Integrated Assessment **2:** 73–78, 2001.

Integrated assessment of land use changes

Machiel Mulder

Wageningen UR/LEI, The Netherlands *

1. Introduction

On March 29th 1999 the RMNO organised a study conference called "Integrated Models: A Bridge between Research and Policy?" The goal of this conference was to determine how integrated models could help to bridge the gap between the scientific world and the political world.

With this goal in mind this paper gives a description of the domain of the Spatial Economic Model (SEM), which has been developed at the Dutch Agricultural Economics Research Institute (LEI). Section 2 is aimed at the political world. In this section attention is paid to the policy problems in the Netherlands with regard to land use and which form the background of SEM. Section 3 concerns the scientific world. In this section an indication is given of the two fundamental notions on which SEM has been developed. Section 4 provides a brief description of the model itself. The paper ends with some conclusions on the ability of SEM to bridge a part of the gap between the scientific and the political world.

2. Policy problem regarding land use: need of integrated assessment

For a long time, spatial organisation in the Netherlands has been attuned to the needs of house-building, agriculture and nature, policy goals regarding the natural environment and the policy goal to maintain the differences in landscape between rural and urban areas [14]. The spatial arrangement, therefore, poses the framework for the development of business. Within the economic policy, however, there is a need for changing the role of the physical planning policy. The suggestion has been made that the latter should follow the spatial demands of firms (see, e.g., [5]). In other words, the spatial organisation should facilitate the regional economic development by means of, for example, infrastructure projects.

Both approaches of the spatial organisation policy, steering vs. facilitating, can be considered as partial approaches, in the sense that no integrated assessments are made of all effects of changes in land uses. Some authors suggest, therefore, that policy choices concerning the spatial arrangement should be based on assessments of both economic, social and environmental factors (see, e.g., [6,12]).

In favour of the discussion of the optimal spatial organisation from an integrated perspective, it is desirable to translate the various spatial concepts[1] in Geographic Information Systems (GIS), so that studies can be made of the developments within different aspects, such as regional economy, society and natural environment. This is why at the LEI a start has been made with the development of a Spatial Economic Model (SEM).

3. Scientific approach of the policy problem

3.1. Introduction

To make a contribution to the integrated assessment of the effects of land-use changes, two basic notions are relevant. The first is that the economic science offers a framework for an integrated approach of choice problems, which is well suited for application in government policy considerations. The second notion is that computer models are very useful instruments for analysing concrete problems. In this section both notions are described.

3.2. Economics and policy

In essence economics is directed to the problem of allocation of scarce goods which can be applied in alternative manners. The allocation is the result of the decisions of individual actors in choice problems regarding scarce goods. The focus on choice problems is typical for the economic approach. This distinguishes the economic approach from other social sciences. In the sociological approach of society, for instance, the central focus is on human interactions in society.

An implication of the orientation on choice problems is that decision opportunities are transferred in terms of costs and benefits. Costs in economics are defined as opportunity costs, which are the profits foregone by not choosing another alternative use of scarce goods. The benefits of an application of a good are the contributions of that good to the utility of an actor. Principally, it is not relevant whether or not those costs and benefits can be valued by means of money. The monetarisation of costs and benefits is no more and no less than a way of calculating the net welfare effects of a certain

* The author is presently working for the Central Planning Office, CPB, The Hague.

[1] Examples of those concepts are city districts, city junctions, corridors and meshes between corridors, ecoregions, country places, rural areas and urban areas [20].

decision opportunity or a development in the application of goods.

From an economic point of view space can be viewed as a scarce good which can be used in different manners. Society has therefore to decide on which way space will be used. When there is a perfectly functioning market, which is the case when there is perfect competition and full information about demand and supply for all actors, the market allocation of space will lead to the most efficient use of it. In practice, however, these conditions are not satisfied. Space has characteristics of public goods, namely it is not exclusive and its consumers are not mutually competitive. These characteristics would result in a suboptimal welfare outcome of the allocation of space by the market [8], which is why the government could intervene in the allocation of space [13]. Another reason for government intervention could be a politically unwanted distribution of the benefits and costs for citizens.

An economic analysis of the allocation of space, then, results in statements about the *efficiency* of the allocation and the *distribution* of the efficiency results within society. In those statements all aspects relevant to the utility of citizens are incorporated. Therefore, the economic approach offers a concept for an integrated assessment of, for example, land-use changes. The results of this approach – the statements of effects on efficiency and distribution – can be inputs for the political discussion about the direction of use of space.

3.3. Use of computer models

The development of a computer model in favour of the analysis of policy problems can be viewed as using an instrument in order to think systematically and consistently about complex processes. A computer model is not a "truth machine", which whispers politicians which decision they should make. A computer model is an assistant for the analysis of lots of information in an efficient and effective manner. However, an important condition which should be met is that much attention should be paid to a computer model's construction. Generally the phases of conceptualisation and operationalisation can be distinguished in the building process of a computer model.

In the first phase the conceptual and mathematic models are developed. In the conceptual model it is established which questions have to be answered and which factors and relations have to be incorporated in the analysis. The mathematic model is a systematic description of the conceptual model in terms of quantities, dimensions, indices and relations.

The second phase is directed to the realisation and application of a concrete computer model. In order to convert the mathematic model in a computer model that can be used in an efficient and effective manner, the model developer should work very conscientiously. Software engineering offers various methods and criteria that can be used in this phase. The following quality criteria are common [1]:

(a) ability to reproduce model variants at later moments;

(b) ease of transmitting the model to other users;

(c) ease of maintenance of the code of the model.

To satisfy these software-engineering quality criteria in the SEM project, the model has been developed using a so-called "5 globes architecture" [17].[2] In addition, the project team consists of members with different backgrounds and expertise, such as economists, spatial experts and IT experts.

Experience shows that in the development process of a computer model about half of the time is needed for the execution of the conceptualisation phase. Often policy problems are formulated in too general terms, so that a lot of analysis and discussion between policy maker and model developer is needed to get a precise conceptual and mathematical model. This means that computer models are not only assistants who handle lots of information in a systematic and consistent manner, but they are also useful as incentive for policy makers to think accurately about their policy problems.

4. Spatial Economic Model (SEM)

4.1. Conceptualisation: domain

"Domain" refers to the collection of questions that have to be answered with the model. The domain of the Spatial Economic Model consists of the choice problems regarding the optimal use of the scarce good. Generally, space can be used in favour of business activities, liveability in society or the natural environment (see figure 1). Because of the scarce character of space it is not possible to realise all possible ambitions within these three themes. When, for example, a piece of land is used for housing, it is not possible anymore to allocate the plot for a firm or natural park. In economic terms, the opportunity costs of using a piece of land for housing consist of the foregone benefits of firm sites and nature.

An implication of restricting SEM to the domain of choice problems regarding land use, is that principally the

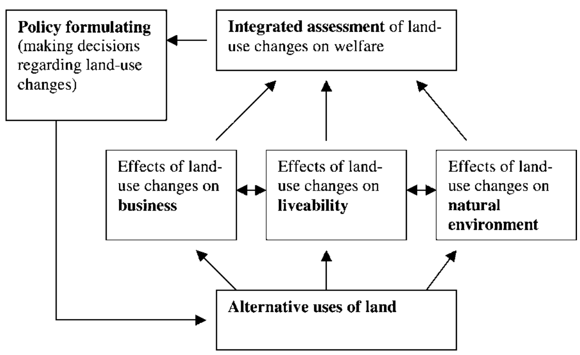

Figure 1. Domain of SEM.

[2] These globes are: calculations, data base operations, presentation, user interface and logistics of information between the globes.

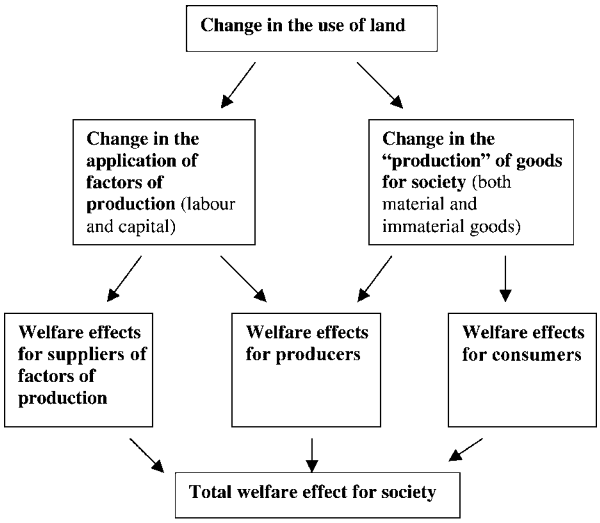

Figure 2. Cost–benefit analysis as an instrument for integrated assessment.

attention is not focused on location problems. There, the object of analysis is the optimal location for a certain actor or land-use category, such as agriculture firms or a natural park (see [10]). For such spatial problems the starting point of analysis is an actor or land-use category for which a site is sought. In the spatial problems that belong to the domain of SEM the starting point of analysis is a certain piece of space at a certain location for which an application is required.[3]

To find the optimal use of space, the first step in the analysis is determining the effects of different choice alternatives on the various aspects of welfare. As mentioned earlier, a distinction can be made between business activity, liveability and the natural environment. The effects of land-use changes on these different aspects can only be determined in joint research between various scientific disciplines, like ecology, sociology and economy. An ecologist, for example, is needed for analysing the effects of a certain change in the application of land on the quality of the natural environment, whereas the task of a sociologist is answering the question which changes will occur in the liveability as a result of another organisation and use of space. The effects on business activity have to be analysed by a business economist. A welfare economist can integrate all those different effects by using cost–benefit analysis. The cost–benefit analysis is shown in figure 2.

Since land is viewed as a scarce good with different application possibilities, each application coincides with benefits on the one side and costs on the other. The benefits consist of the value of the goods produced by the application of space. These goods can be material, like wood or agricultural products, or immaterial, like the attractiveness of the landscape or silence. The costs related to the production of these goods consist of the opportunity costs of the used production factors. The welfare effects of these benefits and costs can be further divided into welfare effects for consumers (the so-called "consumers surplus"), the welfare

[3] An example of a spatial economic study in which the same type of question is answered is Turner et al. [16].

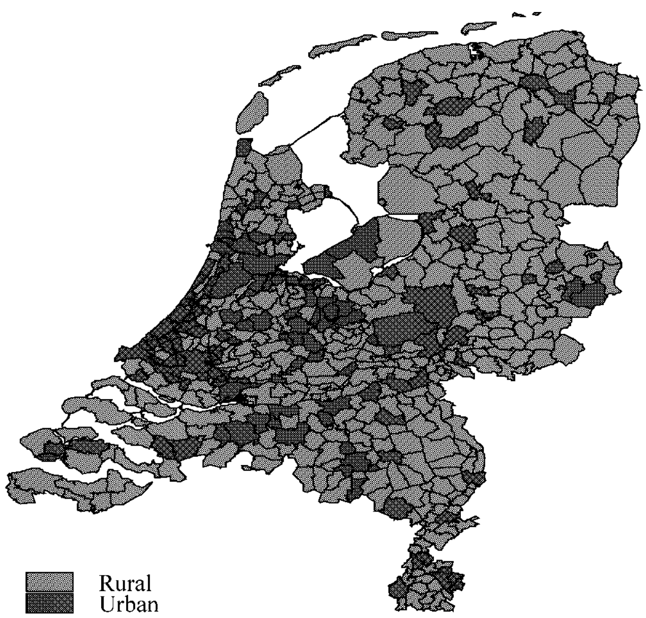

Figure 3. Rural and urban regions in the Netherlands.

effects for producers (the so-called "producers surplus") and the welfare effects for the suppliers of factors of production (labourers and owners of capital). The sum of these three welfare effects is the total welfare effect in society as the result of the change in use of land. As mentioned before, the welfare effect has two components, namely the efficiency result (i.e., total benefits minus total costs) and the distribution of that result within society.

4.2. Operationalisation

There are several phases involved in the operationalisation of SEM. In the first phase, which was finished at the end of 1999, a spatial economic information system was realised. This information system has as functions the collecting, appointing and representing of information about business activities, quality of liveability and developments in the natural environment in spatial defined areas in the Netherlands. In this way, this system integrates a lot of information about historical and current developments within various aspects of use of land. In figures 3 and 4 some examples of these are given. Figure 3 is a map of the Netherlands divided into rural and urban regions, whereby the degree of rurality is based on the population density. Figure 4 gives some information about differences between the rural and urban regions pertaining to business activity, liveability and natural environment.

Job availability, as one of the possible indicators of business activity in the rural regions, for example, proves to be significantly lower than in the urban regions. The income per head, as one of the indicators of liveability, is also lower in the rural regions than in the urban regions. Strangely enough, perhaps the proportion of nature in the use of land is higher in urban regions than in the rural regions. The explanation is the high proportion of agricultural land use in rural land use.

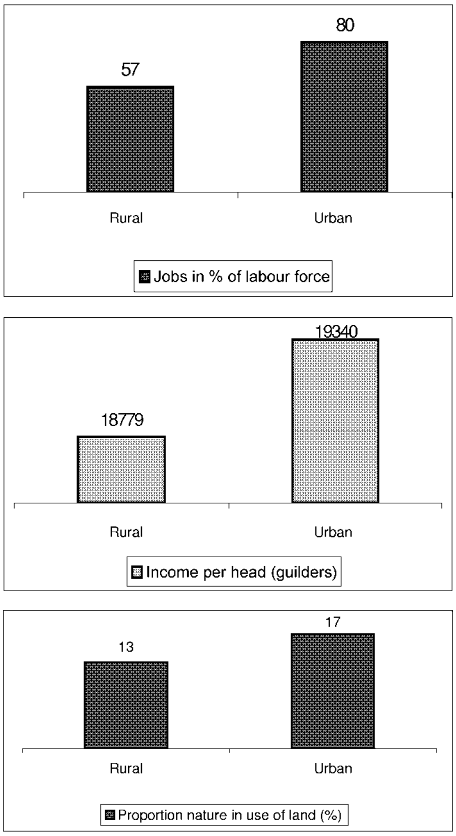

Figure 4. Business activity, liveability and natural environment in rural and urban regions in the Netherlands, 1996. Source: CBS.

While the product of the first phase of the SEM project is targeted at giving information about historical and actual spatial developments in business, society and nature, the second phase is focussed on operationalisation of the cost–benefit analysis. The aim of this phase is to develop a standard approach for executing a cost–benefit analysis, resulting in a handbook with a step plan and information needed to perform a cost–benefit analysis.

The core of this handbook is the formulation of the mathematical model, which means the collection of rules for calculating the costs and benefits. In its most simple form this mathematical model consists of the following rules:

(1) calculation of consumer surplus:
(value for consumers − costs of consumption) × change in goods supplied;

(2) calculation of producer surplus:
(sales of producers − costs of production) × change in goods supplied;

(3) calculation of surplus for suppliers of factors of production:
(revenues of production factors − opportunity costs of production factors) × change in use of production factors;

(4) calculation of total welfare effect:
consumer surplus + producer surplus + surplus for suppliers of factors of production.

The calculation with this mathematical model consists of the determination of

(a) the time horizon and spatial horizon in the assessment of the effects of the land use change (for example, how many years after realising the land use change have to be taken into account;

(b) the discounting factor for future costs and benefits;

(c) the change in goods supplied as a result of change in land use (for example, less agricultural products and more wood);

(d) the value consumers award to the change in supply of goods and the related costs of consuming those goods (for example market prices for the consumed goods (if they exist) and travel time to the site where the good is supplied);

(e) the change in sales of producers and their costs of production (which consists of costs for production factors, labour and capital, costs of non-production factors, like energy and external costs[4] such as corrosion of landscape beauty and environmental damage);

(f) the change in revenues for labour and capital and the related opportunity costs of the use of these factors of production.

Stepping through the mathematical model means that various assumptions have to be made. Sometimes these assumptions can be based on scientific literature (such as the value of landscape beauty),[5] databases (such as the opportunity costs of labour) or expert judgements (such as the effects of the land use on, for example, the provision of recreational opportunities). In other cases political choices have to be made, such as concerning the time and spatial horizon and the discounting factor.

All the assumptions used in a cost–benefit analysis have to be made explicit, so that it will be clear to everyone how an integrated assessment is made. An important result of this approach is that political discussions can take place at the level of assumptions, while the calculation of the integrated costs and benefits is the result of logical reasoning. However, the outcome of the cost–benefit analysis, which consists of information about the efficiency result and the distribution of this result within society, is an input for a further political assessment. As said before, it belongs to the domain of politicians to weigh overall efficiency results against the distribution aspects of costs and benefits.

As a preliminary study a cost–benefit analysis has been made of the policy option to locate an airport in the province Flevoland in the Netherlands. In accordance with the above-mentioned mathematic model and stepping stones, the following assumptions are made:

[4] External costs are costs that occur without a market where the goods that are used or the damage that is produced is paid for.
[5] See for an overview, e.g., [9].

(a) the time horizon is the period from 2005 till 2055 and the spatial horizon is the Netherlands;

(b) the discounting factor is 4%, as is usually done in the assessment of public investment projects [12];

(c) the building of an airport in Flevoland will result in an expansion of the possibilities to travel by plane, a decrease in the supply of agricultural products and a corrosion of the landscape beauty and liveability in the region (as a result of a decrease of air quality, quietness and safety);

(d) the valuation of these changes in the supply of products are based on literature;[6]

(e) the cost of producing the products are based on estimations of the volumes of used factors of production and other inputs and the remuneration which will be given in this investment project;

(f) the determination of the opportunity costs of a unit of labour and capital are based on data about the remuneration of those factors of production in alternative sectors.

The results of this preliminary study are given in table 1. It appears that the integrated effects of constructing an airport in Flevoland are positive. The national benefits, which consist of the benefits of more air travel and a higher remuneration of labour and capital, exceed the national costs, consisting of the various external effects. This positive welfare effect runs into those actors who organise the building of the airport (e.g., the producers who get the producers surplus) and those actors who supply labour and capital. The consumer surplus is assumed to be zero, on account of the assumption that the price consumers pay for making use of the airport is equal to the utility they derive from the airport. However, actors who live in the neighbourhood of the airport will suffer a negative welfare effect, since they bear the costs of corrosion of landscape beauty and environmental damage. The level of these costs is low in comparison with the profit of other actors. In theory it is therefore possible that the owner of the airport will pay compensation to neighbours. Whether or not the airport should be built and the neighbours compensated, is in the end a matter of politics. In the political discussion the results of the cost–benefit analysis can, however, be used as sensible inputs.

Table 1
Integrated costs and benefits of constructing an airport in Flevoland, the Netherlands (× billion guilders), period 2005–2055.

	Quantities in mathematical welfare economic model	Discounted value
(1)	Value for consumers of:	
	– airport	234
	– agricultural production lost	0.3
	total value for consumers	234
(2)	Cost of consumption of:	
	– airport	234
(3)	Consumers surplus = (1) − (2)	0
(4)	Sales of producers	234
(5)	Costs of production	
	use of labour and capital	124
	non factor inputs	51
	external costs:	
	– decrease quietness	0.8
	– decrease air quality	0.6
	– decrease safety	0.3
	– corrosion landscape and nature	0.4
	total costs of producers	177
(6)	Producers surplus = (4) − (5)	57
(7)	Remuneration of labour and capital	124
(8)	Opportunity costs of labour and capital	80
(9)	Surplus of suppliers of labour and capital = (7) − (8)	44
(10)	**Welfare effect** = (3) + (6) + (9)	**101**

Source: [19] and own calculations.

[6] The value of silence, for example, is based on CPB [2], the value of landscape qualities, including nature, is based on SEO [15] and the value of safety and clean air on a study of IOO [7].

5. Conclusions

The goal of this paper is to give information about the possibilities of cost–benefit analysis in general and the SEM project in particular in bridging the gap between the political and the scientific world. On account of the foregoing sections the following conclusions can be drawn:

(a) the significance of integrated models is primarily dependent on the degree in which politicians have to make integrated assessments. Within the policy issue regarding the optimal use of space, more and more attention is paid to effects on several aspects of society. This means that in this field of policy questions there is a need for integrated assessments;

(b) economic science offers both an analytical framework and operational techniques for an integrated approach of land-use problems. The analytical framework is that land is viewed as a scarce good that can be used in various ways. Every specific application of land involves costs and benefits. The benefits consist of the effects on the utility of actors. Costs consist of the use of factors of production, labour and capital, which consequently cannot be used in other applications. Those costs are, therefore, called the opportunity costs. By measuring all benefits and costs as far as possible and in monetary units, it is possible to calculate the integrated effects of a specific land use on total welfare in society. The outcomes of costs–benefits analysis must, however, not be viewed as the ultimate answer in policy deliberation questions, but as input for further political discussions. Also the executing of a cost–benefit-analysis cannot be done without making political assumptions. The role of this method of integrated assessment must therefore be viewed as an instrument to improve the logical consistency of political discussions;[7]

[7] Cost–benefit analysis should, however, not be the only instrument in policy analysis, but it “should be part of a whole suite of decision-aiding methods, including environmental impact analysis, local economic multiplier analysis, citizen juries and public referenda” [4].

(c) by applying cost–benefit analysis attention should be paid to the way the use of data and calculations is organised. Using computer models, therefore, requires working according to principles of software engineering, so that the risk of calculation errors is minimised.

These three conclusions form the starting points in the further development of the Spatial Economic Model at the Agricultural Economics Research Institute. It can, therefore, be expected that the model will be a useful instrument in bridging the gap between the scientific world and the political world.

References

[1] F. Bouma, De software kwaliteit van modellen op LEI-DLO; problemen en aanbevelingen voor verbetering, LEI-DLO, Den Haag (1997).

[2] CPB, Grenzen aan Schiphol?, Centraal Planbureau, Den Haag (1997).

[3] C. Gorter, P. Nijkamp and M. de Bruijn, Ruimtelijke verschillen in werkgelegenheidsgroei, Planning: methodiek en toepassing 48 (1996).

[4] N. Hanley, Cost–benefit analysis of environmental policy and management, in: *Handbook of Environmental and Resource Economics*, ed. J.C.J.M. van den Bergh (Edward Elgar Publishing, UK/USA, 1999).

[5] J. Heijs, H. de Groene and W. Kleyn, Ruimte voor werk: nog geen uitgemaakte zaak, ROM-magazine 7/8 (1995).

[6] H.J. van Houtum, F.W.M. Boekema and J.G. Lambooy, Op zoek naar het denkmodel achter de nota "Ruimte voor Regio's", NIROV, Stedebouw & Ruimtelijke Ordening, themanummer Ruimte en Economie 2 (1996).

[7] IOO, Externe kosten van het personenvervoer, Instituut voor Onderzoek van Overheidsuitgaven, Onderzoeksreeks nr. 57, Den Haag (1994).

[8] P.O. Johansson, An introduction to modern welfare economics (1991).

[9] P.O. Johansson, Theory of economic valuation of environmental goods and services, in: *Handbook of Environmental and Resource Economics*, ed. J.C.J.M. van den Bergh (Edward Elgar Publishing, UK/USA, 1999).

[10] J.G. Lambooy, Enterprise, economic and geografical environment, in: *Regional and Local Economic Politics and Technology*, eds. M. de Smidt and E. Wever, Nederlands Geografische Studies, Vol. 99, Amsterdam/Utrecht (1989).

[11] Ministerie van Financiën, Evaluatiemethoden; een introductie, SDU-uitgeverij, Den Haag (1992).

[12] Ministerie van Landbouw, Natuurbeheer en Visserij, Beleidsverkenning landelijk gebied 21e eeuw (werkdocument), Den Haag (1997).

[13] R.A. Musgrave and P.B. Musgrave, Public finance in theory and practice (1984).

[14] RIVM/DLO, Natuurbalans 1998, Bilthoven (1998).

[15] SEO, Natuurlijk vermogen; een empirische studie naar de economische waardering van natuurgebieden in het algemeen en de Oostvaardersplassen in het bijzonder, Stichting voor Economisch Onderzoek der Universiteit van Amsterdam, SEO-rapport 465, Amsterdam (1998).

[16] R.K. Turner, J.C.J.M. van den Bergh, A. Barendregt and E. Maltby, Ecological-economic analysis of wetlands, Tinbergen Institute, 050/3, Rotterdam/Amsterdam (1998).

[17] T. Verwaart, Software-architectuur voor de eenentwintigste eeuw, Den Haag, LEI-DLO (1997).

[18] Werkgroep Leefbaarheid Platteland, Nieuw elan in de aandachtsgebieden leefbaarheid platteland, Rijswijk (1995).

[19] W. Wijnen, Welvaartseconomische analyses van veranderingen in het landelijk gebied, LEI-DLO, Den Haag (1999).

[20] P.P. Witsen and W. Zonneveld, Balkanisering in conceptenland?, NIROV, Stedebouw & Ruimtelijke Ordening, themanummer Ruimte en Economie 2 (1996).