Support of the Reallotment Process in Land Development Projects in the Netherlands

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1. Introduction

Land development in the Netherlands is an important instrument in realizing policy aims for the rural areas. The mechanism of land exchange (reallotment) is considered an important part of this land development process. By means of this reallotment land of different owners can be allocated at the most advantageous position from various points of view.

In the past the reallotment process has proven to affect the environmental conditions in the land development areas in a negative way. Over the last decades land development has gradually shifted from an instrument aimed at the improvement of an area in an agricultural way to a multi-functional instrument, in which more attention is paid to the possibilities to conserve and improve, e.g. ecological and environmental conditions in an area. The introduction of a policy document on nature protection and development in 1989 [*Min. LNV, 1989*] has had a large impact on land development projects. Lately also environmental demands have been introduced more explicitly within the land development projects [*Min. LNV, 1995*].

Recently much research has been done on the translation of ecological demands into criteria that can be used when addressing spatial problems such as the land development problem. Survival chances of flora and fauna species are dependent on several characteristics of the environment they live in. One of the aspects that can be influenced through land development is the realization and protection of green elements they use as a living environment. The most commonly used concept in this matter is that of the metapopulation [*Opdam, 1988*]. The chance of survival of a species is according to this model dependent on several characteristics of the landscape elements this species uses as a living environment. Important characteristics are the size of the landscape elements, the connectivity between these elements and the quality of these elements.

The realization and protection of the necessary larger landscape elements during a land development project is mostly guaranteed by their inclusion the land development plan. But the metapopulation concept also attaches great value to the smaller landscape elements (e.g. wooded banks, hedges and rows of trees) for the survival of flora and fauna species, since they facilitate movements between habitat patches. These smaller landscape elements are not explicitly included in the land development plan, but their realization and protection is dependent on the reallotment process. When designing an agricultural optimal plan parcel boundaries will be cleared away to be able to create large, preferably rectangular parcels. Since the smaller landscape elements are often located at parcel boundaries, they are cleared away, conserved or relocated especially during this process.

The evolution of the land development instrument from an agricultural instrument to a multi-functional instrument has to have an impact on the way the reallotment process is carried out since the landscape elements present in the land development area are taken into account more.

Also the length of the land development process is reason for concern. The realization of a land development plan takes in average 5 to 10 years. A disadvantage of this lengthy process is the risk that the ideas presented in the land development plan are outdated by the time the land development process is completed. An answer to this problem has been the use of less precise land development plans. An example is the designation of regions in the land development area where a certain amount of green elements need to be planted instead of appointing a set location and size for each planting element separately. This delay of decisions until the execution phase of the land development process increases the complexity of the reallotment process even more.

2. Support of the Design Process: A Combination of a Geographical Information System and a Knowledge-Based System

The delay of design decisions to the reallotment phase and the awareness that the elements realized and protected during this phase play an important role in the ecological welfare of the area call for the strict monitoring of this process. Developments in information technology make this monitoring possible. Other disciplines, such as architecture, industrial design and site planning, show several examples of the application of decision support systems during a design process [*Yoon, 1992*].

The reallotment problem is a spatial problem, involving knowledge about the current parcelling situation within the land development area, the land development plan and the (multi-functional) guidelines according to which a new parceling must be created. A Geographical Information System (GIS) provides the facilities to store and analyze this information in an efficient way. It can store both geometric information, such as location, size and perimeter of the parcels, and attributes such as owner and use of the parcel and type and ecological value of a line element. Besides storage and evaluation of design solutions the computer could be benefited from even more.

In the research project the reallotment problem has been considered a design problem comparative to layout problems within other fields of research such as architecture or electronic circuit design. In architecture, for instance, much effort has been put into the development of computer systems able to support this design process. A complex problem as design cannot sufficiently be expressed in the problem definition required by conventional programming techniques, so more sophisticated methods were sought. Artificial intelligent techniques or the more popular knowledge-based systems, seem better to suit the ill-defined nature of design problems and have proven to be capable to solve layout problems for buildings, offices and houses [*Mitchell, 1994*].

Taking advantage of the characteristics of both Geographical Information Systems and knowledge-based systems, a prototype of a decision support system has been developed that can support the design of a new parceling in a land development area and even perform simple design decisions itself [*Buis, 1996*].

3. Control of the Design Process

The most apparent problem in addressing design problems is the explosive nature of the search space when trying to find a solution. To limit this search space several techniques can be applied such as the use of a top-down approach, breaking down the problem into several independent subproblems and the use of an efficient control mechanism. These techniques are also used when designing a new parceling for a land development area.

The reallotment problem is handled top-down. First a global value allocation plan is calculated (figure 1 missing). This plan states which owner gets what part of their property allocated in which block unit[1], thus providing a rough location and size for the parcels to be designed. This value allocation plan can be determined using computer models based on heuristics or linear programming.

Then the detailed parceling will be designed for each block-unit separately. In the Netherlands a GIS is already being used in the final stage of the reallotment process. During this stage this GIS is used to exactly calculate the areas of the designed parcels. If necessary the parcel boundaries can be relocated by the system in order to create parcels that have the desired size (according to the value allocation plan).

The prototype developed during the described research project, supports the design of the detailed parceling. This final design-step can be controlled by the knowledge-based system.

4. The Reallotment Process

During a design process use has to be made of problem related knowledge: knowledge on design strategies, domain knowledge and knowledge on the design itself [*Buis, 1996*].

4.1 Design Strategy

The control mechanism used to steer the design of a new parceling is a data-driven approach. A well-known example of this approach is the generate-and-test method, which is also used to address this particular design problem. The computer controls the search for a design solution by evaluating intermediate design steps and choosing the best design step at that moment: a hill-climbing (depth-first) strategy. This design strategy is translated into rules.

4.2 Domain Knowledge

Domain-specific knowledge of the design problem is important to be able to control the design process effectively. For this problem e.g. a distinction has been made between field parcels and farm parcels[2]. Each parcel type has its own specific design procedure. This domain knowledge can partly be found within the rules the knowledge-based system uses and partly within the object oriented representation of e.g. parcel-types.

4.3 The Design Itself

The existing parceling situation is considered an important starting point for solving the design problem. The GIS contains the geometric description of the original situation with both agricultural and ecological characteristics that play a role in the design of the new parceling. Important agricultural characteristics are size and user of the parcels and distances from the farm buildings to the parcels of the same owner. Characteristics that are important from an ecological viewpoint are length and width of landscape elements and the type, age and area of these elements. The knowledge based system uses objects to store this information concerning the design itself.

4.4 Designing Parcels

During the reallotment process first the farm parcels are designed. Farm parcels have a set location, since the protection of the existing farm parcels is a strict guideline during the reallotment process. This significantly limits the number of design alternatives for this kind of parcels. After designing the farm parcels, the field parcels will be designed. The design

1. **A block-unit is a part of the land development area that contains the same type of land use, quality of the soil and it is often delimited by larger roads and waterways. The size of a block-unit is approximately ten parcels.**
2. **Farm parcels are the parcels wherein the farm buildings are located.**

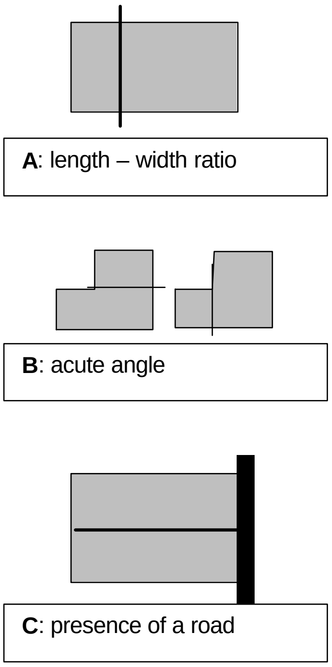

Figure 2

alternatives for these parcels are limited to the space left over after design of the farm parcels.

The design of a parcel (both farm parcels and field parcels) can be subdivided into two separate processes: the locating and shaping of the parcel. Locating a parcel means appointing a parcel, present in the 'before'-situation, to form the basis of the shaping procedure. Shaping of the parcel consists of expanding or dividing up the existing parcel. The necessary actions can be determined by the difference in size between existing parcel and the desired size of the parcel according to the value allocation plan. After all farm parcels are located they are shaped, then the field parcels are located and shaped.

4.5 Locate a parcel

The locating of a new farm parcel is simply the existing farm parcel. Locating a field parcel is more complicated though. Two different situations can arise: the farmer can already be using a parcel in the block unit for which a new parceling is being designed or his parcel is newly introduced within the block unit. In the first case his original parcel will be used as a first location. For the other field parcels a completely new location needs to be found. This new location is found using a shortest route algorithm, in which the distance between farm buildings and field parcels is considered. If two or more parcels are located at the same initial location a choice will be made based on the extent to which the size of the desired parcel fits the original parcel.

4.6 Shape a parcel

The shaping of a parcel means either a division or an expansion of the parcel. First those parcels that are too large are divided. The residual part of these parcels can then be involved in the further design process. The way a parcel is divided up dependents on both the characteristics of the parcel itself and the elements surrounding the parcel.

An example of the first category is the ratio of length to width of the parcel, an intersecting line will be chosen perpendicular to the longest side of the parcel, which is the best choice when looking at the shapes of the two thus created parcels (figure 2a). Another important characteristic of the parcel itself is the existence of an acute angle (figure 2b).

An example of the second category is the presence of a road adjacent to the parcel. In that case an intersecting line will be chosen in a way that both residual parcels will stay adjacent to the road (figure 2c).

Secondly the parcels that are too small are expanded, starting with the parcel that has the least expansion possibilities. During these actions several guidelines will be taken into account when choosing between different design alternatives.

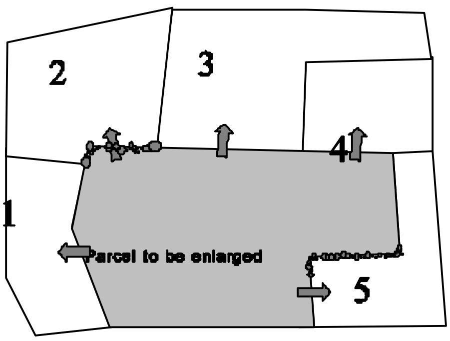

Figure 3.

In the example of figure 3, five alternatives exist for enlarging the grey parcel. When taking into account the shape of the newly created parcel (important from both an agricultural and an environmental point of view) alternative 5 is the best option.

If we take into account the value of the disappearing boundary line (important from both an ecological and landscape point of view), alternatives 2 and 5 are undesirable because of the valuable tree lines that will disappear.

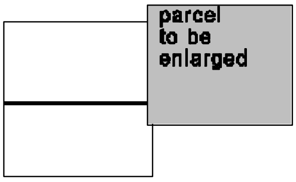

Figure 4.

Dependent on the relative weight of the criteria one of the alternatives will be chosen by the system. If none of the alternatives is possible according to the criteria of the system, enlargement of the parcel will not take place. In that case an additional parcel will be designed for the user.

or expanding a parcel, division of the neighbouring parcel may also be necessary. In that case the shape of the original parcel can form an extra characteristic decisive in the determination of an intersecting line (figure 4).

5. Weighing of Criteria

In order to resolve the conflicts between ecological and agricultural demands, a weight can be attached to both types of demands. The user can choose to have either agricultural or ecological demands prevail, or to have an equal weighing of both types of demands. Also the user needs to state which existing boundary lines or other topographical elements could be removed or replaced according to their appointed value or type.

The first criterion, relative weight, is used when the system needs to take a design decision that is beneficial to one function, but detrimental to the other. The second criterion excludes certain line elements from the negotiation process of the design beforehand, while the survival of others is dependent on the way this process evolves.

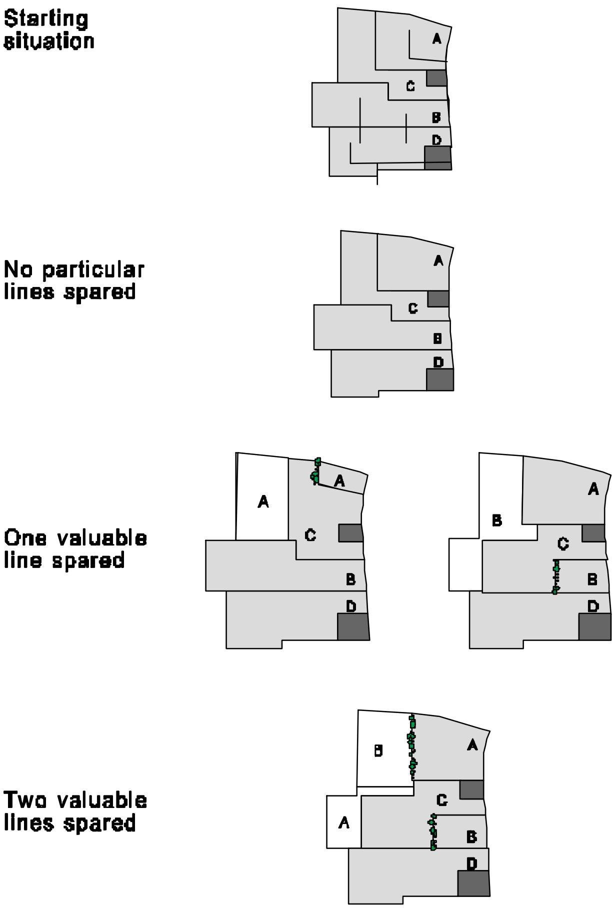

Figure 5.

When for instance two parcels are combined, this will cause the disappearance of the borderline that might consist of a landscape element. If the agricultural demands prevail, this combining will take place, assuming that the line is not excluded from the negotiation process beforehand. If the ecological demands absolutely prevail, this combination will not take place. In all cases, first alternative combinations will be examined in an attempt to reduce negative effects on the other function.

6. Results of the Design System

The design system has first been tested using the small design problem shown in figure 5. In this example several existing boundary lines have been appointed lines to be spared, resulting in different design solutions. The introduction of more ecological demands (more boundaries to be spared) results, as could be expected, in a solution that is less attractive from an agricultural point of view.

Further testing of the prototype shows that it is possible for the system to create design solutions that meet the demands that are made upon the design process. This can have an undesired effect on some of the other criteria, as the example of figure 5 already shows. One of the most conspicuous effects is the subdivision of total area of land that has to be appointed to one owner in a block unit over several parcels. This effect can be diminished by the user by shifting parcels, or by adjusting the value allocation plan. In further development of the system more rules could be incorporated within the system which will also reduce this effect.

7. Benefits of Computer Support

Both geographical information systems and the knowledge-based systems show characteristics that are useful when supporting the design of a layout. A GIS can be used to store the information that is relevant to the design process. Here the value appointed to line elements has been used, other information such as the total length of specific line elements in a certain area could be calculated.

The knowledge-based system enables the decision support system to perform simple design decisions itself. The use of a data-driven approach makes the intervention by the user possible. This intervention possibility is necessary since not all design situations can be coded into the computer program. One example is the evaluation of the shape of a parcel. Finding a measure to have the computer evaluate the shape of a parcel is very difficult, an evaluation that a human designer can more readily perform by examining the map.

A large portion of the information necessary for the design process can be made available to the computer system. The user in that way only has to consult just one information source during the design process. This reduces the chance of information being overlooked. Also the system can be instructed to give the user necessary information at crucial moments, reducing this chance on overlooking information even more.

A related benefit is the fact that the computer system will not relax or tighten its criteria during the design process, as a human designer inevitably will. The criteria will remain unaltered during the design process unless the designer explicitly states different criteria for different stages in the design process.

Tests with the prototype show the possibilities the system has to create alternative design solutions, though the use of the proposed heuristic method cannot guarantee an optimal solution. In the manual approach to the design problem most likely only one design would be worked out completely by the designer. Depending on the criteria that are at the base of the problem the computer can calculate different alternatives. The designer can in this way explore the effects of certain design decisions. These effects are made clear by the computer, leaving the final decision to the designer.

The system is developed to support the designer in taking design decisions. It will not take over this task completely. Incorporating more criteria and rules than are now available within the support system is possible, but it is not likely that all decision cases can be modeled. It is also debatable whether it is worthwhile to model all (rare) cases. Especially for those cases that require creative solutions contributions from the designer seems inevitable. The system can alleviate the task of the designer by performing routine design actions, so the designer can concentrate on the more challenging and creative tasks.

8. References

[Buis, 1996] A.M. Buis and R.A. Vingerhoeds, *Knowledge-based systems in the design of a new parcelling*, in: Knowledge-Based Systems, 1996, p. 307-314

[Min. LNV, 1989] The Ministry of Agriculture, Nature and Fisheries, *Natuurbeleidsplan* (Note on nature development, in Dutch), SDU, The Hague, 1989

[Min. LNV, 1995] The Ministry of Agriculture, Nature and Fisheries, *Dynamiek en vernieuwing* (Policy intentions, in Dutch), SDU, The Hague, 1995

[Mitchell, 1994] W.J. Mitchell, *Three paradigms for computer-aided design,* in: Automation in Construction, 1994, vol. 3, p. 239-245

[Opdam, 1998] P. Opdam, *Populations in a fragmented landscape,* in: K.F. Schreiber (ed.), Connectivity in landscape ecology, Münster, 1988

[Yoon, 1992] K.B. Yoon, *A constraint model of space planning*, in C.A. Brebbia and J.J. Connor (eds.), Topics in Enigneering 9, Computational Mechanics Publications, Southampton, 1992