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# SERIE RESEARCH MEMORANDA

## The scope of meta-analysis for transport policy impact analysis in environmental economics

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# The Scope of Meta-Analysis

## for

## Transport Policy Impact Analysis .

## in

## Environmental Economics[1]

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**Abstract:** Meta-analysis offers an analytical framework for research synthesis based on a comparative study of research findings undertaken by different researchers. In this paper, we investigate the possibilities of applying meta-analysis to transport policy impact studies in environmental-economics. The heterogeneity of studies in this field however makes it difficult to apply meta-analysis directly. We therefore propose a general equilibrium framework as a benchmark for comparison, and as a synthesis of the research findings we obtain from studies underlying a met a-analysis.

A meta-analysis of studies results in decision rules that obtain the environmental impact of a transport policy as a function of the characteristics of these studies, i.e. variations in environmental impact of the transport policy can be attributed to variations in specific characteristics of these studies. The transport policy impact studies underlying a meta-analysis in environmental economics can be seen to derive their characteristics from a common general equilibrium framework. This framework leads to a classification of all possible characteristics of transport impact studies, that can be used as a basis for several types of meta-analytic methods to distinguish the most relevant ones among them. Policy makers can then improve the effectivity of their policies by concentrating on these relevant characteristics.

# 1  Meta-Analysis in Environmental Economics

In the past decades many advances have been made in the social sciences by applying principles from met a-analysis. Meta-analysis is a research methodology that serves to bring together in a succinct and systematic way findings from previous research on a given issue or topic, undertaken by different researchers. Thus, the main aim of meta-analysis is to offer an analytical framework for research synthesis, usually based on comparative case study research. This approach has gained quite some momentum in environmental economics and related disciplines (see for a review and applications, van den Bergh et al. (1997)).

The popularity of meta-analysis in environmental economics is caused by two factors: (i) meta-analysis is particularly useful in case of comparison of behavioural or policy outcomes that are not reflected in the 'measuring rod of money'; and (ii) meta-analysis can also be applied in case of qualitative effects of decisions or actions, a situation which is often present in case of environmental phenomena.

The complexity of environmental economic phenomena is often rather high. Even in cases where monetary valuation is applied (e.g., in social cost-benefit analysis) the research efforts are often so high, that an easy application in other cases is often prohibitive. This has prompted the development of value transfer methods, which aim to translate research findings to other, comparable case studies (see Bal and Nijkamp (1998)).

In recent years also various applications of meta-analysis to transport economics in relation to environmental economics can be observed, for example, on the comparison of price elasticities in public transport (see e.g., Nijkamp and Pepping (1998)). But as a whole, applications in this field are still scant, although there might be quite some potential for fruitful applications.

An important research question is now whether it is possible to develop a research methodology that can act as a general framework for the application of meta-analysis studies at the interface of transport economics and environmental economics. This is once more important, as meta-analysis is generally shifting its meaning from a rather narrowly defined statistical approach to a general approach for comparing findings of different studies on similar topics or issues, not only empirical, but also theoretical and methodological.

In the present paper it will be argued that a general equilibrium approach, including externalities and transportation, may offer such a comprehensive methodology framework. The structure of this paper is as follows. First, the changing scene of transport will be sketched (Section 2). Then the relation between transport, land use and economic activities will be outlined (Section 3). In the next section (Section 4) the foundations of a general spatial-economic equilibrium framework including the environment will be laid down. Section 5 will then be devoted to a classification of transport impact studies, while analytical approaches for comparing such impact studies will be outlined in Section 6. The paper will be concluded with some pressing research questions in Section 7.

# 2 Current Trends and Issues on Transport and the Environment

The last few decades following the Second World War have shown a rapid increase in economic activities all over the world. In the Far East formerly underdeveloped countries like Taiwan, South-Korea, or Indonesia rapidly became fast growing economies, while in Europe the countries that make up the European Union are making progress to a far stretching integration of their economies into one big market with the clear objective to increase economic activities and efficiency. This growth trend has certainly an impact on geographical mobility.

Rienstra (1998) describes trends in European transport concerning the growth in mobility and trends in the modal split for passenger and freight transport. The last 20 years have shown a strong growth in the number of passenger kilometers in Europe, especially in Southern European countries like Italy, Portugal and Spain which previously lagged behind the other European countries because of lower welfare levels. He expects this growth to continue in the future, although at a lower rate than in past decades. This expectation of a lower growth rate is based on a stabilization of the population growth rate, the limited availability of infrastructure capacity, the high external costs involved with an unlimited expansion, the limitations on the time budget of individuals for travelling, and the stabilization of car ownership levels.

Apart from growth, transport has also seen a fairly structural development pattern in modal split. Rienstra (1998) mentions that the highest growth rates can be found in air transport and private car use, while the growth of rail transport was much slower. This trend can be observed in all European countries, although the private car has a relatively lower market share in many Southern European countries (see also Salomon et al. (1993)).

Freight transport shows similar trends as in the passenger sector, although at a lower growth rate. The share of road transport in freight (trucks) has even become more pronounced than in passenger transport. In addition to freight transport by air, it is the only significantly growing mode, while other modes such as rail transport have largely stabilized.

The existence of an elaborate transportation network is central to the development of an economy. Practically everyone demands transport on a daily basis, in terms of personal mobility or through the consumption of goods that have to be transported to him or her. An increase in economic activities imposes a higher demand for transport, and without the necessary improvements in transport giving physical access to resources, markets, jobs, education etc., the economy stagnates and the aforementioned developments would come to a halt. For a more detailed description and survey of the consequences of transport (infrastructure) for economic development we refer to Nijkamp (1999) and Rietveld and Nijkamp (1999).

Transport however also affects the local and global environment in a negative way. At a local level, the rapidly increasing use of road transport has led to substantial congestion and inaccessibility of cities, while globally, especially road transport has turned out to be one an important contributor to global warming (see for many details also Nijkamp et al. (1998)).

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Such effects influence the personal welfare of many people in adverse ways. Economists refer in this case to the negative external effects of transport.

Verhoef (1996) distinguishes four types of negative external effects of transport. Road transport is one of the main causes of noise annoyance, while it contributes to a large extent to environmental externalities such as smog, acid rain, and ozone pollution. It turns out to cause many accidents and fatalities in many countries and, last but not least, the increased demand for transport due to increased economic activities has led to congestion in many cities all over the world. OECD (1995) reports among others that almost all large towns and cities are congested in the central and inner areas for most of the day leading to an estimated cost of road congestion in OECD countries equivalent to about 2 per cent of GDP. Deaths and injuries on urban roads occur in unacceptable numbers. Its costs are estimated to be equivalent to 1.5 to 2 per cent of GDP. Air pollution is present in almost all cities and its costs are estimated to cost the equivalent of about 0.4 per cent of GDP in OECD countries. Furthermore, smog and acid rain do not remain on the place where they originated, but are regularly exported to other cities and countries. OECD (1995) estimates these costs at 1 to 10 percent of GDP.

The external effects of transport affect the environment at different spatial and sectoral levels. Externalities may be intra-sectoral in the form of congestion (i.e. within the road sector) or inter-sectoral in the form of environmental externalities, concerning natural environments or social environments. They range from instantaneous effects on the local level such as congestion and noise annoyance to long-term threats to the environment in the form of its contribution to global warming. Furthermore, externalities vary according to the specific characteristics - such as the vehicle used, time of driving, area of driving, route chosen, and the length of the trip - by the individual road users.

Verhoef (1996) distinguishes both efficiency and equity aspects in transport externalities. The efficiency aspect refers to the nonefficiency of the competitive market outcome in the presence of externalities, while the equity aspect refers to the fact that the receptors of a negative (positive) externality are clearly worse (better) off under the existence of the effect, unless compensation takes place. The existence of externalities drives a wedge between the marginal social cost and the marginal private cost, which causes the market outcome, where private welfare is maximized, to be nonoptimal from a social point of view. A social welfare maximum can be restored by a policy that internalizes the externality costs, i.e. a policy that includes the (marginal) external costs in the price of the good that causes the externality. For instance, a policy that imposes an appropriate quantity restriction or a Pigouvian tax on the activity. Such policies however also have a redistributional effect on welfare, and therefore have a social impact.

These external effects of transport make local, as well as national and supra-national authorities realize that, on current policies alone, transport trends are unsustainable. The World Bank (1996) distinguishes three kinds of sustainability with respect to transport, namely economic and financial sustainability, environmental sustainability, and social sustainability. Economic and financial sustainability implies that transport must be cost-

effective and continuously reponsive to changing demands. Environment al sustainability concerns the effects of transport on the environment, while social sustainability concerns the need to design transport systems that help less privileged people with physical access to employment, education and health services. Current predictions of transport use impose such excessive pressures on ecological and social environments that regulation of transport at various spatial levels is urgent.

In a response to this threat to society, OECD countries have developed and implemented several transport policies. These policies are directed towards regulating both the supply side and the demand side of transport. Transport supply side policies in the EU are inter alia set up within the Transeuropean Transport Network, which considers **responsible infrastructure investments aimed at removing bottlenecks and linking individual modes within an intermodal system, and** *efforts* **to complete the internal market in those modes of transport that are generally environmentally-friendly alternatives and where there is excess capacity (see** EC (1996)). Nowadays, EU-countries (e.g. the French, German, and Dutch) are trying to revitalise their neglected railroad systems by improving the existing networks, increase frequencies, and lower fare levels. Many cities are replacing bus systems again by tram or metro systems, or promote the use of environmentally-friendly modes of transport such as bicycles, such as in the Dutch or Danish case. Alternative supply side measures are the limiting of parking supply in inner cities, the redistribution of road space in favour of public transport and pedestrians (e.g. in Zurich), or the imposition of certain fixed thresholds on the presence of CO, $SO_2$, NO,, and ozone, beyond which the amount of traffic is reduced by law until these levels fall below their thresholds (e.g. in Milan).

Apart from direct regulation, transport demand side policies consist of various transport pricing policies. EC (1996) concentrates on these policies as a possible answer to the trend towards unsustainability of the existing transport system, Such policies should give citizens and businesses the right incentives t 0 find solutions to pressing environment al problems. This strategy requires that prices reflect all underlying scarcities. According to the evidence in EC (1996), there exists currently a significant mismatch between the prices paid by individual transport users and the costs they cause. Some costs, especially the ones related to environmental problems, accidents and congestion are only covered partly or not at all. EC (1996) considers this situation both unfair and inefficient. Prices paid for individual journeys should therefore be better aligned to the real costs of these journeys. Technological developments in the field of telematics may provide a substantial contribution to the further introduction of fair and efficient prices.

In addition to the policies aiming at influencing demand and supply of transport services, another policy direction concerns the spatial distribution of activities (work places, residences, facilities etc.). It is clear that the intensity of land use, the spatial patterns and the mixture of activities in particular zones have far reaching effects on the volume and composition of transport flows and on the shares of the previous modes.

# 3 Transport as a Derived Demand

Nijkamp and van Geenhuizen (1997) describe a number of driving forces that are behind the current state of transition in transport in the EU. First of all, companies and regions are increasingly engaged in global trade, causing a shift from regional competition towards global competition. This requires sourcing materials, labour use, and marketing over long distances using often fragile networks.

The modern European society is showing a shift towards individualization. The traditional nuclear family is losing ground to alternative modes of living, leading to a larger number of households with different consumption patterns, working schedules, and retirement schemes. The emergence of new lifestyles leads to different patterns of mobility varying from a mobile society, with more development towards individual mobility, to a homebound society, with more activities around the house.

Then there is a tendency towards a spatial separation of residential and employment sites, which is leading to an ever increasing need for commuting between city-centres and suburbs, and for intra-suburban trips using a complex network of different transport modes. Suburbanization itself was the consequence of the development of public transport decades ago. The extent and scale of suburbanization have been unprecedented since the early 1960s when the private car and higher income levels brought low-density housing within the reach of large groups of upper and lower class families. This provides a nice example of the interaction between transport and land use.

Economic efficiency is more and more replaced by eco-preservation as a goal. Under eco-preservation, the emphasis is on the long term stability of eco-systems based on the joint interests of man and nature. Among others, this has led to a recycling of products and waste materials. The organization of an underlying production and distribution chain has major impacts on the demand and organization of transport.

It may be clear that all these changes in society have their influence on the demand for transport via the economic activities people develop in response to these changes. Transport demand can therefore largely be seen as a derived phenomenon resulting from the need to move and communicate in order to perform economic activities in a modern economy. Figure 3.1 gives an integrative view on transport, economic activities, land use, and the environment. (See Nijkamp and van Geenhuizen (1997))

In Figure 3.1 we consider an agent that engages in economic activities such as the consumption of commodities or the supply of labour hours to the labour market. In order to be able to do this, the agent is forced to seek means of transport to obtain or provide these commodities. He can choose among different modes of transport, each of them having its own price. Notice that the agent's demand for transport is a consequence of his economic activities. Transport can hence usually be seen as a derived demand. Conversely, notice that the use of a transport mode is limited by its infrastructure. Hence, the agent can be rationed in his demand for transport by this mode. Consequently, he might be limited in his economic activities by the infrastructure in the country. We say that this transport mode is

congested. This relation is expressed in Figure 3.1 by the double arrow between 'Economic Activities' and 'Transport'.
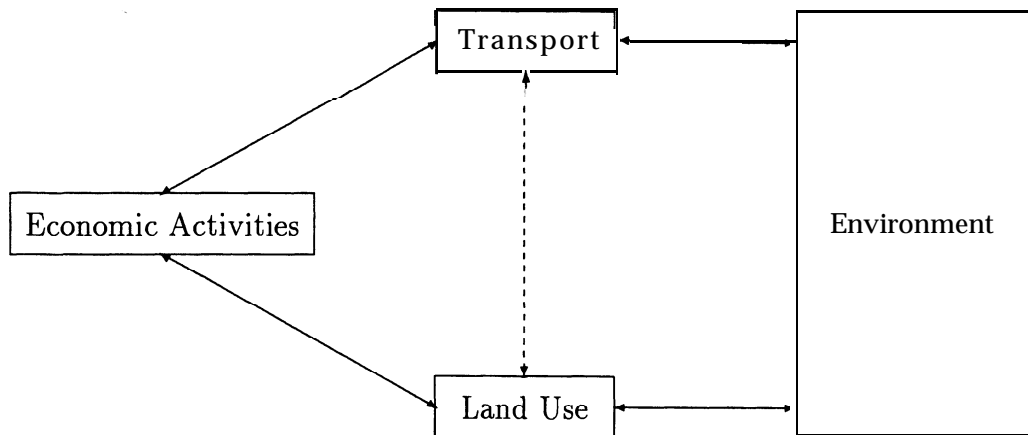


**FIGURE** 3.1: The relation of transport and land-use with respect to economic activities on the one side and the environment on the other side.

Each transport mode has its own negative effects on the environment in the form of pollution, noise, and accidents. This relation is expressed in Figure 3.1 with the arrow from 'Transport' to 'Environment'.

Although the present paper focusses on transport, it is worthwile to notice the relation of transport with land use. Land use has a relation to economic activities and the environment that is very similar to that of transport. Economic activities determine the particular use of a region, while a certain region can have qualities that make it particularly suitable or unsuitable for certain economic activities. A region located at the sea shore may have a bay that makes it suitable for a harbour. The existence of a large city in a certain region makes this region suitable for the location of particular specialized service industries. For more details on the relation between economic activities and land use we refer to Hayashi and Roy (1996). In Figure 3.1 this relation is represented by the double arrow between 'Economic Activities' and 'Land Use'. It is obvious that the use of land has a noticeable impact on the environment. Designating a certain area to industrial purposes for example causes soil pollution. Figure 3.1 illustrates this relation with the arrow from 'Land Use' to 'Environment '.

Figure 3.1 also shows a dashed double arrow between 'Transport' and 'Land Use', indicating a symmetric weak relation. The use of land determines transport by affecting where people live and where activities take place, while the particular use of an area is also determined by the existence of sufficient transport mode alternatives connecting this area with the economic centers of activity. We have already mentioned suburbanization in this context.

The remaining part of this survey abstracts from the impacts of transport infrastructure and economic activities on land use and thus assumes land use as given. It only considers

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transport and its relations to the economic activities and the environment through the spatial perspective in which a particular transport study takes place, e.g. whether we are considering transport in an urban or rural region. In the sequel we will address in particular the question whether it is possible to design some sort of an 'umbrella' architecture for a transport model including externalities, so as to encapsulate the various studies undertaken by numerous authors.

# 4    The Architecture of a Transport Impact Model

In this section we aim to lay the foundation for a modelling framework which is integrative and comprehensive vis-a-vis distinct studies undertaken elsewhere. In particular, the aim is to design an arche-type of model which can be used as a 'benchmark' for comparative analysis of various models. In this context, recent methodological advances inspired by meta-analysis may play an important role.

Meta-analysis seeks to synthesize research findings from different studies. These techniques draw inferences from these studies through their common relevant characteristics, or attributes as we mainly refer to them in this paper. In order to be successful, the set of studies underlying a meta-analysis should preferably have relatively homogeneous attributes. Bal and Nijkamp (1998) refer to this as a joint conceptual and experimental background of the studies.

The existence of such a joint background has led to the popularity of - often controlled experimental - meta-analytic techniques in medicine and psychological studies, contrary to the social sciences, where research can be very different in its characteristics. This variety in research is the consequence of the common use of the so-called ceteris paribus clause in economics, which causes any study on this field to concentrate itself on the elements that are most relevant to the study, while assuming the nonrelevant but often heterogenous background elements as given. This demarcation process has led to comparative studies ranging from the micro-economic behaviour of economic subjects to the functioning of global trade.

The variety in studies that exists on any particular subject in economics undermines the successful application of meta-analysis, and might not be easily overcome. General equilibrium models however may provide a solution to the problem. Under the ceteris paribus clause, many economic studies can be seen as encapsulated inside a general equilibrium model. As such they concentrate on a particular part of this kind of model. Moreover, within an encapsulating general equilibrium model, all these studies derive their attributes from a joint conceptual and consistent background. A meta-analysis of studies can then be undertaken with reference to a general equilibrium model that encapsulates the studies.

This survey considers the application of meta-analysis to environmental impact studies of transport policy. We introduce a framework for the studies underlying a meta-analysis in this field. It is based on the applied general equilibrium models introduced in Shoven

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and Whalley (1992), but it explicitly concentrates on the modelling of the transport sector into the economy and its impact on the environment. The advantage of general equilibrium models is that the equilibrium is seen as the result of an adjustment process among the economic variables in the model. It therefore not only takes account of the economic factors that play an important role in a transport and environment model, but it also describes the behaviour of the agents that might result in such an equilibrium.

In Roson and Small (1998), several authors use a general equilibrium model to study policy alternatives with respect to transport externalities. We use the ideas behind these models but we adjust them to incorporate the idea of transport as a derived demand from the economic activities in a country as introduced in the previous section.

The model describes the economy of a country that consists of several regions. The country offers several modes of transport where each transport mode has its own infrastructure, which we consider as given. A transport mode might be interpreted as road transport or rail transport, but it can also be interpreted as peak-hour transport or the transport of data through a telephone network. Each region is supposed to consist of a representative consumer, and a representative producer that produces the region's composite commodity.

Figure **4.1** illustrates our model. For reasons of simplicity we only consider one region, which we denote with region 0, with a similarly denoted consumer and producer, and we have aggregated the other regions' consumers, producers and commodities into one aggregate consumer **1,** one aggregate producer **1** and one aggregate commodity 1. The different transport modes are aggregated into a public transport mode 0 and a private transport mode 1.

In Figure 4.1 we have specified the part of Figure 3.1 that concentrates on the external effects of transport, where transport is derived from the economic activities in the country. The economic activities in the country are modelled by the two consumers 0 and 1 that supply labour hours to the country's labour market and capital to the country's capital market, and two producers 0 and **1** that produce the consumption goods, using labour and capital as primary inputs, and each other's commodities as intermediary inputs. Each consumer has a time endowment which he allocates between labour and leisure. The consumers spend the income they obtain from labour and capital on the consumption of each good.

In order to be able to participate in these economic activities, the consumers as well as the producers need transport. The consumers do not obtain direct utility from transport, while transport is only a cost to the producers. We measure transport in volume units. In the case of for example road transport these units might be ton kilometers, but in the case of information transfer these could be bytes. Given the per unit price $q_0$ of public transport and $q_1$ of private transport, each consumer demands passenger units by public transport and by private transport, while each producer demands freight units by public transport and by private transport.

Given the prices $p_0$ and $p_1$ of the consumption goods, the transport prices $q_0$ and $q_1$, the wage rate $w$ and the interest rate $r$, each consumer derives income from his labour and capital supply. He spends this income on consumption and leisure in such a way that he
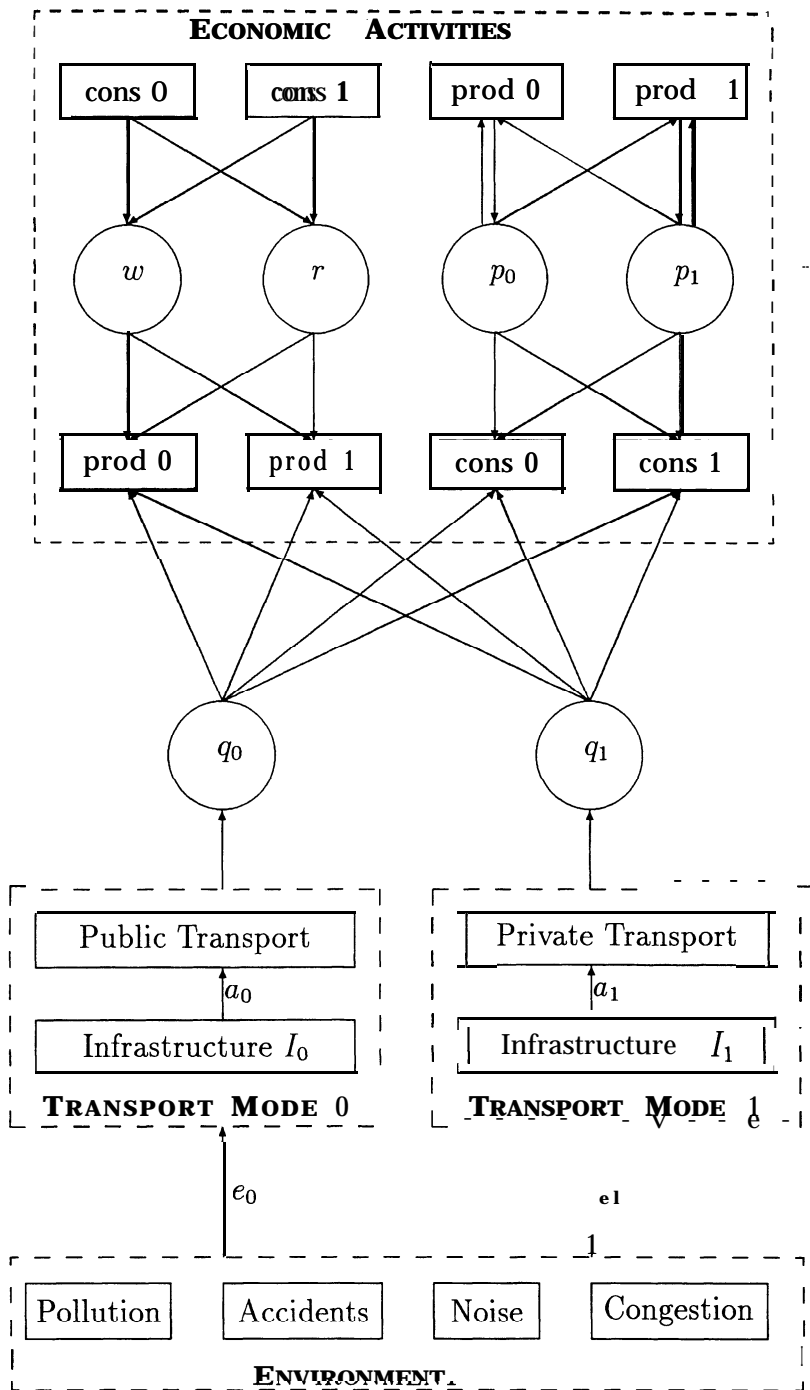
**FIGURE 4.1:** Graphical representation of the general equilibrium framework. The variables $p_0, p_1, q_0, q_1, w$, and $r$ denote the prices of commodities **0** and **1**, transport modes **0** and **1**, the wage rate and the interest rate on the underlying markets. An arrow pointing towards a market represents a supply and an arrow pointing from a market represents a demand of the good traded on this market by the agent on the other end of the arrow. $a_0$ and $a_1$ denote the input demand for infrastructure, and $e_0$ and $e_1$ the environmental costs of transport mode **0** and 1 respectively.

obtains a maximum amount of utility. In order to obtain this utility it is necessary for him to spend some of his income and time endowment on transport. The transport price and the speed of each transport mode determine his optimal bundle of the available transport modes. The producers maximize their profits from supplying their output of their commodity to the market, given his production technology. They need to spend some of their profits on an optimal, i.e. cost minimizing, mix of transport modes given the prices and speed of each transport mode.

Each transport mode consists of an industry and the underlying infrastructure. The transport industries, such as Dutch Railways in The Netherlands, provide units of transport to the public and private transport markets. On the public transport market, the industry can obtain $q_0$ per unit of transport supplied, while the private transport industry can obtain $q_1$ per unit supplied.

We assume that each transport industry has a constant returns to scale production technology. In this way, their activity levels are determined by the total demand for their transport units. Apart from having infrastructure as an input to its production technology, each transport industry also uses environmental quality, denoted by $e_0$ for the public transport mode and $e_1$ for the private transport mode. Environmental quality is interpreted here as an input into the transport mode's production function. As such we can also refer to the environmental costs of each transport mode. This reduction in environmental quality can be in the form of emissions, but also noise or accidents. A fourth type of external effect of the transport industry is given by congestion. We call a transport mode congested if its demand for infrastructure, $a_0$ for transport mode 0 and $a_1$ for transport mode **1** in Figure **4.1,** exceeds its infrastructure's capacity $I_0$ respectively $I_1$. Notice that infrastructure input demand and capacity determine the speed of the transport modes. Speed can also be seen as an output of the transport industry. There does not exist a market for transport speed. Also, the production of speed may not necessarily exhibit constant returns to scale.

We concentrate on the impact of the economic activities on the environment through its use of transport. This impact is given in this model by the use of environmental quality by each transport mode. A change in environmental quality has its influence on the utility of the consumers and profits of the producers, and it can therefore be interpreted as an external effect to the consumers and producers.

Since this section deals with a general equilibrium model, all important variables are determined by the model itself. The wage rate $w$ is determined as the clearing rate of the country's labour market, and the interest rate $r$ as the clearing rate of the capital market. The prices $p_0$ and $p_1$ of the commodities clear the underlying commodity markets. For the private transport market the price $q_1$ clears the market. On the other hand, the price of the public transport mode $q_0$ is usually set by the national or regional/local governments in the EU according to some pricing rule.

We have assumed that the transport industries apply a constant returns to scale technology to provide transport units to their respective markets. Then, the per unit price of

the private transport industry $q_1$, is determined by the per unit cost, while the activity level clears the private transport market. The activity level of the public transport industry also clears the market.

Figure 4.1 clearly shows that no market exists for environmental quality. Consequently, there does not exist a price that regulates the use of environmental quality by the different transport modes, and these transport modes therefore do not take account of their impact on the environment. The external effects of transport in the form of emissions, accidents and noise directly affect the utility of the other agents in a negative way. The consequences of congestion on other agents' utility is indirect. We already mentioned the reduction in speed of the transport mode when demand for infrastructure or transport itself increases. In the case of congestion of a transport mode, the consumer as well as the producer is rationed in his demand for transport by this transport mode. Under these circumstances, they switch to another transport mode or they forego some of their economic activities. Due to congestion, the consumer cannot obtain all the consumption or supply all the labour he desires, and therefore he has less utility. The producer cannot sell all his output, or obtain all the necessary inputs, and therefore cannot fulfil1 the demand for his output good.

This general equilibrium architecture serves as a framework for the heterogenous studies on transport impact analysis in environmental economics. With respect to the ceteris paribus clause that is often applied in these studies, we now also have defined the attributes that are considered exogenous by each of these studies. In a sense, this framework can be seen as the world where these studies take place.

This framework therefore offers the joint background necessary to perform a meta-analysis in environmental economics and it can serve as a benchmark against which we can compare the studies. The heterogeneity of these studies is found in the different attributes of the general equilibrium framework that a study considers endogenous. A meta-analysis of these studies should determine the most relevant attributes from this set of studies and their impact on the environment. To do this, the next section presents a classification of the attributes of the general equilibrium framework found in various transport impact policy studies in environmental economics.

# 5 A Classification of Transport Impact Studies

Following Nijkamp and Pepping (1998), choices regarding different attributes of research on the impact of transport policies on the environment may have consequences on the size of these impacts. For example, the results of transport impact studies may vary with the underlying geographical scale, i.e. urban or national, or when they concern passenger or freight transport. Meta-analytic techniques are able to derive results with respect to the impact of a transport policy on the environment, given the various choices made in the underlying studies with respect to these attributes. Differences in outcomes accross the

studies are then attributed to differences in certain characteristics. In order to be able to distinguish different characteristics, we need to classify the various attributes of transport policy studies. This section provides a classification of the various attributes in the general equilibrium framework in Figure 4.1 that can be found in many transport impact studies on policies in environmental economics.

We use a tree $T$ to describe the classification of attributes. A tree is a special type of network which consists of nodes and branches that connect these nodes. In a tree these nodes can be subdivided over different layers. The classification tree $T$ is given in Figure 5.1.
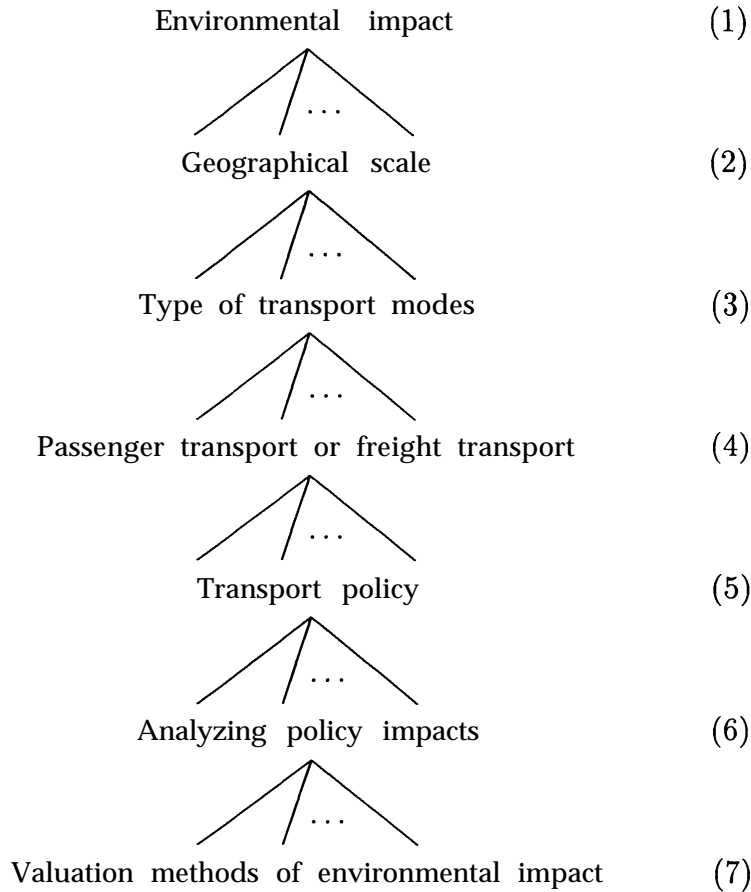


Environmental impact (1)

Geographical scale (2)

Type of transport modes (3)

Passenger transport or freight transport (4)

Transport policy (5)

Analyzing policy impacts (6)

Valuation methods of environmental impact (7)

**FIGURE** 5.1: The classification tree $T$. The numbers between brackets refer to the layer of the tree. Each layer of the tree defines an attribute.

*Types of environmental impact.*
The focus of all transport policy studies considered in this survey is on their impact on environmental quality. Verhoef (1996) and others distinguish four types of environmental costs of transport, namely noise, accidents, congestion and emissions (air, water and soil pollution). Emissions are ecological environmental effects, while noise and accidents are social environmental effects of transport. The *first level* of the tree, distinguishes transport impact

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policy studies according to these four types of environmental effects.

### Geographical scale.

The focus of transport impact policies also varies from different spatial perspectives as well as the environmental effects of transport themselves. Environmental effects like congestion are intra-regional, but other environmental effects such as pollution can also influence the environment of other regions. Consequently, policy studies that try to assess the impact of transport on the environment vary with the regional scale of the environmental effects of transport. From this point of view, the nodes on the *second* level of the tree characterize the geographical scale of possible transport impact studies. In the framework of Figure 4.1, this determines the regions.

### Types of transport modes.

The ***third level*** of the tree describes the character of the various transport modes considered by the transport impact study. This set may vary from one mode in the case of a transport study that is solely focussed on, for example, road transport, to studies that consider transport modes varying from a comparison among road, rail, and air transport, to transport by private car versus car pooling. Notice that one can also use telecommunication networks as a means of transport. In this case a study could consider the use of a car or the train to go to work or shopping on the one hand, and so-called 'teleworking' or 'Internet shopping' at home on the other hand.

### Passengers versus freight transport.

Transport of passengers and freight have usually been modelled separately. This means that the framework provided in Figure **4.1.** is not followed here. A separate treatment of passenger and freight transport means that several potentially important interactions between the two are not considered. For example, in the production block both movements of goods and people (workers) are considered. Similarly in the consumption block movement of goods and people (consumers) occurs. Important are also the interactions between the two elements in the transport block since a certain type of infrastructure is often used for both freight and passenger transport (for example, rail, road). This means for example, that problems of congestion in passenger transport may reinforce congestion problems in freight transport, and vice versa. A separate treatment of passenger and freight transport in the case of congestion is therefore not recommended.

### Transport policies.

In order to influence the environmental costs of each transport mode, transport policies therefore have to concentrate on travel demand on the one hand, or to transport supply factors, such as infrastructure, infrastructure demand by this transport mode, and the environmental cost function itself. This makes transport policies a combination of transport demand measures and transport supply measures.

Transport supply policies concerning the specification of the environmental cost function aim at technological improvements which make a transport mode more environmentally friendly. Alternatively, such measures might also add a more environmentally-friendly or cleaner mode to the already existing transport modes. 0 t her transport supply measures address the congestion problem. They consider infrastructure investments aimed at removing bottlenecks and linking individual modes of transport within an intermodal system. While the first option implies an increase of the transport mode's infrastructure, the latter option combines two transport modes to obtain an available infrastructure that is the combination of the underlying infrastructures of these two transport modes. Such measures are, for example, taken by the Dutch government in the form of the construction of the 'Betuwe-Route', a rail connection between the port of Rotterdam and its hinterland in Germany. The construction of intermodal systems is stimulated in many countries, e.g. by investments in high quality "park-and-ride" facilities and in multimodal freight terminals Policies to improve the efficiency of use of infrastructure by the transport modes concerns, for example, the introduction of "double-deck" trains, the use of 'transport telematics'and the exploitation of economies of scale and scope in hub-and-spoke networks. Investments in infrastructure and infrastructure input have their influence on the transport mode's spatial penetration and speed which makes this transport mode more attractive to consumers and producers. In order to offer a more attractive, i.e. speedy and environmentally-friendly, alternative to road and air transport, the EU is currently making large investments into an EU-wide high speed train network.

Transport demand management measures aim at influencing the demand for transport according to total volume, modal choice, route choice (express ways versus other routes) and time of day (peak versus off-peak). This demand is a result of the economic activities in the economy (cf. Figure 4.1). In order to obtain their utility or profit maximizing bundles of goods, t he consumer as well as the producer choose a combination of the transport modes according to the prices on the transport markets. Hence, by influencing these transport prices, a government can influence the use of each transport mode, and change the environmental effect s of its transport system.

Nowadays, the EU and many of its member countries are considering the use of such so-called transport pricing policies to reach their objectives. See also EC (1996) and 'Ministerie van Verkeer en Waterstaat' (1997). According to these studies, there exists a significant mismatch between the prices paid by the consumers and producers for using these transport modes and the costs they cause. This mismatch is reflected in the model by the lack of a market for environmental quality, and therefore a price for environmental quality. The transport industry does not consider the use of environmental quality in its production process, since, to them, environmental quality has a zero price. Transport pricing policies try to attach an appropriate non-zero value to the use of environmental qualitiy in order to align the price of using a transport mode with all the costs it causes. An example of such policies is the current interest in road pricing. The *fifth* level of the classification tree therefore distinguishes transport pricing policies and transport supply policies as attributes of

environmental impact studies of transport.

### *Analyzing policy impacts.*

Table 5.1 shows the existence of a large variety of approaches in incorporating transport into environmental policy analysis. First we follow Nijkamp and Blaas (1994) in distinguishing these approaches into "ad-hoc"-approaches and structured approaches. "Ad-hoc"-approaches refer to situations where no possibility exists for a structured approach due to time constraints, non-repetitive situations, or lack of data. In such cases one can draw on "expert-judgement", or do interviews. A structured impact analysis refers to a testable statistical or econometric model, based on quantified data. This data with respect to passenger transport demand and freight transport demand is obtained from the choices among the various available transport modes made by the consumers and producers in the study. We can distinguish between models that are based or built on disaggregate data and models that are based or built on aggregate data.

| Method | Aggregate data | Disaggregate Data |
|---|---|---|
| Structured approach | Four-stages model <br> Transportation Network Models <br> Partial Equilibrium Models <br> General Equilibrium Models | Stated Choice Models <br> Revealed Choice Models |
| " Ad-hoc" approach | Expert Judgement <br> Direct Interviews | Expert Judgement <br> Direct Interviews |

TABLE 5.1: Classification of approaches to analyze impacts of transport policies.

Models built on disaggregate data or micro economic models take the individual behaviour of the consumers and producers as a basis to determine transport demand. Given prices in the economy, the consumer chooses among the available transport modes a combination that maximizes his individual preferences in the form of a utility function, while the producer acts similarly to maximize profits. Many models have been based on data that are obtained by direct observation of travel behaviour. Such data is 'revealed', and these models are therefore known as revealed choice models. These models however have their limitations, such as the unavailability of sufficient data. An alternative is given by the stated choice models, which obtain their data on transport mode choice from exposing individuals to hypothetical situations in laboratory experiments. For a review of various approaches in the modelling of transport we refer to Ortuzar and Willumsen (1993).

Models built on aggregate data focus on specific geographical areas as the generators of transport demand data. The individual consumers and producers in each area are aggregated in such a way that the available aggregated data on transport demand can be interpreted as generated by their transport choice behaviour. The classical model is the so-called 'Four-Stages model' (see Sheppard (1986)) which distinguishes four submodels to

determine transport demand, namely trip generation, which determines transport demand in terms of the number of trips leaving a region during a fixed period of time and based upon attributes of that region; trip distribution, which determines the number of trips made by an agent in one region and terminating in another region; modal split c.q. modal choice, which determines the demand for each transport mode; and trip assignment, which refers to the chosen route. Fischer (1993) criticizes such models for being theoretically deficient and lacking in a behavioural rationale.

Partial equilibrium models consider transport demand and supply as the result of an explicit modelling of the decision problems of the economy's agents. In such models, transport demand is considered as one of many goods among which each agent has to choose. In Figure **4.1,** the consumer's decision problem can be given by the utility maximization problem, assuming that the consumer's preferences over consumption and leisure can be represented by a utility function. This utility function contains environmental quality as a positive externality. The consumer cannot decide on this good, but his utility is directly affected by it, as a consequence of the decisions taken by others. The producer's production technology as well as the transport industry's are modelled by production functions. These production functions also contain environmental quality as an external factor. Both production sectors maximize profits.

Partial equilibrium models only provide an explanation of the transport markets. The influence of transport policies on the other, exogenous, variables, is not explained. To this end, general equilibrium models have been developed. It generalizes the partial equilibrium models to the explanation of the consequences of transport policies on all markets in the economy.

As such, these general equilibrium models only take the infrastructure underlying each transport mode as exogenous. In order to explain this we could introduce a production sector for infrastructure into the model, but this would deny the typical network character of infrastructure. Transport network equilibrium models might offer a solution to this.

Transport network equilibrium models consider each region of the country as a node in each network that represents the infrastructure of a transport mode. The arcs between each pair of nodes in the network represent the possibility of transport of a good directly between the two regions under consideration. We refer to Friesz (1985) for more information on transport network equilibrium models, and to Takayama and Judge (1972) or Samuelson (1952) for the concept of spatial price equilibria.

### *Valuation methods of environmental impact.*
Figure 4.1 does not exhibit a market for environmental quality, due to the lack of clearly defined property rights with respect to the environment. Consequently, a transport mode does not take the environmental costs of his activities into consideration. To him, environmental costs are zero in his profit maximization problem. Nevertheless, since the transport sector's environmental effects have an impact on social welfare, one would like to put a monetary value on these effects. This allows us to include the impacts of transport policies on

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the environment in a social cost-benefit analysis. A major distinction in the class of valuation methods is between revealed preference and stated preference methods. In addition, short-cut approaches may be distinguished (Verhoef (1996)).

Well-known examples of revealed preference are the ***Hedonic Price Method*** and ***Travel Cost Method.*** These methods are so-called indirect methods in that they either assume private goods to be complementary to environmental goods, or that environmental quality is incorporated in the private good, so that the value of the environmental good can be calculated from the demand for the private good. The Travel Cost Method is based on the travel costs to visit the location where the economic activity takes place, while the Hedonic Price Method is usually based on property values. The Hedonic Price Method analyzes surrogate markets in which the environmental quality is indirectly reflected.

As an example of stated preference methods, we mention the ***Contingent Valuation Method.*** A change in environmental quality leads to a change in utility for each consumer and a change in profits for each producer. A Contingent Valuation Method tries to attach a monetary value to this change in utility or profit by asking the consumer or the producer how much he is prepared to pay in order to compensate for this change in utility or profit. In applied general equilibrium modelling the Hicksian Equivalent Variation is a well-known method.

Short-cut approaches are an alternative where valuation approaches become too costly. Instead of the external costs themselves, short-cut approaches assess the costs of actual or potential defensive, abatement or repair programmes.

The next section gives an overview of methods that use the research findings of a set of transport impact studies to define a mapping over the classification tree $T$. Such a mapping defines decision rules that relate the attributes of the studies with a certain environmental impact of the transport policy under study. Variations in environmental impact of this transport policy can then be attributed to variations in the characteristics in $T$.

# 6   A Short Survey of Meta-Analytic Approaches

Given the large number of transport studies that have been carried out in various countries there is a clear need for comparison and synthesis. In the present section we will discuss methods for meta-analysis that enable one to carry out such a comparison in a systematic manner.

The approaches and models surveyed in Section 5 deal with a large numbers of parameters. Scientific and political discussions often focus on certain parameters that are of particular interest. To give some examples.

1. The fuel price elasticity of demand for automobile-kilometres. This elasticity indicates the sensitivity of car use for changes in petrol prices; it is a key parameter since it enables policy makers to assess the potential consequences of fuel taxes.

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**2.** The valuation of emissions. Policy measures to reduce the level of emissions related to transport will have impacts on both the environment and the economy (production and consumption levels). Therefore a valuation of emissions is an important input to the problem of setting appropriate emission standards in order to ensure that a proper balance is achieved.

**3.** The link between economic growth and modal choice. For long run projections in a growing economy it is important to know how production processes and passenger transport develop because the necessary infrastructure has to be prepared in time. One needs to know for example to what extent economic growth leads to a sectoral shift implying a change in modal choice in transport.

**4.** Parameters linking transport movements with indicators of environmental pressure. These parameters are partly technical in nature, but one must be aware that in the long run technology is not autonomous. Therefore these parameters also depend on the efforts to develop more environmentally friendly technologies as well as on the adoption of these technologies by users.

**5.** The effect of the introduction of a new type of policy such as road pricing. Existing models may not be suitable to analyze these effects because time specific prices are not included in standard models. An ex-ante analysis based on a survey of road users may be used to investigate the willingness to pay the prices charged. An alternative approach would be to ask experts for their opinion (possibly in qualitative form).

A comparison of transport models becomes particularly interesting and useful when it is used for a systematic investigation of the differences in parameters like the ones mentioned above. This will shed light on many issues that cannot be answered on the basis of individual studies. For example:

**1.** Is the result that in a certain study the fuel price elasticity of demand is very low influenced by the particular data of estimation method used?

**2.** In a certain country it is found that the valuation of emissions is so high that its internalization would lead to an entirely different structuring of production and transport. To what extent can this result be transferred to other countries?

**3.** In a rich country like the USA air transport has a large market share. Can a similar pattern be expected for European countries as they get richer, or is the orientation on air transport in the USA a rather unique phenomenon related to for example the spatial structure of the country and idiosyncratic preferences?

**4.** The speed of adoption of environmentally friendly transport technologies in various countries may differ substantially. To what extent can differences in adoption be explained by differences in fuel prices?

5. Qualitative expert opinions on the potential effects of road pricing under various conditions can be used for a systematic analysis of the relative importance of these conditions for road pricing schemes.

In the rest of this section we will discuss methods that can be used for a systematic comparison of individual transport studies.

Consider a set of transport impact studies in environmental economics on a certain policy issue. In the previous section we saw that all these studies can be characterized by the classification tree $T$.

Apart from a synthesis of the results of the set of studies considered, meta-analysis also wants to distinguish the relevant attributes in the classification tree that determine the outcome of the studies. In this way, one can identify the most important attributes of the studies on which one should focus in order to achieve a solid policy analysis.

The techniques that are used to this end can be subdivided into classification techniques, - such as Cluster Analysis, Rough Set Analysis, Neural Networks, or Discriminant Analysis -, and statistical techniques which try to obtain a mean effect size of transport on the environment from the set of studies considered, and corresponding confidence intervals. These techniques also can be used to the influence of moderator variables on effect sizes observed.

*Statistical Methods* combine the results of and analyze the variation in these studies. Van den Bergh et al. (1994) provides a summary of the ideas behind these methods. This kind of meta-analytic study is mainly used in medicine (see Pettiti (1994)), where research reports have a more uniform structure than in economics. Medical studies consider the effectiveness of a specific medical treatment or medicine to cure diseases by subdividing the group of patients into two groups. One group, the experimental group $E$, is given the treatment or medicine under study, while the other group, referred to as the control group C, does not receive any treatment or medicine.

The observations from the experiment can then be used to obtain an estimation of two indicators, say $\mu_E$ and $\mu_C$, for the experimental group and control group respectively, referring to the effect of the medicine or treatment on both groups. We may then obtain an estimate for the effect size of the medicine or treatment, given by $\delta = (\mu_E - \mu_C)/\sigma$, where $\sigma$ denotes the standard error in the observations. If we assume that the observations in each study are generated by a probability distribution, then the estimator for $\delta$, denoted by $D$, also has a probability distribution, which we can use to construct a confidence interval for $\delta$, and to test hypotheses on the value of $\delta$.

The estimator $D$ itself uses a set of studies on this area to provide a sample for the estimation of an effect size $\delta$ for a medicine or treatment. $D$ provides an effect size estimate for every study and hence a sample of effect size estimates. The main question is then how to combine this sample of effect size estimates into one estimate, regularly a mean effect size. Differences between the various estimates of can be partially attributed to the fact that studies use different samples of the total population and partially to other reasons like the

different conditions under which the studies took place. This kind of meta-analytic studies therefore use a homogeneity test to judge whether it is justified to combine the various estimates of the effect size into one framework. It tests the hypothesis that in every study the same effect size occurs. If this hypothesis is rejected, we should take account of the factors that explain the differences between the outcomes. Statistical methods do this by estimating a linear regression model that associates the observed effect sizes, as dependent variables, with a number of independent variables, or moderator variables.

Transport policy studies can be seen to compare a benchmark situation with a counterfactual situation, instead of a control group with an experimental group. The benchmark situation of an economy is a representative state of the economy before the implementation of the transport policy, while the counterfactual situation considers the state of the economy after its implementation. A set of transport policy studies in environmental economics allows us to estimate an effect size in the form of a change in environmental quality for each study. We can then apply the aforementioned type of tests to these effect sizes on environmental quality.

Notice that, in economics, one regularly has prior information about the impact of transport policies. Classical statistical methods as applied in the meta-analytic methods described above do not incorporate such information. Contrary to the classical statistical approach, a Bayesian approach does include prior knowledge by assuming the existence of a prior distribution of an effect size. If we adopt the Bayesian approach in meta-analysis, then each study provides new information with which the prior distribution can be updated to obtain a posterior distribution of the effect size. This approach is rather rare in meta-analysis. We refer to Lubbe (1999) and Ouwersloot et al. (1998) for the occasional applications of Bayesian statistics in meta-analysis.

The classification tree $T$ however shows a large variety of transport impact studies that may be used. Differences between the effect size estimates in the sample obtained from the studies can therefore to a large extent be attributed to other reasons than the use of different samples from a population, such as for example the various models used to assess transport demand or supply. A homogeneity test is therefore likely to be rejected, and we are obliged to take account of the influence of the classification tree through the estimation of a regression model on the data obtained in the form of estimated effect sizes and the independent attributes in the classification tree.


The **Classification techniques** partition the set of studies into groups of studies referred to as classes or clusters in various methods, such that the studies within such a group lead to results which are 'similar'. These classes are determined by a minimal set of attributes. The following overview is based on Spierdijk (1999).

*Cluster Analysis* imposes a certain type of structure on the data. We can distinguish three types of cluster analysis, namely *partitioning methods, hierarchical methods,* and *clumping methods.* Partitioning methods aim to partition the set of studies into a specified number of disjoint groups, so that each study belongs to one and only one group. For each number

of these groups, one seeks a partition which is optimal in terms of the stated clustering criterion.

One is often interested in investigating the structure in the data of the various studies at several different levels. One could be interested in how the groups in a partition are related to each other. Hierarchical cluster analysis tries to give an answer to this question.

The groups of studies produced by partitioning methods are defined to have no studies in common with each other. On occasion, this condition is unnecessarily restrictive. In clumping methods the groups of studies are allowed to overlap. Such overlapping groups will be called clumps and a division of the set of studies into clumps such that each study belongs to at least one clump, is called a covering of the data set considered.

*Rough Set Analysis* (see Pawlak (1991) and Slowinsky (1992)) is a nonparametric classification technique. No a priori assumptions are made about the underlying distribution of the data. By means of Rough Set Analysis both quantitative and qualitative data are transformed into ordinal data. The main principle of Rough Set Analysis is the indiscernibility equivalence relation. Let $\mathcal{P}$ be any subset of the attributes in the classification tree $T$. Then we call two studies P-indiscernible, if and only if these studies have the same values for all attributes in $\mathcal{P}$. This equivalence relation generates a partition of the set of studies considered into equivalence classes of P-indiscernible studies, to which we refer as P-elementary sets.

The classification tree $T$ itself leads to a classification of the set of studies. Given this classification with respect to all attributes of the classification tree $T$, we want to find a minimal set of attributes $\mathcal{P}$ that gives the same quality of classification of the studies as $T$. This concept is known in Rough Set Analysis as attribute reduction. The classification of the studies may be characterized without losing any information, using only the attributes of $\mathcal{P}$. On the other hand, leaving out one of the core attributes will deteriorate the quality of the classification. Based on this approach, Rough Set Analysis derives decision rules which are a statement of the form, "IF the core attributes have these values THEN the decision vector, in our case the impact on environmental quality, has that value".

The literature contains a quite elaborate theory of *Neural Networks,* so we refer to Gallant (1995) for details. Briefly stated, a neural network consists of a set of computational units (also called cells) and a set of one-way data connections. At certain times a unit examines its inputs and computes a signed number, called an activation, as its output. The new activation is then passed along those connections leading to other units. Each connection has a signed number, called a weight that determines whether an activation that travels along it, influences the receiving cell to produce a similar or a different activation according to the sign ($+$ or $-$) of the weight. The size of the weight determines the magnitude of the influence of a sending cell's activation upon the receiving cell. Thus a large positive or negative weight gives the sender's activation more of an effect on the receiving cell than a smaller weight.

Neural networks are built according to the human brains. The cells correspond to our neurons, activation corresponds to neural firing rates, connections correspond to synapses, and connection weights correspond to synaptic strength.

There are many types of neural networks, e.g. backpropagation networks, radial bias networks and Hopfield networks. Very roughly, they can be divided into two classes: networks that need supervised learning, and networks that need unsupervised learning. Supervised learning consists in showing the network both the input and the desired output, whereas unsupervised learning only needs the input. In what follows, we suppose that we have to do with a supervised learning network.

The main question we want to answer, is how to use a neural network for classification purposes. Each study underlying a meta-analysis can be characterized by a number of independent variables (and their values) and some dependent variables. First, we need to train our neural network. That means that we show a specific part of our data set (e.g. 75% of it, randomly chosen) to the network (both independent and dependent variables). We tune the network in such a way that the network 'predicts' the value of the dependent variables as good as possible. Then we show the test set to the network, but this test set only consists of the values of the independent variables. The network then predicts the values of the dependent variables and it is to us to compare those values to the real values of the dependent variables. If the network classifies most elements (e.g. 95%) of the test set correctly, then the network will probably work well on other test sets.

*Discriminant Analysis* considers the problem to classify any study into one of, say two for the ease of presentation, classes, based on the characterstics in *T*. Each vector of characteristics has a certain distribution in the population, with respect to each class. Assume that we can quantify the characteristics in ***T.*** Discriminant Analysis then uses a linear combination of the characteristics in *T,* where the coefficient of each characteristic is chosen in such a way that the obtained line separates the two classes in an optimal way. Optimality is defined as a function of the means and variances of the two classes. The optimal coefficients we obtain this way say something about the weight of the characteristics in determining the outcome of the studies.

Statistical methods as well as the methodological approach, synthesize the research findings of the set of studies underlying a meta-analysis in environmental economics into a mapping of the relevant attribute values in the classification tree into the environmental impact of the policy under study. Statistical methods obtain this mapping as a linear regression model, while the methodological approach obtains it as a set of decision rules. The mapping can as such be compared to what transport policy studies refer to as 'reduced form equations'. In such studies, reduced form equations give a direct relation between the parameters and exogenous variables of the model that are influenced by the policy and the impact on the environment. Hence we can interpret the obtained mapping as a 'reduced form mapping', which gives a direct relation between the relevant attributes of ***T,*** and the effect size of the

policy on the environment.

In order for the reduced form mapping to be of interest to economists, we should formulate an economic model that describes the interactions of the relevant attributes in the classification tree which result in the impact of the transport policy on the environment, as considered by the set of studies. Proceeding with our analogy in transport policy analysis, we should formulate a structural form mapping that results in our reduced form mapping. Pawlak (1991) refers to this as 'theorizing'. An obvious candidate for synthesizing the research in the studies under consideration is the model in Figure 4.1.

# 7  Conclusions

Economic development in many countries has led to an explosive growth in demand for transport. Many governments replied to this with an increased effort to invest in infrastructure, mainly roads. This all has led to questions about the environmental sustainability of the transport system, i.e. questions concerning the increased degradation of environmental quality and congestion, causing governments to redirect their policies with respect to transport. Consequently, traditional transport supply policies were complemented with a growing interest in e.g. transport pricing policies (see EC (1996)).

The growing interest in transport pricing policies has led to a diffuse and heterogeneous number of studies on the impact of such policies on the environment. These studies vary with respect to the environmental impact under consideration, the transport modes, geographical scale, and the kind of models that are used to model transport demand and supply. With all these different attributes, studies also came up with very different results, which makes it difficult for a policy maker to interpret these results. So how can we compare these different results, how can we synthesize all the knowledge obtained from these studies, and what are the most relevant attributes in these studies that determine the outcome?

This paper investigated the scope of applying meta-analysis to provide an answer to these questions. Meta-analytic techniques derive conclusions with respect to the environmental impact of certain transport policies from a comparative study of very heterogenous research findings. This results in decision rules that relate the effect of a transport policy to the most relevant characteristics of the studies underlying a meta-analysis. However, we cannot blindly apply meta-analytic techniques in economics due to the inherent heterogeneity of studies that results from the often applied ceteris paribus clause in this field. We have therefore introduced a general equilibrium model that may serve as a framework for the different attributes or characteristics of the studies in a meta-analysis. This general equilibrium framework provides the various attributes that can be distinguished in transport impact studies in environmental economics, which we were able to classify. The resulting classification tree can then be subjected to meta-analytic techniques to determine the aforementioned decision rules, and the attributes that are most relevant for the effectiveness of the transport policy under study.

We conclude this paper with some remarks on research directions that may be taken from here. A first direction can be to operationalize the architecture of the general equilibrium framework for-a meta-analysis on transport policy in environmental economics into an applicable general equilibrium model. This requires the specific modelling of the spatial character of transport into these models, something that is relatively new to this field. The spatial context of transport is given by the network character of transport. It could therefore be an interesting opportunity to combine such an applied general equilibrium model with the so-called transportation network equilibrium models often applied in operations research. In order to calibrate such a model, one needs to obtain values for several parameters such as price elasticities. They are usually picked arbitrarily from the literature, but this could be significantly improved by applying a meta-analysis on several studies on this field, using the applied general equilibrium model as a framework. The EU program TRACE intends to deliver an 'Elasticity Handbook' (see de Jong (1998) for details) which could be used for such a met a-analysis. Other interesting topics for applications of meta-analysis have been suggested in the first part of the previous section.

In this paper we shortly surveyed several meta-analytic methods we can use to derive results from a heterogeneous set of studies. So, which method is most appropriate to use? As Spierdijk (1999) suggests, this comes down to a classification of methods. We here refer to the last mentioned author for more interesting details on research along this line.

The statistical methods originated in medical sciences, while the classification methods originated in decision analysis, and thus are not specific to economics. These methods do not allow for the processing of prior information although we are likely to have such information in economic science. This seems inefficient. The existence of prior information therefore suggests the development of a Bayesian approach to applying a meta-analysis in environmental economics.

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