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ECO-PRICING OF MOBILITY

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ABSTRACT
This paper discusses mobility pricing concepts from viewpoint of ecological targets and sustainable development. The current Finnish mobility pricing system is used as a starting point, and then proceeding along the lines of discussion towards its strengths and weaknesses with regard to environmental policy agenda. Since the Finnish practice has a long tradition of internalizing the external costs of ecological and environmental costs, it serves as a good spring board towards eco-pricing. If eco-pricing would be adopted, there would be necessary economic trade-offs. Hence, the question turns into political and social one: how much are we willing to pay for ecological mobility? The technological issues are considered in the end, as eco-pricing will require the employment of different technologies. However, the technological challenges are probably easier to tackle than the political, social and institutional ones. Finally, some aspects of advanced vs. developing economies are discussed.

Keywords: Externalities; Mobility; Pricing; Transport

1. INTRODUCTION
Mobility, transporting goods and people, is seen not only as means of enhancing economic welfare, but also nowadays as one key drivers of climate change and deterioration of our ecological system. The intensive mobility increase taking place especially in countries with aggressive economic growth, such as many countries in Asia, will further enhance undesired effects. Yet, mobility is and will continue to be for the long term the enabler of economic growth sought by most countries in the world.

Innumerable studies have been carried out and papers written about external costs of transport. Some of the still very relevant basic work can be found in Boyer (1998), Verhoef (1998), Waters (1961) and a more practice-oriented work of UNITE project (2003), to name a few. What is typical for these studies and analyses is that they treat externalities as a single problem – which it is not. The most recent externality is, of course, the exhaust emissions from different means of transport. Especially carbon dioxide emissions have been in focus due to recent discoveries about global warming, not taking into account how reliable the discoveries actually are. Nonetheless, they have had a tremendous impact on our view of transport and mobility, also on technological development of vehicular and engine technologies.

One may ask the motivation behind pricing – why is pricing needed? First, it is a question of covering the costs. The costs comprise direct costs related to infrastructure which has to be operated and maintained. Furthermore, infrastructure needs upgrading and capacity enhancing investments. These costs have to be covered.

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The externalities, or the indirect costs, are those imposed to third parties. For example, material damages of accidents are covered by users of mobility systems through insurance payments, but all medical care costs and losses of production are not included. The latter are examples of the externalities that have to be covered by somebody. The just way is to have them covered by those who cause them.

Secondly, mobility is a market commodity and hence a way to make money. Some entrepreneurs take advantage of the opportunity and profit from peoples' and goods' needs to be shifted from one place to another. These entrepreneurs are public transport operators (some publicly, some privately owned), logistics service providers and all kinds of transport and terminal operators one can imagine. Pricing of mobility is a market activity when it comes to situations where users voluntarily pay for mobility services. There is a price and a pricing regime in place, but it is not covering any other costs other than those of the service providers.

Third, there is a pure fiscal purpose for the state and local governments to raise revenues from mobility. This is a purpose officially not stated very often, but it is there, no doubt. For example, in Finland in 2009 the tax revenues collected by the state from road traffic exceeded six billion euros. The total tax revenue volume for state of Finland was a little less than 34 billion euros. It is evident, that tax revenues from mobility are a significant share of state's income.

Finally, pricing is a means to control mobility patterns and behavior. The objective is to have as rational behavior of individuals and organizations as possible. The best trip could be the one that is avoided.

2. SCOPE, CONTRIBUTION AND DEFINITIONS

2.1. Scope and contribution

This paper looks into the following research problem: why do we need pricing of mobility and what should we understand by eco-pricing? The Finnish pricing regime is analyzed in brief, showing its architecture and hopefully bringing forth both its strengths and weaknesses. The paper will show that selection of pricing regime and structure is first and foremost a political choice, no matter how rationally we approach the question. In fact, the more rationally we approach it, the more apparent will the political side appear. Ultimately, it is a question what do we want out of our mobility system: efficiency, safety or eco-friendliness? All aspects are usually present in e.g. investment appraisal but there are problems on the way when trying to find a balanced approach.

This paper will identify different policy-oriented strategies in selecting the pricing regime, mainly using the Finnish example as an empirical case. It will be discussed that different components of benefits and costs are conflicting with each other, such as efficiency objectives with environmental and safety targets. Prioritization is needed if a true change is pursued. Finally, the different pricing strategies in different contexts will be discussed very briefly, e.g. strategies for highly developed countries and strategies that are called for in countries that need faster economic boosting, or the different target settings that are relevant for a particular country or region.

The expected or at least hoped contribution is to make it clear that no single approach or strategy satisfies all objectives of the transport system. There are trade-offs, and in some cases some sectors or citizen groups end up paying more than the others – and vice versa some benefit more from different pricing regimes than others.

2.2. Definitions

A couple of definitions are in order. Marginal costs are effectively the same as variable costs.

Typically, variable costs depend on volumes of production, output or resource consumption during one accounting period. Fixed costs are constant during the accounting period. An accounting period can vary, but typically is regarded as approximately one year, and most often a calendar year. Of course an accounting period can be, for example, 18 months for some organizations. In fact, there is not a single correct definition for variable (marginal) and fixed costs, but it depends on the situation and purpose. For practical purposes, we can satisfy ourselves, with simplification, that variable costs are costs that do change according output or input volumes within about one year.

Even fixed costs are variable in the longer term. For instance technological changes can cause a shift between fixed and variable costs. In marginal benefit-cost analysis, wealth is maximized as long as the variable costs are covered by the benefits. In simple words, since fixed costs are fixed, regardless of the volume (e.g. traffic volume) it is enough that we get back our increased variable (i.e. marginal) costs. As long as we do that, we are maximizing our economic well-being, but only after we have covered the full (i.e. fixed and variable) costs. This principle is useful in investment analysis, as an investment represents the marginal change introduced to the system. Adding a piece of infrastructure, such as a stretch of new road, it satisfies the criteria that the benefits exceed that marginal investment cost.

Cost recovery can be assessed at network level, when all aggregate costs and revenues are identified and quantified. This viewpoint is always looking at total costs and revenues, distinct from marginal analysis. External cost is a cost not directly covered by anyone, but still affecting the society or certain groups of people. An accident is always partly covered by insurers, but some elements, like loss in the production volume because of the inability to work and pure human grief are not paid by anyone. Still they do incur costs.

Basic text books on the abovementioned concepts can be found in Jehle and Reny (2001), Pearce and Nash (1989), and Layard and Glaister (1994).

3. THE FINNISH PRICING REGIME

3.1. Guiding principles

The Finnish pricing regime for mobility has been partly balanced between transport modes. Both passenger trains and buses are covered in approximately the same way as their social marginal costs, for instance. The same applies to freight trains and trucks. For other modes of transport the balancing does not exist. (Leviäkangas and Talvitie, 2004; Metsäranta, 1999)

According to European Union policy initiatives, the pricing should be based on social marginal costs, i.e. the variable direct costs and the externalities. Hence the users should pay all these and the pricing regime should be non-discriminatory, fair and efficient (European Commission, 2001 and 1998). However, it is sad to see how these policy papers have been consumed by the passage of time and by and large overlooked today.

Hence, we can conclude that even if the theoretical pricing regime based on social marginal costs is well accepted, it is weakly, to put it mildly, implemented across the EU and few words have been said about them during very recent years. What has become apparent is the commercialization of infrastructure networks and pragmatic orientation to view infrastructures as assets to make money. (Leviäkangas, 2008)

3.2. Example traffic on public roads

3.2.1. Revenues and costs

The fiscal state revenues of road transport sector come from the below listed sources (The Finnish Information Centre for Automobile Sector, 2011):

- Fuel taxes, which varies according to type of fuel. In 2009, diesel and gas engine vehicles paid 2 198 million € to the state, plus the value-added tax (VAT) on fuel sales 1 009 million €.
- Registration tax, which was 687 million € for the state in 2009. Registration tax is paid when purchasing the vehicle.
- Annual vehicle tax varies according to the exhaust emissions of the vehicle. The less consumption and less emissions, the lesser the tax. In 2009, the state received 654 million €.
- Then one can further add taxes on services supplied to vehicle owners (corporate income and VAT of repair services, car parts, etc) and taxes on insurance services. All these yielded to 1 531 million € in 2009.

All in all, the state received in 2009 about 6.1 billion € tax revenues from the road sector. The cost side can be divided into several parts: infrastructure, administration, user costs, and external costs. These can be further defined as in Table 1. For road user costs and externalities there is an assumption based on the fact that 67% of the total vehicle kilometers of travel occur on public roads. (Finnish Transport Agency, 2010).

No wonder that the attention has been on 'efficiency' enhancing, i.e. time saving targeted measures. Time costs present 6.5 billion € costs to the society. The largest road user cost item is fuel costs, but much of this is just wealth transfer from drivers to the state (collecting fuel taxes) and suppliers of diesel and gasoline. Efficiency targeted measures are those that save time and road user costs. To put it simply, these measures are capacity and efficiency enhancements on the road network, meaning more lanes, faster links, etc. This domination of efficiency-thinking is visible when looking at an example of four case studies and how the benefits are divided between the aforementioned components in Figure 1 (Tervonen et al., 2010). There are some changes on how projects are appraised whether using the old unit costs (2005) or the newer ones from 2009. The relative importance of driving costs has increased from 7% to 11% whereas the emission and noise costs continue to account only for 2% in investment appraisal.

3.2.2. Cost recovery on network level

The last notable cost recovery calculation on a network level was done in 1998 (Leviäkangas and Talvitie, 2004). This calculation was done for both full cost recovery and marginal cost recovery. The definitions for cost recovery ratios were as follows:

$$\textit{full cost recovery ratio} = [\textit{fixed and variable revenues}] / [\textit{fixed and variable costs}] \times 100\%$$
$$\textit{marginal cost recovery ratio} = [\textit{variable revenues}] / [\textit{variable costs}] \times 100\%$$

The ratios were calculated for different vehicle types, different road classes and different regions of Finland. Examples of the results are shown in Figure 2. In some respects, the analysis differed from the previous listing of costs in Table 1. In the 1998 analysis only fiscal costs (infrastructure and administration) and external costs, excluding noise, were considered. The revenues in the 1998 analysis did include VAT, although it is debatable whether it should have. On one hand VAT is a general tax and not exclusively something for mobility, but on the other it is real cash flow for the taxman. In a way, the 1998 cost recovery calculation was a comparison of fiscal costs and revenues adding externalities to the cost side. Driving costs were not considered, because they are wealth transfers.

Table 1 Approximate costs of road sector (only public state roads, no streets)

Cost component	Subcomponents	Definition	Total values in 2009; mill. €
Infrastructure (The State of Finland, 2009)	Maintenance	Day-to-day winter & summer maintenance operations, and minor repair and rehabilitation projects that are not included in investments	531
	Investments	All investment, including new road links and upgrading	161
	PPP-projects	Service, availability and shadow toll payments to concessionaires in public-private partnership (PPP) projects	58
Administration (The State of Finland, 2009)	Ministry and central administration	Ministry and central administration departments dealing with road sector	133
	Central administration departments dealing with vehicle registration	Central administration departments dealing with vehicle registration	12
	State aid and compensations	State aid to private roads; buying of land, compensations	53
Road user costs (driving costs) (Tervonen et al., 2010; Kallberg, 2010; Mäkinen and Auvinen, 2011)	Fuel consumption	Fuel (gasoline, diesel) consumption paid by users	10,156
	Other driving costs	Tires, maintenance, repairs	
	Capital costs	Interest and depreciation of capital spent on vehicles	
	Time	Work and leisure time spent on travel; different unit costs (€/hour) for different types of vehicles and different types of trips	6,543
Externalities (Tervonen et al., 2010; Kallberg, 2010; Mäkinen and Auvinen, 2011)	Accidents	Socio-economic costs of accidents, including material, healthcare, and human losses	2,833
	Emissions[a]	Carbon, sulfur and nitrogen oxides (CO_2 , CO, SO_2 , NO_x) and particles ($PM_{2.5}$) emissions in tons; different unit cost (€/tn) depending on area (urban, non-urban)	505
	Noise[b]	Number of inhabitants exposed to different levels of road traffic noise; different unit cost (€/person/year) for different noise levels	35
		Total costs	21,020

[a] Authors' own calculations based on Kallberg, 2010, and Mäkinen and Auvinen, 2011.

[b] Authors' own calculations based on Kallberg, 2010, and Mäkinen and Auvinen, 2011.

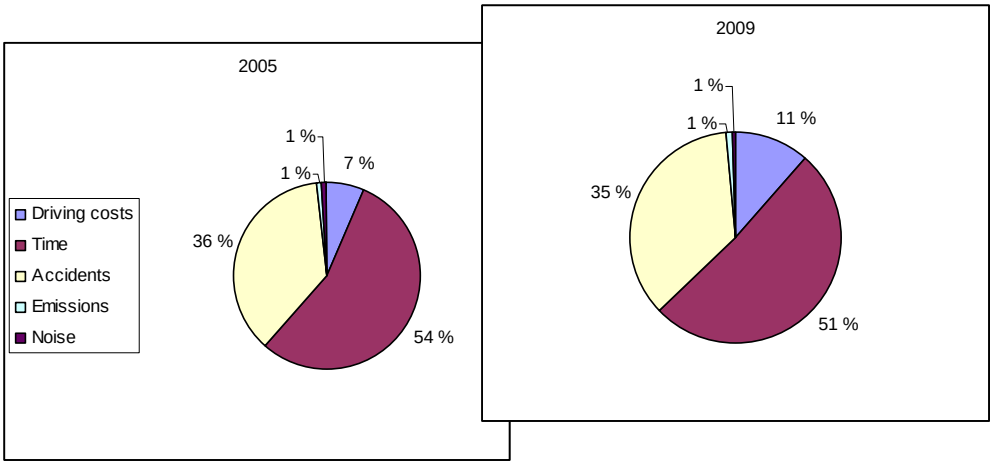

Figure 1 The change in the weights of cost components in four case projects; 2005 unit values vs. 2009 unit values (Tervonen et al., 2010)

When using approximately the same cost and revenue items for 2009 data as were in 1998 cost recovery calculation, it is possible to make a rough comparison for the full cost recovery ratio. For marginal cost recovery this would require a much deeper and more thorough analysis. The full cost recovery ratio in 2009 was about 105% as shown in Table 2.

It seems that full cost recovery ratio has fallen from 151% (Figure 2, right panel, the uppermost bar) in 1998 to 105% in 2009. It is probable that also marginal cost recovery ratio has the same pattern, though perhaps not as clearly. There is no official explanation for this except the 'users pay' principle that has been set by the European Commission in number of policy papers. In Finland this has clearly taken place. At the same time, the state's fiscal revenues have fallen relatively by one third compared to the costs of the road sector.

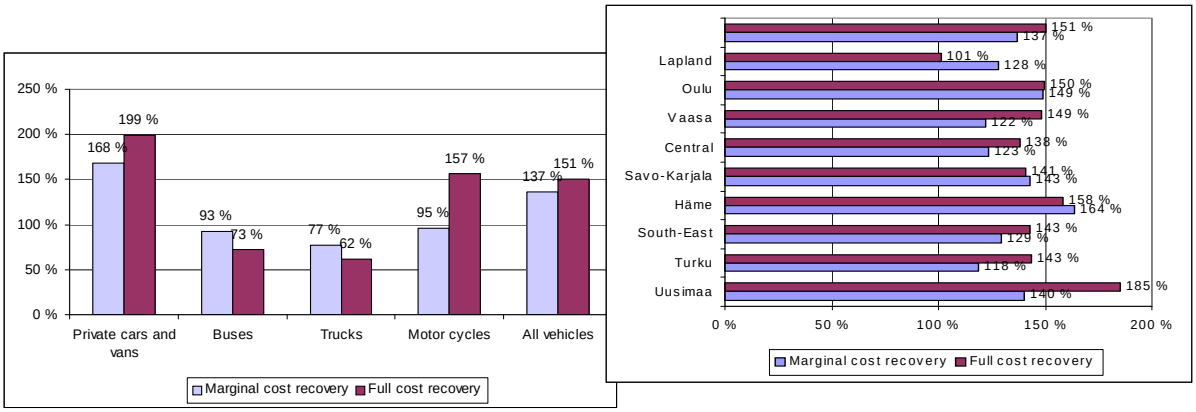

Figure 2 Cost recovery ratios for Finnish road traffic on public roads in 1998; per vehicle type (left panel) and per region (right panel) (Leviäkangas and Talvitie, 2004)

Table 2 Cost recovery estimate for 2009 when using 1998 approach and analogies

Costs [mill. €]		*Revenues [mill. €]*	
Maintenance	531	Fuel taxes	2,198
Investments	161	VAT of fuel sales	1,009
PPP-projects	58	Registration tax	687
Ministry and central administration	133	Annual vehicle tax	654
Central administration departments dealing with vehicle registration	12		
State aid and compensations	53		
Accidents	2,833		
Emissions	505		
Noise	35		
Total in 2009	*4,321*		*4,548*
Full cost recovery ratio = 4 548 / 4 321 × 100% = 105%			

3.2.3. Marginal analysis (investment appraisal)

From cost recovery point of view, road traffic on public state roads covers all its costs almost up to the point of the users' benefit. This means that the overall pricing of transport does the job of 'users pay' principle. But where does the marginal analysis, i.e. appraisal of projects, lead the system?

In marginal analysis, the benefits and costs have already been listed:

Costs: investment cost (*C)*

Benefits: change in driving costs (*ΔD*), change in maintenance costs (*ΔM*), change in accident costs (*ΔA*), change in emission costs (*ΔE*), and change in noise costs (*ΔN*).

The benefit-cost ratio (*B*) is then simply stated as:

$$B = \left[\sum_{t=0}^{30} \frac{\Delta D_t + \Delta M_t + \Delta A_t + \Delta E_t + \Delta N_t}{(1+r)^t} \right] / C \quad (1)$$

where *r* is the required return on investment, i.e. the discounting rate, and *t* is the number of the year.

Those projects that create positive changes in abovementioned cost items are the profitable ones that ought to be realized. This is proved through traditional benefit-cost analysis by discounting the future benefits to the present, using normally 30 years investment horizon for major road infrastructure projects. As it was shown in Figure 2, time costs and accident costs dominate the cost savings, representing 80%...90% of the total benefits to be expected. This will inevitably favor projects which address the two particular benefits. Other benefits are of minor importance. What kind of infrastructure development does this lead to? Capacity enhancements, motorway links, and similar projects are most likely to be favored as they usually deliver both efficiency and safety.

The other determining factor is the discount rate. The higher the rate is set, the more crucial become shorter-term benefits as after 20 years the discounting factor will soon be very small. In Finland, the agreed social rate is 5% for transport investments. Even this is debatable, e.g. when appraising investments in technological systems, such as intelligent transport systems (ITS) (Leviäkangas & Lähesmaa, 2002) or rail projects which have a considerably longer investment horizon than road projects (Leviäkangas et al., 2009).

4. ECO-PRICING STRATEGIES – WHAT KIND OF MOBILITY DO WE WANT?

The Finnish example showed that even if the pricing system as whole seems fair and even ecological, one of the key problems lies in investment appraisal. The pricing system is set to take into account the emission levels of vehicles (vehicle tax) and the amount of mobility exercised (fuel tax). The less emission, the lower the vehicle tax and the less you drive with an economic low-consumption vehicle, the less you pay for fuel and hence as fuel taxes. But, as transport system is developed, the ‘efficiency’ gains still rule and ‘environmental’ gains are subordinated. And this development might even be contrary to the development towards eco-friendly transport system. In other words, even if the aggregate mobility pricing system is self-sufficient and taxed according to environmental principles, it might not lead to an ecological end result if the investment appraisal methods favor ‘efficiency’ oriented projects. The 1% weight in emission costs when making investment appraisal will hardly stop climate change.

In order for the system to be developed towards an ecological one, we first need to set the prices right. There is a philosophical question here: what is price? Some define price as an agreed compensation for transaction. Some consider that price is an expectation of the future value. This is the logic that for example the stock market follows. The market price of a share equals the discounted present value of the cash flow it is expected to generate. In an environmentally focused eco-pricing system we should follow the very same principle. In the Finnish example the costs of emissions and noise were derived from empirical data, but not taking into account in any way the changing situation, meaning the changing climate.

Even if climate change could be challenged in many respects, there is a possibility - a risk - that the change is real. This should be reflected in price, as do the risks of future prospects in the prices of shares quoted in stock market. Hence, the unit cost values (prices) of emitted tons and persons exposed to noise should be lifted to a level that corresponds to the policy targets when making public investments. If policies state an environmental and ecological agenda, this should be visible in unit cost values as well. So far, the political jargon and investment appraisal methods have not corresponded - not at least in Finland and probably not too well elsewhere either.

What performs well in the eco-test is the aggregate Finnish pricing system. It clearly follows the policies of 'users pay' and encourages the shift towards low-consuming and less-emitting vehicle fleet. So perhaps the problem is not with policies and policy makers, but with those who have to implement those policies? In this particular case of Finland the Finnish Transport Agency faces a need to adjust its appraisal methods to be more coherently in line with the environmental strategies and agendas.

There is one more critical dilemma, that is, if the investment appraisal methods and aggregate pricing regime do not cohere. The majority of investments might for instance enhance capacity while the pricing regime might encourage less mobility. This might lead to a very sub-optimal situation, where the investments (which are always intensively capital consuming) encourage more mobility and the pricing regime takes the road users' money from that: first a lot of money is spent on capacity enhancing infrastructure and then the users are made to pay for that and for the increased mobility. As a society, we have spent the money twice! From a purely fiscal point of view, this is of course profitable to the taxman, be it the state or regional government.

Needless to say, eco-pricing has a trade-off. If environmental and ecological goals are to be achieved, there is possibility that efficiency goals should be partly be given up. To conclude, eco-pricing system of mobility includes at least the following approaches and measures:

1) the price of environment and ecology should be set high enough to reflect the future expectation – one should not stay solely with empirical price setting analysis but take into account the political and societal long-term agenda.
2) the pricing regime and investment appraisal methods should match – if the other encourages more mobility and the other less mobility there is a risk of spending money twice and ending up with only satisfactory result.
3) whatever pricing system is pursued, there needs to be a very good information management and governance in place – the Finnish system, for example, relies very much on efficient and transparent vehicle registration system and data bases enabling that.
4) technology enablers should be utilized to maximum – automatic identification, positioning, data base and information management technologies will make more sophisticated and manageable systems possible; however, the technology must be made to serve, not to master.

In any way, there is not too much difference between the developed and developing economies how eco-pricing should be deployed. Probably the biggest challenge of developing economies is the institutional development of enablers, such as a reliable and transparent vehicle registration system. Technologies and systems in themselves can be purchased from the market. Knowing where the vehicles are (registering), of what type they are (emission levels) and how much they on average travel (emission volumes), is a very good start.

Another key point when considering developing economies' challenges in mobility pricing is the contradiction between economy and ecology. [There is a deeper question not touched in this

paper concerning what we actually mean by wealth or well-being, raised by many modern economists.] Economic growth, pursued and desired by developing economies, means more mobility is order to enable economic activities to expand. Setting too rigid pricing regimes in place which could create a bottleneck for growth is a real threat to be recognized. This we must acknowledge: some countries can probably afford to be more eco-friendly than the others.

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6. REFERENCES

Boyer, K.D., 1998. *Principles of Transportation Economics*, Addison Wesley Longman, Inc.

European Commission, 1998. Fair Payment for Infrastructure Use: A Phased Approach to a Common Transport Infrastructure Charging Framework in the EU, *White Paper COM* (98) 466, July 1998.

European Commission, 2001. *European Transport Policy for 2010*: Time to Decide, COM(2001) 370 final, White Paper by the Commission on 12 September 2001.

Finnish Transport Agency, 2010. Finnish Road Statistics 2009, Helsinki.

Jehle, G., Reny, P., 2001. *Advanced Microeconomic Theory*, 2nd edition, The Addison-Wesley Series in Economics.

Kallberg, H., 2010. Tieliikenteen Kustannusarvio 2009 [Costs of Road Transport 2009], Working Paper, the Finnish Information Centre for Automobile Sector, 20.4.2010.

Layard, R., Glaister, S., 1994. Cost-Benefit Analysis. 2nd edition. Cambridge University Press.

Leviäkangas, P., 2008. *Commercial(ising) Transport Administrations*. In: Helsinki University of Technology Summer School, June 2-6 2008.

Leviäkangas, P., Kallberg, V-P., Seise, A., Rönty, J., Eckhardt, J., Permala, A., Lahti, P., Järvi, T., Mäkelä, K., Rosenberg, M., 2009. Seinäjoki-Oulu. Yhteiskuntataloudellinen vaikutusarvio [Seinäjoki-Oulu double-track socio-economic appraisal]". VTT Research Reports VTT-R-03550-09, 2009.

Leviäkangas, P., Lähesmaa, J., 2002. Profitability Evaluation of Intelligent Transport System Investments. *ASCE Journal of Transportation Engineering*, May/June 2002, Volume 128, Number 3.

Leviäkangas, P., Talvitie, A., 2004. Cost Recovery on Finnish Public Roads. *In: Proceedings of 10th World Congress on Transportation Research*, July 4-8, Istanbul 2004.

Mäkinen, K., Auvinen, H., 2011. *Road Emissions in Finland 2009*. In: LIPASTO Traffic Emissions Web Service Pages: http://lipasto.vtt.fi/liisae/total.htm. VTT. Read in February 22, 2011.

Metsäranta, H., 1999. Cost Recovery of Transport in Finland – A Review of the Calculations and Methodology. *Publications of the Ministry of Transport and Communications* 15/99. Helsinki.

Pearce, D.W., Nash, C.A., 1989. *The Social Appraisal of Projects*. In: Pearce, D. W. (Ed.) Cost-Benefit Analysis. London: Macmillan, 1989.

Tervonen, J., Ristikartano, J., Sorvoja, S., 2010. Specification of Road User Costs. Background report 2010. *In: Research reports of the Finnish Transport Agency 33/2010*. Helsinki, 2010.

The Finnish Environment Institute, 2011. In: http://www.ymparisto.fi/default.asp?node 1316&lan=fi#a0. Read in February 22, 2011. in any way

The Finnish Information Centre for Automobile Sector, 2011. Internet Services: http://www.autoalantiedotuskeskus.fi/. Read in February 22, 2011.

The State of Finland, 2009. The State's Budget Proposal for 2009.
UNITE project, 2003. *Unification of Accounts and Marginal Costs for Transport Efficiency*, Final Report for Publication, version 1.0.
Verhoef, E.T., 1998. *The Implementation of Marginal External Cost Pricing in Road Transport*, Tinbergen Institute Discussion Papers no 98-091/3, Free University Amsterdam.
Waters, A., 1961. The Theory and Measurement of Private and Social Cost of Highway Congestion. *Econometrica*, Vol. 29, No. 4, pp. 676-699.