

# **ECONOMIC IMPACTS OF ROADS**

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**INDEVELOPMENT**

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## **1 INTRODUCTION**

The purpose of this paper is to present an overview of current regional and multiregional economic models that intend to forecast the economic impacts of transport (roads) infrastructure interventions. The most common classification of developing countries is based on economic indicators such as the Gross National Product per Capita. Income is indeed an important distinguishing criterion with the respect of development issue. Low-income levels show a high correlation with among others, high population growth rates, high infant mortality rates, high total fertility and low life expectancy. However it should be noted that the average, says nothing at all about the distribution of income within a country. Transport infrastructure investments lead to changes in generalised transport costs, via shorter distances or higher speeds, which give rise to reductions in fuel, capital, and labour costs. Such changes will have impacts in the transport system in the form of mode choice, choice of time of day and the generation and attraction of trips per zone. It is widely believed that the reduction in generalised transport costs lead to an increase in productivity in firms. However it is not always clear if the firms located in the investing country, province, district or other geographical area will benefit from the improved transport system.

Directly or indirectly, transport infrastructure may affect:

- Production processes
- Interregional/international trade
- Industrial location
- Distribution systems
- Housing/labour markets
- Land prices
- Price setting

Basically there are three opinions about the relation between transport and regional development. The first one states that transport hardly influences the regional economic development. Availability of transport is considered only a precondition for economic development, but does not stimulate it.

The second basic opinion (Voigt 1973) is the opposite of the first. Transport is considered to have major indirect impacts on the regional economic development. Improvements in transport are considered to be a crucial factor for regional economic development. The third and most accepted opinion is that the reciprocal relation between transport improvements and economic development is a not understood “chicken or egg” relationship.

## 2 ECONOMIC INDICATOR

Economic feasibility studies are basically investment studies focussing on the economic interests of a specific region. It is concerned with a project's profitability from the point of view of the region as a whole. The question is what is the single aggregate criterion that could be used to assess the profitability of the project? Macro-economics tend to use criteria:

1. Gross National Product
2. Gross Domestic Product

Gross regional product

Similar to the concept of gross national product (GNP), the gross regional product (GRP) can be defined as total production without duplication or as the economic product of all factors of production residing in the regions.<sup>1</sup> It is the total value of goods and services produced by factors of production owned by residents of the region. The Gross Domestic Regional Product GDRP is the equivalent of the Gross Domestic Product at national level. The GDRP can be calculated with the following formula

Gross Domestic Regional Product

$$\text{GDRP} = \text{GRP} + \text{IDN} - \text{IDRW} + \text{WI} - \text{WO}$$

In which:

IDN; interest and dividends to non-residents

IDRW; interest and dividends from the rest of the world

WI; wages earned by in-commuters

WO; wages earned by out-commuters

It should be noted that GRP or GDRP per capita figures do not correctly represent the average purchasing power, but more importantly do not give any information about the distribution of the income and welfare in a particular region, due to the investments.

In the following chapters, this paper will discuss a number of regional economic forecasting models.

It discusses models with regard to prediction of location of prediction activities. There is a large range of models to forecast the economic impacts of infrastructure. The most common methods are:

- Micro-surveys with firms
- Estimation of quasi production functions
- Partial equilibrium potential functions
- Macro and regional economic models
- Land use/transport interaction models
- Spatial computable general equilibrium models.

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<sup>1</sup> William A. Schaffer: Regional Impact Models, July 1999

### **3 LOCATIONAL ANALYSIS**

It is not possible to forecast the economic impact in GRP or GDRP of additional production activities in a particular region. This chapter therefore solely discusses models that predict location patterns of production analysis.

#### **3.1 DESCRIPTIVE ANALYSIS**

All managers have to make choices concerning output quantities, technology but also every now and then about the location of its company. This paragraph will discuss common views related to location theories.

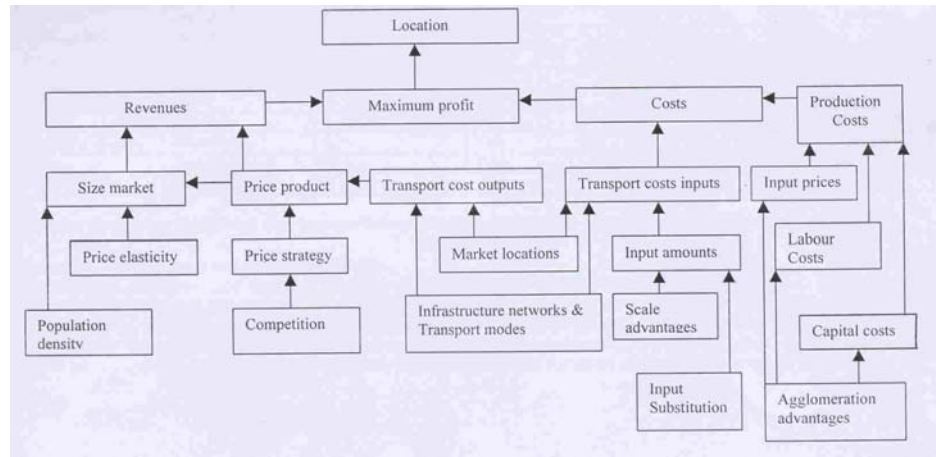
Perroux

According to Perroux, producers concentrate themselves geographically, because they are dependent on each other. Especially when companies tend to specialise themselves, the industries require each other's inputs. These centres tend to be attractive to other companies, which are pulled towards the centre, the growth pole. According to Perroux starts the economic growth of a region with a key firm, "firm motrice". This is usually a big company in a growing sector, which depends on many and intensive contacts with other companies. A major criticism on the growth theory that it does not explain how firm motrices can be attracted to the weaker regions. It is referring to the location theories. Furthermore, if the weaker regions do not have a minimum production capacity, it is unlikely that other firms would locate themselves in these regions, even if the firm motrice were located there.

Myrdal

Myrdal warns that expansion of these centres have backwash effects on the periphery regions. Migration, cash flows and interregional trade tend to go through these centres. However there are also spread effects of this phenomena. The centres require agricultural products and raw materials from the periphery regions. Furthermore deconcentration will occur due to increasing costs for ground (lack of space), shortage of skilled labourers, reduced accessibility due to congestion problems. However the deconcentration often results in new centres close to the original centre. Geographical deconcentration does not lead to levelling of the regional-economic differences. Due to increased competition, producers are forced to innovate in products and production processes. The centres always seem to attract impulses for additional growth. The important communication and transport nodes are usually located in these centres. The knowledge bases and education institutes are also based there. The centres have additional benefits due to the economics of scale.

Paelinck and Nijkamp designed the below-presented location theory, whereby the firms are expected to optimise their profit.



The relationships between the different push and pull factors vary from one production sector to another.

Economist usually analysis the reality from a perspective of the economic person. The economic person knows all relevant information. However in reality producers do not have all information. And the available information is based on many assumptions. According to Simon are firms not operating as optimisers but as satisfiers. Firm location patterns are strongly influenced by their life cycle. In the first place when a firm starts to exist, it is mainly dependent on the residential location of the starting entrepreneur. Infrastructure does not play an important role here. It does play a role however, in the success of firms. Successful firms need space for expansion, which often not available at the original location. It is relocation decisions that infrastructure may be expected to play a more important role.

Furthermore coal can only be mined on places where it is available in the ground. In general, availability of resources, location of population as a source of labour and as potential markets, soil, climate and technical conditions rule out many locations for specific economic activities.

Von Thünen, Launhardt and Weber focused on minimizing the transport costs for obtaining inputs and selling the outputs. It was assumed that there are no limitations on the market and all products could be sold. This means that that the amount of required inputs and outputs are considered "as given" and are not controlled by the firm.

Christaller

Christaller was interested in the relationship between market functions and the spatial patterns of settlements. Firms producing consumer products depend for their sales on the location, size and income of these settlements. Everybody will recognize this typical spatial pattern. Village with limited goods and services. Towns and cities with many more available goods and services. The companies in the cities tend to serve larger areas and many shops or service providers have developed themselves in specialized organizations.

According to Christaller, larger settlements accommodate companies and organizations of higher order than smaller settlements.

Supermarkets are considered of a higher order than a grocery shop. A college is also considered to be of a higher order than primary or

	secondary schools. Christaller’s philosophy is widely adopted in spatial planning, in particular for planning of administrative and social related facilities.
Hotelling	According to Hotelling, entrepreneurs do take into account and even anticipate on the behaviour of their competitors. In particular if the market is limited, competitors seem to locate themselves centrally of that market. Thus unlike Christaller had suggested the competitors do not locate themselves to distribute the markets equally among the firms, select the locations on basis of potential largest market share. In a closed economy, in which the market is given and limited, the firms will locate them centrally in that market.
Edgar Hoover	Edgar Hoover indicated that spatial expansion includes higher transport costs. In his view expansion would only be justifiable if the reduction in production costs, due to economics of scale, is higher or equal than the increased transport costs. The market expansion thus should result in reduced production costs. Often such an expansion is only justifiable with additional investments in technology to exploit the economics of scale opportunity.
Simon	Simon changed economics drastically. He classified entrepreneurs not as optimisers but as satisfiers. Entrepreneurs have to deal with risks and often risks are a result of incomplete and unreliable information. Entrepreneurs try to make rational decisions, certainly on issues like locating new businesses, but the rationality is limited to the available and reliability of the information available.
Mental maps	Mental maps and regional images have a big influence on the location analysis of entrepreneurs. Often people do not make choices on what they really know but more on what they think they know. Entrepreneurs are in general no different. The most common approach is to conduct interviews among different businesses about their specific preferences. The design of these questionnaires is crucial, because businesses easily manipulate such questionnaires.

**3.2 QUANTATIVE ANALYSIS**

	An investment in transport infrastructure reduces the transport costs and therefore could make a particular region more attractive. The attractiveness actually depends among others on prevailing price policy.
Mill price	When consumers buy the goods at the location of the supplier and ship the goods at their own costs, the price policy is named mill pricing.
Uniform price	Uniform pricing means that not only the supplier ship the goods to the buyers but it charges everywhere the same retail price, regardless the distance to the buyer.
Discriminatory pricing	In this case the supplier varies the retail price, with the objective to increase profits. In a spatial monopoly it is possible to calculate the profit functions of the firms:
Mill Pricing	

$$G_M = \sum_{j=1}^l pD_j [p + t d(s, x_j)] - \sum_{i=1}^m [p_i + t_i d(x_i, s)] q_i.$$

Uniform pricing

$$G_U = \sum_{j=1}^l [p - t d(s, x_j)] \Delta_j(p) - \sum_{i=1}^m [p_i + t_i d(x_i, s)] q_i$$

Discriminatory pricing

$$G_D = \sum_{j=1}^l [p_j - t d(s, x_j)] D_j(p_j) - \sum_{i=1}^m [p_i + t_i d(x_i, s)] q_i$$

In which:

G; Profit

p(x) full price paid by customers at distance x

q<sub>i</sub> actual production in location lt<sub>i</sub> transport cost per unit of commodity in location l

Unfortunately we do not live in spatial monopolies but in a spatial oligopoly. Till now there are not many established models to predict the profit of firms at a certain location and the influence of the transport costs on that profit. Hurter and Lederer found a promising relationship to forecast profits of firms under discriminatory pricing. The model derived from the Hotelling model. The model was reported to be applicable for a number of firms, no uniform distribution of customers and two-dimensional market area.

$$G_i = \int_0^l t |s_j - x| dx - T(s_1, s_2), \quad j \neq i$$

$T(S_1, S_2) = \int t \text{Min}\{ [S_1 - x], [s_2 - x] \} dx$  is the sum of the transportation cost incurred by the firms.

#### **4 TRANSPORT INFRASTRUCTURE AS A PRODUCTION FACTOR**

Transport infrastructure can be considered as a stock of a certain type of capital available to a region or a country. In theory it would be possible to formulate a general production function for a production sector in a region. Whereby the employment in the sector, private investment in the sector have to be known. The usual approach is to estimate/design a macro-economic production function.

The production function has the following shape:

$$Y_r^t = f(L_r^t, K_r^t, \text{Infrastructure}_r^t)$$

In which:

$Y_r^t$ ; is GDP of region r in time period t

$L_r^t$ ; Labour stock of region r in time period t

$K_r^t$ ; Capital stock of region r in time period t

$\text{Infrastructure}_r^t$ ; infrastructure stock of region r in time period t

In reality it is not easy to take in account the network properties of the transport infrastructure in the production function approach. Only if these properties are adequately represented in the production function, the production function can be used to give an ex-ante prediction of specific projects (Bruinsma: Infrastructure and Space Economy).

The table below clearly shows that the different transport economists are not unanimous about the formulation of the production function.

<i>Author</i>	<i>Country</i>	<i>No of sectors</i>	<i>Labour included</i>	<i>Capital included</i>	<i>Form of production function</i>
<i>Biehl et al</i>	<i>EU</i>	<i>1</i>	<i>Yes</i>	<i>No</i>	<i>Cobb-Douglass</i>
<i>Blum</i>	<i>F.R.G.</i>	<i>3</i>	<i>No</i>	<i>No</i>	<i>Cobb-Douglass</i>
<i>Andersson et al</i>	<i>Sweden</i>	<i>1</i>	<i>Yes</i>	<i>Yes</i>	<i>Cobb-Douglass</i>
<i>Snickars/Grah.</i>	<i>Sweden</i>	<i>21</i>	<i>Yes</i>	<i>Yes</i>	<i>Leontief</i>
<i>Nijkamp</i>	<i>Netherlands</i>	<i>1</i>	<i>Yes</i>	<i>No</i>	<i>Cobb-Douglass</i>
<i>Fukuchi</i>	<i>Japan</i>	<i>3</i>	<i>Yes</i>	<i>Yes</i>	<i>Cobb-Douglass</i>
<i>Kawashima</i>	<i>Japan</i>	<i>8</i>	<i>Yes</i>	<i>No</i>	<i>Lineair</i>
<i>Mera</i>	<i>Japan</i>	<i>3</i>	<i>Yes</i>	<i>Yes</i>	<i>Cobb-Douglass</i>
<i>Costa et al</i>	<i>USA</i>	<i>3</i>	<i>Yes</i>	<i>Yes</i>	<i>Translog</i>
<i>Deno</i>	<i>USA</i>	<i>1</i>	<i>Yes</i>	<i>Yes</i>	<i>Translog</i>
<i>Sasaki</i>	<i>Japan</i>	<i>1</i>	<i>Yes</i>	<i>Yes</i>	<i>Cobb-Douglass</i>
<i>Forslund &amp; Joh.</i>	<i>Sweden</i>	<i>1</i>	<i>Yes</i>	<i>Yes</i>	<i>Cobb-Douglass</i>
<i>Seitz</i>	<i>Germany</i>	<i>1</i>	<i>Yes</i>	<i>Yes</i>	<i>Translog</i>
<i>Prud'homme</i>	<i>France</i>	<i>1</i>	<i>Yes</i>	<i>Yes</i>	<i>Cobb-Douglass</i>

A general comment on all these models that they are not industry specific. Thus the production function for export orientated industries and support industries are for example similar. Furthermore modelling of the infrastructure stock requires complex econometrics. As indicated there are three perceptions about infrastructure's influence on economic impacts. It also should be kept in mind that the transport infrastructure stock does not do anything itself. It only facilitates transport. It is generally accepted that the developed models are not useful for ex-ante evaluation studies of infrastructure projects. To produce ex ante evaluation models, researchers developed the concept of accessibility. The accessibility of region r is expressed with equation

$$\text{Accessibility}_r = \sum_s Y_s f(C_{rs})$$

$C_{rs}$  is the sum of the communication costs between the regions r and s, f is the distance decay and is negative digressive by nature. This formula not only takes into account the accessibility of markets and suppliers in other regions (s) but also includes the accessibility to markets and suppliers in the region. With this concept is possible to estimate the economic impacts of infrastructure improvements between two or more regions.

The communication costs can be expressed in distances and/or costs, including all kinds of other costs like tariff and non-tariff barriers.

Related to the accessibility is the so-called economic potential of a particular region r.

$$\text{Potential}_r = Y_r \sum_s Y_s f(C_{rs})$$

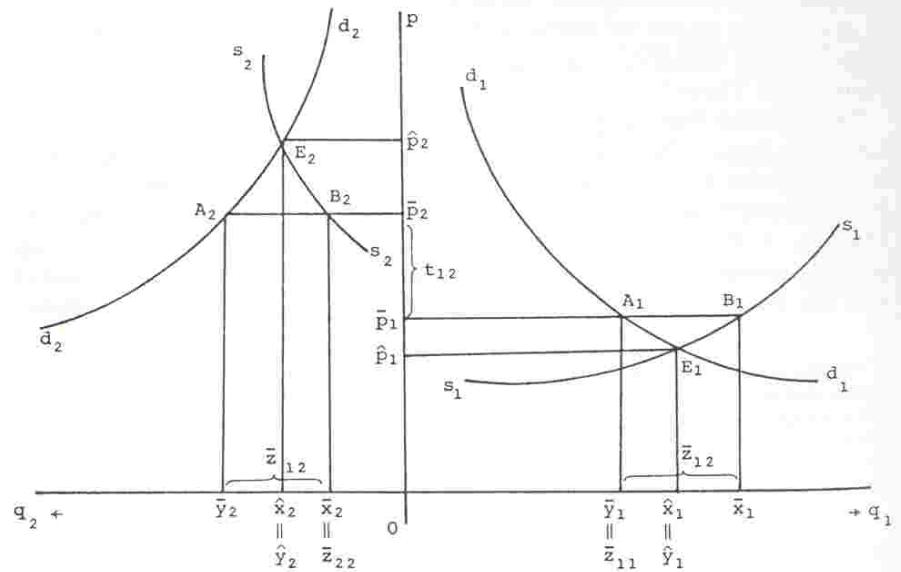
Rietveld (1989) has indicated that this model however does not necessarily result in correct estimates of future economic impacts of new infrastructure.

The following discussion paper presents details of production functions: Andreas Stephan: The Impact of Road Infrastructure on Productivity and Growth: Some Preliminary Results for German Manufacturing Sector, 1997. This paper downloadable from:

<http://skylla.wz-berlin.de/pdf/1997/iv97-47.pdf>

### 5 SPATIAL EQUILIBRIUM MODELS

Many road or other transport infrastructure projects have the objective of enhancing trade between two geographical areas. In particular if trade is currently blocked between the two regions due to insufficient infrastructure. If trade is completely blocked the prices for commodities in the different regions have no relationship and are set independently.



Infrastructure provision is a first step for trade but is not a guarantee that trade actually will take place. Traders will not enter into the new markets if they do not see the profitability, e.g. if transport costs are too high. In such situations the transport costs are higher than the price difference in the two regions.

If trade will develop, immediately the question arise: how much commodities will be shipped from one place to the other and what will happen to the prices of these commodities in these regions.

However such analysis are complex. T. Takayama and W.C. Labys describe the situation between two countries that trade one commodity (wheat).

By defining the quantity of wheat traded as  $Z_{12}$  (quantity shipped from country 1 to country 2), the unit transport cost as  $t_{12}$  and also the equilibrium trade quantity and prices as  $Z_{12}$   $P_1'$  and  $P_2'$  we can express the equilibrium relationships among these quantities and prices as follows:

$$\begin{aligned}
 P_1 &= d_1(z_{11}) \\
 d_1(z_{11}) &= s_1(Z_{11} + Z_{12}) \\
 P_2 &= d_2(Z_{22} + Z_{12}) \\
 d_2(Z_{22} + Z_{12}) &= S_2(Z_{22}) \\
 P_2 - P_1 - t_{12} &= 0,
 \end{aligned}$$

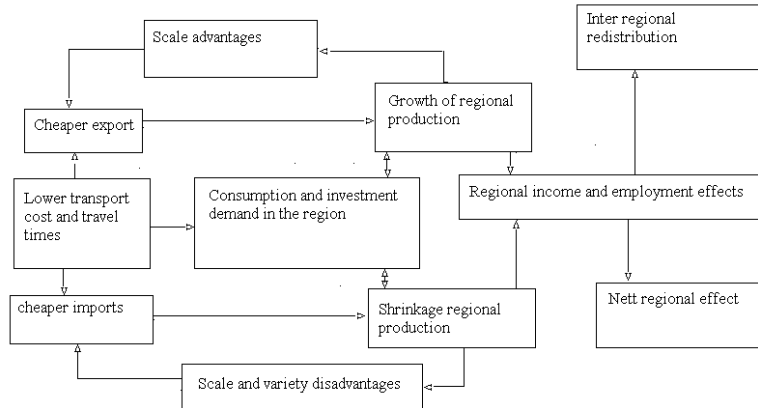
where  $Z_{ij}$  denotes the quantity produced in  $i$  and shipped to  $j$ ;  $d_i(\cdot)$  and  $S_i(\cdot)$  denote demand and supply functions in the  $i$ th country.

We have now five unknowns and five equations. Thus it is possible to find solutions for the unknowns. If there are several countries/regions involved in trading, it becomes very difficult to use this system. Usually the simultaneous equation system is replaced by a mathematical programming approach. Situations with more than one commodity flow are even more complex. The below presented website describes a spatial equilibrium model in more detail.

<http://www.iges.or.jp/en/fc/phase1/ir98-4-7.pdf>

## 6 REGIONAL ECONOMIC MODELS

The Regional Economic Models are designed on basis of the below presented conceptual model.



The conceptual model indicates two effects:

1. Distribution effects
2. Generation effects

The interregional effects are the so-called distribution effects and the generation effects are the net regional effects, as presented in the model. Distribution effects relate to the changing competitiveness of the regions, due to changing transport costs and travel times.

However none of the available models is able to estimate the impacts of changes in infrastructure, accessibility or transport costs.

## **7 LAND-USE/TRANSPORTATION INTERACTION MODELS**

These models are mainly used to predict traffic growth, land –use and to analyse policies with regard to larger urban areas. LUTIs are reported to be of less value to predict the economic impacts of infrastructure interventions.

The following website

[http://www.dft.gov.uk/stellent/groups/dft\\_control/documents/contentserve/ertemplate/dft\\_index.hcst?n=7951&l=4](http://www.dft.gov.uk/stellent/groups/dft_control/documents/contentserve/ertemplate/dft_index.hcst?n=7951&l=4)

Contains a review of existing land-use/transport interaction models.

## **8 SPATIAL COMPUTABLE GENERAL EQUILIBRIUM MODELS**

SCGE models are typical comparative static equilibrium models of interregional trade and location patterns. These models have their basis in microeconomics, in which both consumers and producers opt for maximizing benefits and profit and assumes substitution between all possible inputs. These models assume either monopolistic markets or complete competition.

SCGEs are in theory appropriate means to predict future economic impacts of infrastructure investments.

However the estimation of substitution elasticities of consumers and producers is difficult due to lack of sufficient data about interregional commodity flows. Therefore the models tend to use the national/macro values.

Chapter 3 of TMD discussion paper No. 35 presents the description and application of a multi-region computable general equilibrium model.

The document is downloadable from

<http://www.ifpri.org/divs/tmd/dp/papers/tmdp35.pdf>

Tavasszy, Thissen, Muskens and Oosterhaven describe and analyse another SCGE model "RAEM" in "Pitfalls and solutions in the application of spatial computable general equilibrium models for transport appraisal".

This document is downloadable from:

[www.inro.tno.nl/RAEM/archief/452.pdf](http://www.inro.tno.nl/RAEM/archief/452.pdf)