, especially in case of joint effects of several polluters; identification of delayed effects and accumulated effects of small and moderate levels of pollution. This, together with other problems, makes the choice of specific function very delicate. Note should be made of possible complicated situations when physical response to pollution is not economically relevant, because the individuals exposed to it do not consider it relevant, and damages caused by pollution are not considered significant. For all these reasons, this approach is very demanding in terms of data requirements, it is complex and expensive to use. However, when the DRF and ERF functions are identified, their form may be used in other cases, or ″borrowed″ which may reduce the cost of analysis and give relatively acceptable results.

Benefit Transfer

Benefits transfer is a frequently applied method aimed for economic valuation of environmental changes. The essence of benefits transfer is that use is made of previous valuation studies of similar environmental performances in other countries or regions, and then, with necessary adjustments, is applied in a present study. It relies on methodology and data from previous studies, and it transfers it to the current case, producing estimates for a specific environmental damage.

Relying on the results from previous studies may create a set of problems. The first issue is to which degree can the results of previous studies be generalized. It is believed that the lower the impact of local characteristics, the greater the potential for generalization. For instance, for analysis of global impacts, such as climate changes due to the emission of greenhouse gases, the use of this methodology is fully justified. However, when local impacts are strong and when there are local specific features, previous results should be adjusted and applied with care.

If conditions differ significantly, several parameters need to be adjusted, specifically, income, population size and characteristics, background conditions (before environmental change), level of impacts and other determinants to which the current data refer.

In terms of economic parameters, it is important to indicate the impact of price differences between the country of the original study and the one to which the results are transferred. These price differences have an impact during benefit transfer of WTP from one study to another. The technical literature (Ready et al 1999), in terms of adjustment of WTP, considers that it is correct to use exchange rates calculated based on purchase power parities (PPP). PPP rates can be used in analyzing such environmental resources which are present in the territory of the whole country in equal quantity and quality. However, in analyses with unequal regional distribution, for instance in towns, where certain environmental goods are more expensive, the WTP needs to be further adjusted. For example, if the cost of purchasing a specific environmental good is 10% higher in towns than the country average, the adequate WTP adjustment is not only by changing the PPP, but also by multiplying it with adjustment ratio 1.1.

A detailed description of WTP adjustments is as follows:

WTP_A original in the local currency → WTP_A original in $ or € → by application of exchange rates $WTP_A \cdot PPP_A/PPP_B$ → WTP_B derived •adjustment ratio → WTP_B

In order to have the full adjustment of WTP for the needs of this method, it is necessary to first do interpolar adjustments. For example, if the original study was done in 1994, the WTP needs to be adjusted by retail price index to remove the possible impacts of inflation.

$$WTP_{A\,1994} \cdot RPI \rightarrow WTP_{A\,2004}$$

A separate problem results from situations in which different populations, due to differences in culture, education and the system of values in general, have different attitudes and opinions on environmental issues. In such cases, there are very significant, almost unbridgeable differences in the WTP between different populations in different countries.

Boyle and Bergstrom (1992) proposed the following three criteria for a successful benefits transfer application:

1. Similarity of the environmental good or service to be valued;
2. Similar demographic, geographic, economic and social characteristics,
3. Evidence of sound economic and statistical methodology applied in the preliminary study. The quality of methodology and data used in the original study certainly is of importance to the results of the derived study.

Similar adjustment conditions are presented by King and Mazzotta, 2004, and the EFTC/RIVM study (2000) emphasizes the average income, population size and density, background situation and the levels of impacts.

It is a general belief that this method is far from ideal, but the advantages that it offers in terms of cost-efficient research and low demand on data are beyond dispute. It is up to researchers to apply it adequately and creatively.

Life Risk Valuations

Monetary valuation of environmental impact on human life and health is probably the most complex and the most controversial issue in environmental valuation theory. In this kind of analysis, an individual estimation of personal value of life and health is basic. Valuation of the individual's life made by the other members of society should be added in the next stage, and finally the aggregate social costs incurred by the environmentally caused health problems should be taken into consideration. According to that, life risk valuation includes three kinds of estimates:

A) **VOR**ii refers to the individual's valuation of his own life and health. Adding up individual values for individuals at risk leads to aggregate value of the so-called ″statistical value of life ″ (SVL).

B) **VOR_{ij}** refers to the valuation of another individual, individual *j* assigns to the value of life and health of individual *i* who is the subject of the study. Adding up individual values leads to an aggregate value of lives as perceived by others.

C) **SCI_i** are the costs of illness, or death, of the individual to society as a whole. For example, these are the social costs of medical treatment, or costs of caring for supported family members. The technical literature does not offer many examples of applying the first two types of valuation. It is therefore easier to stick tot eh third type of valuation for which there are adequate data which can be separately expressed.

Statistical value of life

Statistical value of life (SVL) is calculated by adding all individuals' WTP for environmental improvements. To illustrate this in an example, it is assumed the annual death risk caused by a certain environmental change is 0.005 and that the exposed population is 10,000. This means that in the analyzed group there will be 50 death cases in the year to come. If protective measures and policies were implemented, the risk rate would be 0.003, and 20 lives would be saved. If all of the targeted group members are questioned to reveal personal WTP for risk minimization, and the average WTP is 5000 US$. It means that 10,000 men together are willing to pay 50 million US$ (10,000 persons 5000 $ each) for the environmental improvement. In this case, since 20 lives were saved, the average statistical value of life is 2.5 million US$.

The mentioned technique, of course, does not give a real value of life. It is just a way to obtain economic information how much the targeted population cares for the improvements. Because of possible misleadings this method is not very popular.

In order to resolve the problem in practice, certain improvements can be made with "value of a life year" (VOLY) calculations. For example, instead of mortality estimation due to environmental disorder, a valuation is made of the WTP for an additional year of life saved by the environmental improvements. For example, if an implementation of the specific environmental improvement measure has effect in 0.4 years longer life, and the average WTP for cost coverage is 10.000 US$, it can be concluded that an additional year of life has value of 25.000 US$ for the targeted group of people.

A similar technique may be applied in WTA analysis. This, to a certain degree avoids the risk of confusion in interpreting the term value of life. However, the results obtained using WTP and WTA may differ in a range 2-5 times (Gregory 1986). The reason for such drastic deviation can be found in a fact that there are no substitutes for the majority of environmental goods, and men are much more willing to claim for a compensation for the lost benefit, than to pay for environmental resource protection (Hanemann 1991).

In applying the mentioned techniques there is yet another drawback. Namely, the stated WTP for an environmental resource, or the WTA will largely depend on wealth of people analysed. So, the rich will always attach higher values to the environmental goods and services than the poor, irrespective of the real risks, which opens up sensitive issues concerning the ethical adequacy of this technique.

Total (full) social costs

In contrast with previous techniques, based on stated preferences, the total social costs technique starts from the real costs of the human capital losses, costs of its recovery and treatment, incurred by environmental changes. Total social costs are the sum of mortality costs T_m . invalidity costs T_i and morbidity costs T_B .

$$TSC = T_m + T_i + T_B$$

In case of life loss, they are seen as direct (dDC) and opportunity (oDC) costs, or the sum thereof.

$$DC = dDC + oDC$$

Direct social costs at annual level consist of costs of alimony for dependant members of the harmed family (the total annual amount of family pensions *PENZ* multiplies with the mortality rate, due to environmental changes of *mort* which is the difference between annual mortality in environmentally sound and environmentally degraded parts of the country).

Apart from the above, there is need to determine the opportune costs, which are the difference between he annual value of per capita production *GDPpc* from which we deduct the value of average personal consumption per capita, *LPOTpc,* times the number of people lost due to environmental problems. The number of lives lost due to environmental changes is determined by applying to the total number of deaths during the year *BRU,* the total mortality rate *mort.*

$$OT_m = (GDPpc - LPOTpc) \bullet mort \bullet BRU$$

In case of invalidity, or lasting loss of working ability, due to environmental degradation, it is necessary to consider the sum of direct costs DC_i and opportune costs OC_i .

$$T_i = DC_i + OC_i$$

Direct costs are the product of annual amount of invalidity benefits paid *INV* and the rate of invalidity due to environmental degradation *env*. The rate *env* is the difference between the invalidity loss in environmentally sound and environmental degraded parts of the country.

$$DC = ENV \bullet env$$

Opportune costs of invalidity due to environmental degradation OC_i are the costs of lost production. They are the product of multiplication of annual amounts of per capita GDP and the number of invalidity cases due toe environmental degradation (the *env* rate applied to the total number of invalidities in a country *BRI).*

$$OC_i = GDPpc \bullet env \bullet BRI$$

In case of health loss T_B it is necessary to consider the medical costs (including costs of diagnosis and treatment) DT_B irrespective whether they are born by the individual or society, plus opportune costs of forgone economic activity due to illness OC_B .

$$T_B = DC_B + OC_B$$

Direct costs of medical treatment include average annual costs of treatment of certain diseases related to environmental degradation, multiplied by the number of patients treated during the year, which are attributable to consequences in changes of the quality of the environment. The opportune costs, however, are the product of multiplying the number of sick leave days, due to environmental degradation, and the average daily amount of production per capita (GDPpc divided by the number of days in a year).

Although exact at first sight, this method has a strong disadvantage related to the fact that it is impossible accurately to determine the value of loss of human capital due to environmental changes. It is practically impossible to determine with certainty the mortality, invalidity and morbidity caused exclusively by environmental factors. Any assessment and approximation opens up the room for great manipulation.