# Land Use Scanner:

## the continuous cycle of application, evaluation and improvement in land use modelling

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**Abstract**

The Land Use Scanner is a logit model that simulates future land use in a GIS environment. The model uses claims from sectoral models as input, next to physical suitability, distance decay and policy maps. The model has been applied in several planning and decision making processes. In this paper we focus on the preparatory studies for the Fifth Memorandum on Spatial Planning, and especially also to the problem of numerical diffusion in the output grid maps. Evaluation of this application has led to a series of suggestions for further improvement, such as the adaptation of suitability maps, the fine-tuning of the translation of sectoral claims to land use claims, and the refinement of the priority of allocation for different types of land use. In addition, further calibrations of parameters in the allocation module of the model may be required, and possible adaptations of the algorithms themselves.

This paper discusses briefly the development of the Land Use Scanner, its application, and the current and prospective adaptations of the model and its inputs.

## 1. Introduction

The Netherlands, a small country, since long has to contend with scarcity of space. Especially the last few decades have shown a considerable pressure on agricultural and natural land, mainly due to a slow but continuing population increase, rising real incomes and increased personal mobility. A rather strict physical planning system has channelled urbanisation in the form of new towns (1960's and 1970's), urban renewal projects (1970's and 1980's) and the designation of zones for urban outlays (1990's).

In order to support this planning system and to evaluate the consequences of further urbanisation, e.g. for valuable landscapes, nature areas, environment and water systems, it was decided in 1996 to jointly develop an instrument for the prediction of future land use patterns by the National Institute for Public Health and the Environment (RIVM), the Free University (VU), the National Spatial Planning Agency (RPD) and the Agricultural Economics Research Institute (LEI). The aim of the Land Use Scanner was to elaborate different scenarios by the integration and allocation of exogenous land use claims, coming from sectoral models such as housing and employment models. The resulting future land use configurations could in turn be used as input to other models, such as hydrological and ecological models. The Land Use Scanner can serve in this way as an important mode of communication during a planning process (Schotten *et al.* 2001a).

The Land Use Scanner has been applied in several research projects. An example of such an application is the evaluation of various alternatives for the expansion of Amsterdam Airport, e.g. further concentration on the current location, relocation of Amsterdam Airport or the relocation of the runways to a new location in the North Sea accompanied by a rapid transit connection for the management of passenger and freight flows on Amsterdam Airport. These alternatives were assessed in terms of the effects on the locational patterns of employment and population (see Van de Velde *et al.* 1997, Schotten *et al.* 2001b). Another example is the simulation of Spatial Perspectives 2030. These perspectives, stated by the National Spatial Planning Agency in rather qualitative terms, used very different assumptions with respect to trends in lifestyles, locational choices of households and companies, modal split and the future spatial organisation of the Netherlands. The Land Use Scanner has been applied here to elaborate these perspectives in a quantitative way, and to predict for each perspective the corresponding land use in the year 2030 (see RPD 1998, Schotten and Groen 2001).

The most comprehensive application of the model however has been its use for the provision of background information for the Fifth Memorandum on Spatial Planning in the period 1999-2001. This Memorandum gives national policy directions for spatial planning up to the year 2020. Since this was a large project, it has yielded a wealth of information about the strong and weak points of the Land Use Scanner and the data used.

In this paper this particular application will be evaluated. The research question is therefore twofold: what have we learned from the application of the Land Use Scanner to support the Fifth Memorandum on Spatial Planning about its possibilities and limitations, and how can we improve this application in future?

Before we continue, the structure of the model will be discussed in section 2. Then, the application for the Fifth Memorandum on Spatial Planning is considered in more detail in section 3. After as short evaluation in section 4, more attention will be paid to the particular problem of numerical diffusion in section 5. Subsequently, the lessons learned, proposed improvements and their implementation in research programs will be dealt with in section 6. Finally, a short conclusion in section 7 will end this paper.

## 2. The Land Use Scanner: basics of the model

The Land Use Scanner has to be placed in the tradition of equilibrium models, which use assumptions about supply, demand and price setting based on micro-economic theory (Schotten *et al.* 2001a). At the moment the Land Use Scanner is predominantly used for the elaboration of scenarios, since it is not yet really suited for spatial optimalisation questions. This means that more or less qualitative scenarios which indicate future socio-economic developments, serve as input to sectoral models to predict the future demand for land per distinguished land use type. Alternatively, expert judgment may be used to generate land use claims when it is not possible to use models. Normally the spatial unit is defined as grid cells of 500 by 500 metres, but this size can be adjusted if necessary. Also the classification of different land use types is flexible. For most applications, a classification of 15 land use types has been used, namely residential, industrial, roads, railways, airports, pasture, corn, arable land, flower bulbs, orchards, cultivation under glass, other agriculture, forest, nature and water (Schotten and Boersma 2001).

For the allocation of future land use, three main parts of the models with corresponding datasets are of importance (see figure 1):

1. *current land use*;

The current land use map is based on the Land Use Statistics 1996 dataset from the Central Bureau for Statistics and a classified remote sensing image, namely LGN-3. It derives its utility from the fact that the location with respect to certain land use types determines the attractivity, and in this way the suitability for these land use types. Besides it is used for the calculation of the total acreages per land use type in the base year and for the calculation of the initial values of the balancing factors.

2. *land use claims per land use type*;

As said earlier future land use claims are generated by sectoral models or expert judgment, when policy agreements may have reserved areas for the realisation of its aims.

3. *suitability maps*.

Per land use type suitability maps have been created. Suitability maps may include distance relation, policy and physical environment maps. Distance relation maps contain attractivity values, which, comparable to gravity modelling, are calculated by determining the distance to (current) types of land use or features with the help of distance decay functions. Policy maps are needed when future land use changes are known in advance, for example when these locations are reserved for infrastructure, residential or industrial/commercial development because earlier policies, such as the Fourth Memorandum or Betuwe-route, are pursued. It is assumed that these reserved areas are completely filled in with the new land use type. Also the realisation of new nature areas means that often considerable acreages have been designated for land use transformation in some areas, although the exact contours of these areas may be less explicitly known than for residential areas. Usually an indication is then given of the raw boundaries, and the claims of the concerning land use type do not have to fill in the location completely. Physical environment maps contain information about the soil and hydrological situation. This situation may impede the realization of certain types of land use.

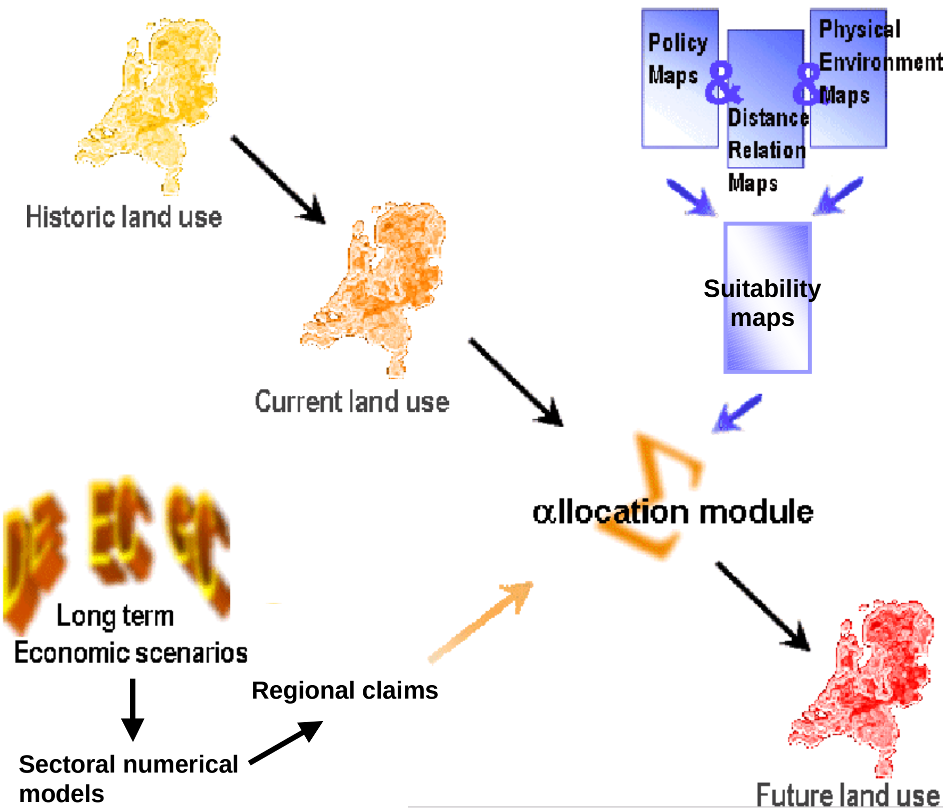


*Figure 1 – Flow chart of the model structure*

The mathematical elaboration of the model uses a logit approach. The probability that a certain type of land use is realized in a certain grid cell, is determined by a comparison of the suitability of this cell for this type of land use with the summed suitability for all other types of land use (see for a more extensive discussion Schotten *et al.* 2001a and Hilferink and Rietveld 1999 and 2001). The model is doubly constrained by the introduction of two balancing factors. The first balancing factor makes the expected amount of land allocated for each land use type equal to total demand for that land use type, the second factor implies that the sum of expected volumes of the various land use types per cell is equal to the total area of the cell (Schotten *et al.* 2001a). In a model run, initial values are chosen based on linear programming techniques. In a number of iterations the solution of the model is reached.

## 3. Application of the model for the Fifth Memorandum on Spatial Planning

The basic goal of the RIVM's preparatory studies for the Fifth Memorandum on Spatial Planning (hereafter called Fifth Memorandum) was formulated as follows: "Supporting policy formulation for the Fifth Memorandum through the presentation of spatial reference images for future residential, industrial and infrastructure developments (for the year 2020) based on verifiable assumptions regarding historical trends and/or existing spatial policy" (Goetgeluk *et al.* 2000).

This first study focussed on residential developments based on a continuation of the Dutch policy of compact urban growth management. Later on, a similar study was made for an imaginary situation in which this strict policy was abandoned, and land could be used according to free market principles (Crommentuijn *et al. forthcoming)*. For both studies, regional claims for residential and industrial/commercial land use were obtained from sectoral prediction models. First, projections of demographic data according to three general socio-economic scenarios resulted in different demand figures for residential construction (for single and multiple family dwellings) at the level of COROP regions. These figures were calculated using demographic and residential market models. In addition, projections of the economic developments per industrial sector were fed into the OPERA shift-and-share model, which resulted in employment forecasts at the level of four digit postal code areas. These forecasts were converted to demand figures for industrial estates and office buildings.

For the allocation of these regional claims to grid cells of 500 by 500 metres, the Land Use Scanner model was used. For the allocation of residential areas, suitability maps were prepared based on regression equations describing the housing developments in the period 1980-1993 (Wagtendonk and Rietveld 1999). This regression analysis showed a strong relationship between residential development and proximity to existing residential areas (partly as a result of the compact planning policy) as well as with the assignment of settlements as new towns by the central government in the 1960's and 1970's. Other significant variables included the accessibility of work locations (jobs) and accessibility of nature areas.

The allocation of industrial/commercial land use to grid cells was made using suitability maps based on expert knowledge, where factors such as proximity to highway exits, railway stations and existing industrial estates were taken into account.

Infrastructural developments were simply taken from existing concrete development plans, such as the Betuwe-route. The same accounted for nature, as the Dutch government has planned to purchase 150.000 hectares of nature areas for development as nature reserves or forest/landscape elements.

For agricultural land use regional claims at the level of municipalities were provided by the Dutch Regional Agricultural Model (DRAM) of the Agricultural Economics Research Institute. The suitability maps were made by combining yield reduction maps and both the existing location and proximity of the concerned agricultural land use type (greenhouses, flower bulbs, arable land and pasture).

In order to make the integrated land use map a hierarchical allocation procedure was chosen. On the present land use map, the following land use types are overlaid: the earlier simulated residential areas, planned (in the first study) and simulated (in the second study) industrial and commercial areas, planned infrastructure, leisure areas, water and natural areas, and finally simulated agricultural areas. In case the amount of land use exceeded the 25 hectares of each grid cell, the area of the last mentioned type (in the row) was reduced until the cell contained the 25 hectares that can be allocated in a 500 by 500 metre grid cell (Schotten and Heunks 2001). Such a method presupposes a unidirectional competition between different land use categories where housing can always pay more than industry and the other categories, and agriculture is always the last in the row to be displaced by all other categories. Agricultural areas are very likely to diminish in view of globalisation and trends in the EU. This means that the claims for additional space by other types of land use will be largely allocated to formerly agricultural land. It is clear from the above that the integrated land use map was not constructed with the price mechanism of the Land Use Scanner.
Figure 2 shows the Land Use Scanner output map, integrated dominant land use 2020 according to the European Co-ordination scenario. In this scenario it is assumed that continuation of the current planning regime will result in highly concentrated urban growth.

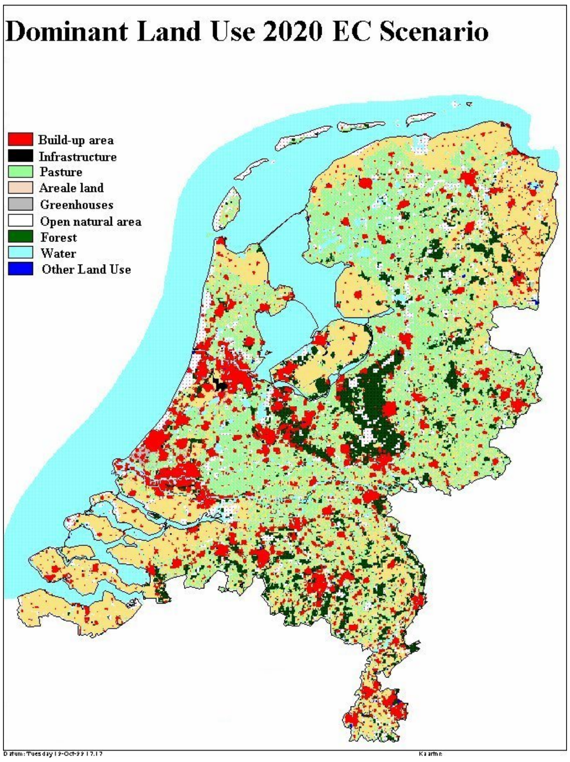


*Figure 2 – Integrated land use map 2020 for the European Coordination scenario, compact urban management and autonomous developments*

## 4. Evaluation: achievements and problems encountered

Evaluating the application of the Land Use Scanner for the Fifth Memorandum, a number of achievements can be mentioned.

The Land Use Scanner proved to be able to use and combine widely varying input data. Demand figures for residential land use were allocated to existing urban areas and to planned development areas (so-called "Vinex locations"). The remaining demand for residential land use was allocated on the basis of probability maps resulting from the regression analysis of historical trends. Where residential land use claims were input at the level of fairly large COROP regions, industrial land use claims were input at the much smaller postal code level, and agricultural land use at the municipal level. Thus, the Land Use Scanner used different types and levels of input data, and suitability maps composed by statistical as well as expert knowledge. An additional advantage of the pre-processing of input data was the creation of a large database containing reusable, basic datasets such as present land use, made by the combination of remote sensing images and land use statistics, and several suitability maps.

In addition, it appeared that the Land Use Scanner could also be used to generate different kinds of outputs. The Land Use Scanner was able to allocate surface area in fractions of hectares or grid cell percentages according to empirically determined densities. The maps of separate land use categories could be combined in an integrated dominant land use map of all categories, as reproduced in figure 2. The Land Use Scanner outputs served as input to other models, such as ecological models, and partly into the OPERA employment prediction model, but also into an analysis of changing living environments (a categorization on the basis of the proportional occurrence of houses, shops, businesses, green spaces), urban hierarchies and infra-structural developments. It can be concluded that the Land Use Scanner can be successfully applied in a sequential chain of models, ranging from housing and employment models to ecological models.

Apart from these concrete results, the Land Use Scanner application studies brought together a wide number of experts and institutions from such wide-ranging fields as information technology, environmental assessment, housing, economic and infrastructure planning. A consortium of founders and clients around the model kept an overview over the developments and applications. The integrated model resulted in better communication between different sectoral bodies, leading to a better integrated spatial planning process. As said in section 1, this was one of the original aims of the model.

However, the Fifth Memorandum application also revealed a number of limitations. One of the major problems concerned the complexity of the research question. The Land Use Scanner model required input data (claims) from different institutions, that were running their models partly on the basis of inputs required from the Land Use Scanner. During the process, other data appeared to be required, e.g. on the actual density of dwellings in new development plans. Therefore, some rough estimations had to be included to make the system work and deliver the output maps on time. It was gradually realised that there was a lack of quantitatively established knowledge about some relationships and indicators. Residential developments could be simulated rather effectively using the regression equations (Wagtendonk and Rietveld 1999), but for other land uses there was a gap between demand and actual allocations. The flexibility and integrated nature of the Land Use Scanner model appeared to have its downside too: model users have to fill in many unknown gaps using common sense, as scientifically underpinned indicators are not available, and the model leaves many issues to be resolved by the user. The step-by-step rather than planned iterative nature of the research process and wide variation in scientific underpinning of input data and suitability maps led to the pragmatic choice for a hierarchical allocation procedure rather than the original Land Use Scanner method of competing land use allocation by means of shadow prices (for a thorough description of this shadow price or land scarcity indicator mechanism, see Hilferink and Rietveld 1999).

Another important problem relates to the free market principle of the Land Use Scanner model. The model departs from a situation of free competition between different land uses, on the basis of the equilibrium principle between demand and supply at macro- (regional) level. However, many spatial developments in the Netherlands are planned by the government. For the Fifth Memorandum study, a number of residential development plans up to the year 2010 were already planned. Similarly, the development of nature areas is planned up to the year 2018. In some regions it was not possible to fill these areas in completely, as there was a shortage of claims and the model does not allow a mixed allocation mechanism whereby part of a land use category is filled without using suitability maps, and another part is simulated. Therefore, the suitability of these locations was raised to a very high level to ensure that the allocation of the concerned land use type actually would take place, but this was based on simple trial-and-error and could not always result in the required allocation. The fixed nature of planned spatial developments also led to the choice for the hierarchical allocation procedure rather than competing land uses. This choice constrained the validity of the model, as the original market equilibrium principle was not applied. Moreover, the model uses a market equilibrium at macro-level, with regional claims from sectoral models as independent demand input figures, without taking into account that this demand may vary depending on supply and suitability data: demand and supply are price inelastic at the regional level.

Thirdly, as the model is a market equilibrium model, it neglects actor-oriented spatial behaviour. Many land use developments are driven by actor-specific, sometimes non-rational or at least non-economically driven behaviour. Some of the sectoral models include behavioural elements, but for the Land Use Scanner their output claims had to be converted to surface area figures. A lot of information was lost or generalized in this conversion process.

A fourth limitation appeared directly from an exploration of the output maps: on all maps the separate allocation of land use, e.g. residential and working locations, was seen to be spread over a much larger area than at present. This spread effect, whereby a relatively large number of cells receive very low acreages, could be defined as ‘numerical diffusion’. It is intrinsic to stochastic probability models to produce such maps if the indicators are very smooth or insecure. This problem was subject to a separate sensitivity analysis, on which we will dwell further in the next paragraph.

Finally, it was found that the Land Use Scanner requires further evaluation in terms of reliability of results and error margins. Although the model has been studied quite extensively and parameters calibrated to a certain extent, the model has never been validated using the original algorithm applied to historical land use data, comparing the result to existing present land use in the Netherlands (see Ransijn *et al.* 2001, Hilferink and Rietveld 1999, Scholten *et al*. 1999, Schotten and Heunks 2001, Van der Waals *et al.* 2001).

## 5. The case of numerical diffusion

In this section, which is based  on a elaborate sensitivity analysis by De Regt (2001), the spread effect mentioned in the preceding section, will be dealt with in more detail. The Land Use Scanner calculates grid cell values, representing the surface area (in fractions of hectares, i.e. various decimals) occupied by a certain land use (e.g. residential housing) within that grid cell (each grid cell covering 25 has.). In that sense the Land Use Scanner is similar to a numerical model. In numerical models, the process of diffusion of values from a higher concentration to a lower concentration, finally resulting in a homogeneous distribution, is referred to as ‘numerical diffusion’. In the analysis the spread of lower values in the Land Use Scanner output maps was attributed to the same ‘numerical diffusion’ process.

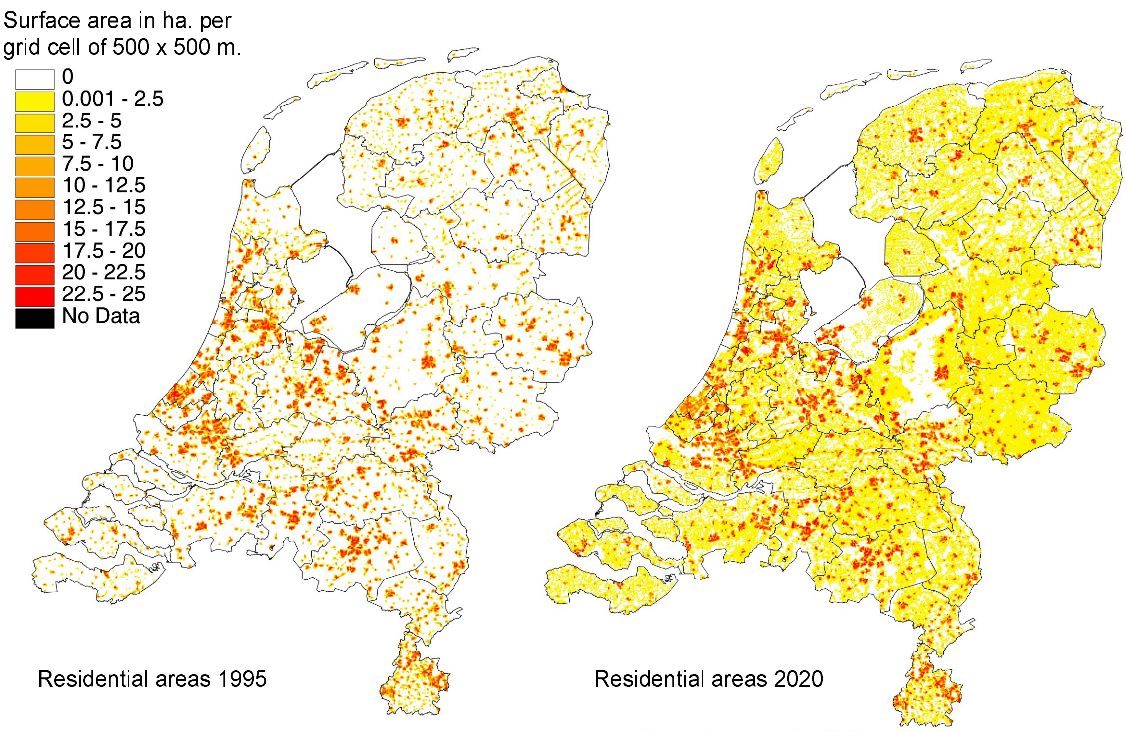


*Figure 3 – Residential areas in 1995 and modelled with the Land Use Scanner for 2020 (European Coordination scenario, existing policy and autonomous developments)*

The comparison of actual (1995) and modelled (2020) residential areas in figure 3 shows clearly that expansion of these areas occurs over nearly the whole country, but generally in very low acreages (less than 2.5 has. per cell). The value attribute table of the modelled map even shows that 75% of the grid cells includes only 1 hectare or less of residential area, and a substantial number of grid cells only a few square metres. This appeared to be similar for all Land Use Scanner output maps. Of course, since the Land Use Scanner is a stochastic probability model, these values do not represent actual allocations of residential space, but probabilities. Nevertheless, a relatively high number of grid cells with such low acreages (or percentages, or probabilities; in this instance three-quarters of the country!) means that the insight that might be gained from this image about future developments is unfortunately rather limited.

Therefore, it is imperative to try to diminish numerical diffusion in the Land Use Scanner model maps. The study found three main causes, or ways to diminish the diffusion. The first cause could be found in the suitability maps. Many of these maps showed relatively little differentiation in values and little concentration, with the largest part of the Netherlands recording low values, above zero, similar to the output maps. Suitability maps are usually composed of different variables very often including GIS neighbourhood functions, especially distance decay functions, e.g. distance to railway stations combined with the focal sum of existing residential areas in a circle around the cell (to specify that houses tend to be built near other houses). The more variables are combined, the more these suitability maps 'smoothen out'. In addition, it was found that GIS neighbourhood functions in themselves cause numerical diffusion.

The left side of figure 4 shows a linear and non-linear version of commonly used distance decay functions. The surface area of lower values is in these cases always larger than the surface area of higher values. The peaked and convex functions at the right side of the figure result in the opposite; such functions therefore do not lead to numerical diffusion, but to concentration of allocations in specific places. However, spatial relationships resulting from regression analysis are usually of the left type. Fixed yes-or-no relationships are uncommon in the socio-economically driven spatial world. Nevertheless, in order to come up with insightful future images, it is recommended to strive for more differentiation in suitability maps, using 'peaked' rather than 'smoothening' functions.

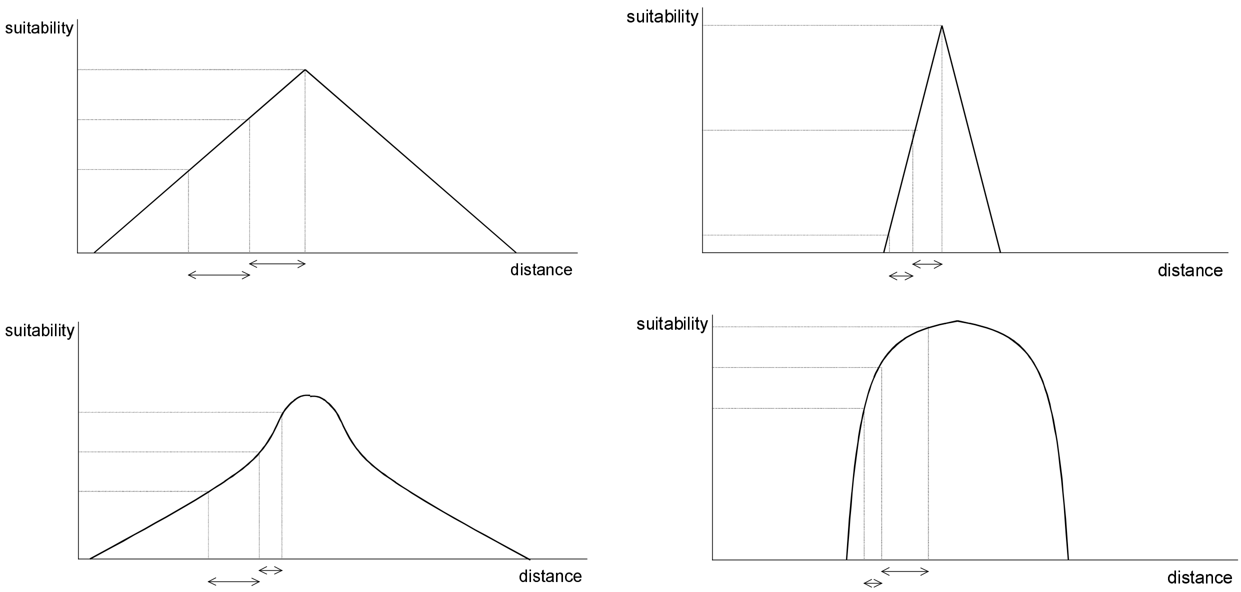


*Figure 4 – Linear and non-linear suitability functions, smoothening and peaked*

Secondly, a solution may be found in the following question: how do we translate probability maps into actual allocation maps? Or: how can stochastic probability models be used as 'predictive' simulation models? Leaving aside the latter question (relevant as it may be, we are eager to get experts' responses), the diffusion problem can partly be circumvented by:

- Setting a minimum level of acreage to be allocated to any one grid cell,
- Clustering the low values, in a final round of re-allocation, using some kind of spatial relationship.

The third final cause, or complex of causes, of numerical diffusion relates to the allocation module of the Land Use Scanner itself. Basically, the algorithm used proportionally allocates land use according to the suitability distribution:

$$x_{cj} = \frac{\exp(\beta \cdot s_{cj})}{\sum_j \exp(\beta \cdot s_{cj})} \quad \text{for all } c \text{ and } j.$$

where $s_{cj}$ = the suitability (net benefits) of land use type $j$ in cell $c$

$\beta$ = a constant, interpreted as the marginal costs for changing the suitability

Up to now, the constant $\beta$ is always kept at 1, which means that the probability $x_{cj}$ is totally determined by the suitability; therefore the diffusion in the suitability maps causes the same diffusion in the output maps. If $\beta$ is higher than 1, the probability of the cells with higher suitabilities increases (Ransijn et al., 2001). In an ArcInfo simulation using a similar algorithm, very few grid cells were filled completely with one land use category, as the suitability was so much spread out that it could not even fill the cell with the highest suitability per region (De Regt 2001).

Another problem arises when the regional land use claim is higher than the total suitable area available within that region. In the ArcInfo simulation this was solved by giving all grid cells a minimum suitability of 1, which caused the allocation to spread out even more. In the Land Use Scanner algorithm, this is solved by the introduction of the balancing factors $a_j$ and $b_c$, where $a_j$ ensures that the total demand (regional claim) for land use type $j$ is met, and $b_c$ that the allocations do not surpass the total area available per cell. The value of these factors is determined in an iterative simulation process, similar to the bidding process in the land market: the land use type with the highest claim in relation to the amount of land that is initially allocated to it will offer the highest bid on the available land. In the Fifth Memorandum studies this shadow pricing mechanism was not used, but replaced by the hierarchical allocation procedure described in section 3. Nevertheless, in a situation where all land use claims should be met and together they are more than the available area, the shadow prices will continue to rise infinitely. Therefore, it is possible to define so-called inequality restrictions, which may indicate the maximum or minimum value of every regional claim, or its bandwidth (see Ransijn *et al.* 2001). This has never been done in a practical application either. In any case, the convergence between regional claims (and the variables used in the sectoral models) and the suitability distribution is a matter of concern.

With regard to the allocation algorithm, the following recommendations are made:

- To make use of the shadow pricing mechanism, possibly in combination with some inequality restrictions,
- To experiment with a varying $\beta$-parameter, so as to allocate relatively more to cells with higher suitabilities, and/or
- To make use of a type of multi-stage allocation mechanism (where highest suitability cells are first filled, to be followed by the next highest level, and so forth) instead of a pure proportional mechanism,
- To create a spill-over option for allocation of excess claims to neighbouring regions.

## 6. Plans for improvement and further application

On the basis of the general evaluation of the Fifth Memorandum applications and the specific suggestions relating to the numerical diffusion problem, the National Institute for Public Health and the Environment (RIVM) has initiated the following plans for improvement of the Land Use Scanner model and its applications:

- Various studies have been planned in order to improve suitability maps for different land use categories. While the study on residential developments was already available (Wagtendonk and Rietveld 1999), another study on industrial estate locations was undertaken (Wagtendonk and Schotten 2000), as well as a study on accessibility indicators (Hagoort 1998). For agricultural land use, the Agricultural Economics Research Institute of The Netherlands has done more work on the elaboration of an agricultural land market model, which can produce regional claims for different agricultural land uses (Koole *et al. forthcoming*).

- Plans have been made to validate and calibrate the model. This includes several sensitivity analyses related to the application of the shadow pricing mechanism, slight variations in assumptions (like the above proposed variation in the $\beta$-parameter), and a validation of the output maps based on a historical comparison or a comparison with a cellular automata model (also used at the RIVM), as well as a comparison between modelled and real/interpolated land prices. These actions may lead to a reformulation of the model, e.g. by including a multi-stage allocation algorithm, a spill-over option, different spatial interaction processes (e.g. agglomeration, substitution, minimal and adjacent spatial requirements, grid-cell interdependency) and/or a feedback mechanism so as to adapt sectoral claims to suitabilities or e.g. land prices (Van der Waals et al., 2001). This may include the specification of elastic demand functions at the aggregate (regional) level, as indicated by Schotten *et al.* (2001a).
- Further research is being undertaken to assess the spatial behaviour of various actors. This actor-specific behaviour may be included by improving expert judgement in the elaboration of the suitability maps. Alternatively, the model may be adapted or reformulated to take into account actor-specific behaviour.
- During the same period another land use model was developed by our institution, based on the concept of cellular automata (Environmental Explorer). Both models have been used for the same type of applications. Therefore, a thorough investigation of the differences and theoretical backgrounds of the two models was necessary in order to make well-founded decisions on the use of one model or the other (Timmermans 1998). At present, both models are being integrated in one common toolbox with similar input and output requirements so as to enable a comparison of results and to apply the most useful part of each of the models. Some of the improvements in the allocation module of the model described in the above two bullets may be solved by including a cellular automata module in the model.
- A number of case studies have been planned for the second half of 2002. In these case-studies, the Land Use Scanner and Environmental Explorer will be applied and tested in a region, so the results can more easily be checked.

Apart from these fundamental research and model development plans, the Land Use Scanner will be used again for the simulation of land use in the context of new policy research initiatives, such as the four-yearly Environmental Outlook of the Netherlands, for a possible continuation of the Fifth Memorandum studies (the Memorandum has not yet been finalized, as the Dutch cabinet fell in the last stage of its completion), or for new spatial scenario studies of the new Dutch Office for Spatial Policy Analysis (RPB). In its subsequent uses, lessons learnt from the previous applications will be put into practice: the research planning should be more comprehensively elaborated, more use will be made of available allocation module options and substantiated, converging sectoral claims and suitability maps.

## 7. Conclusions

It can be concluded that a model such as the Land Use Scanner is never completed. Each application generates new insights in the weak and strong points of the model. Co-operation with other institutes is necessary to maintain and extend its knowledge base, since also a great deal of specialised information about actor behaviour, its spatial consequences, and the causal relations between different entities in the model are needed for this.

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