Anticipation in Evaluation and Assessment of Urban and Regional Plans

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ABSTRACT

In order to start a move toward better computer based supporting tools for the assessment of urban and regional plans, a new research and development endeavour is proposed. In so doing, anticipation and anticipatory computing, i.e. a technique applying modelling and simulation, is found to be an interesting and promising point of departure. Hence, a fuzzy cellular automata computer model (STF) for simulation and anticipation of geographical or physical space is constructed. The main idea is to map an urban plan onto the STF for its assessing. STF has a normalised and continuous, i.e. fuzzy, system variable while both the time and space dimensions take on discrete values. Further, while ordinary cellular automata use local rules, global ones are employed in STF, i.e. there is a total interdependence among all the cells of the automata. Outcomes of STF can be interpreted more as possible future states than exact predictions. Preliminary results seem to be well in line with main characteristics of planned urban or regional geographical spaces. Further, for the managing of multi-criteria choice situations, a fuzzy procedure – the Ordered Weighted Average (OWA) procedure – with continuous control over the degree of ANDOR-ness and with independent control over the degree of tradeoff, is proposed.
Key words: Geographical space, Anticipatory Computing, Cellular Automata, Spatio Temporal Fuzzy Model (STF).

1 INTRODUCTION

In many dominant theories of planning and decision processes the work is divided into three main phases, identification and retrieval of relevant information, creation of alternatives and, assessment and choice (van Gigch 1991). So far, the development of computer support tools, e.g. GIS and CAD, has concentrated on the first two of those. Significantly less has been done for supporting the assessment phase both in general and specially in urban and regional planning (URP). However, in recent years diligent research has been devoted to anticipation (Rosen 1985, Dubois 1997). An anticipatory system being a system which develop a model of itself and its environment and which base its current decisions on simulation outcomes of that model. Hence, a working anticipatory model of a city or region seems to be a tool to be desired for supporting that last phase of the planning process. Further, in recent years fuzzy approaches have proven to be of great value in handling multi-criteria evaluations (Yager 1988, Eastman and Jiang 1996, Holmberg 1997b).

Hence, the purpose of this paper is to shred light on the possibilities and hindrances to design and implement anticipatory and fuzzy devices for assessing urban and regional plans. In so doing the following two principal questions will be discussed:

- What are the contexts and restrictions of URP and plan assessment?
- What may an anticipatory or fuzzy approach provide to plan assessment?

2 URBAN AND REGIONAL PLANNING IN A SYSTEMS CONTEXT

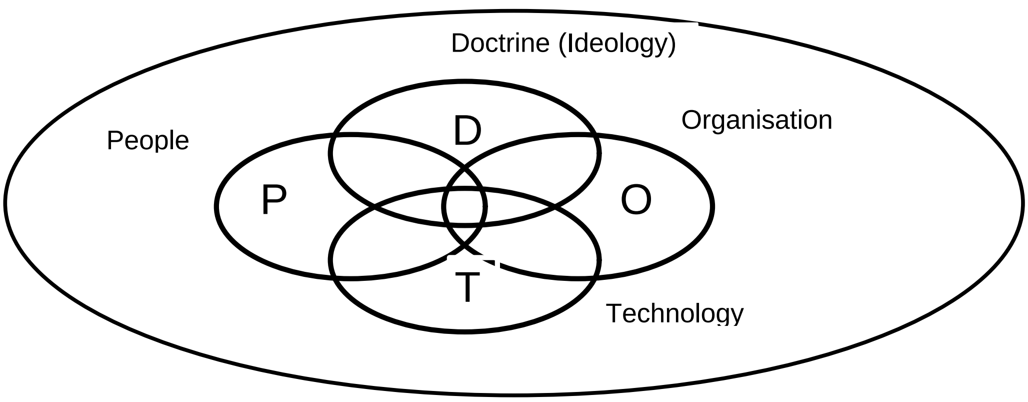
Urban and regional planning (URP) is not a context free activity. Rather, the planning is embedded in a web of organisational units, professional and administrative procedures, real world processes, ideological convictions etc. Some of those relationships and interdependencies are expressed in figure 1. Hence, even if this paper will focus on the assessment of plans it may be worthwhile to start the discussion with a few words on this systemic nature of planning.

First, in looking at the relations between the four spheres of figure 1 and the surrounding world, we find that planning and planning units are embedded in an ever changing society. The changes will be both physical, e.g. communities will prosper or decline, and political or ideological, i.e. the political ambitions and commitments will vary over time. In short, physical, political, economical and other factors will continuously and dynamically restrict or set limits to planning.

Second, even the four spheres of planning will mutually influence each other in excessive and complex ways. Starting with the doctrine sphere, changing influences between rationalistic and engineering viewpoints, e.g. as represented by the Frenche “École Polytechnique”, and more aesthetic or artistic ones, e.g. represented by “École des Beaux Arts”, have had great impact on the manner in which plans are produced and visualised (Lehtonen 1991). Further, Lehtonen (1991) has also shown that due to current technology, organisation of the planning endeavour and its working routines, the professional limits between architects, engineers and craftsmen have also undergone great changes over the years. The general tendency being that planning has become more and more abstracted and alienated from the real world.

At last, isolated programs for technology improvements, competence developments or organisational progress will as best have just marginal effects on the total effectiveness of the planning system if the states of the other spheres and their interrelationships are not considered.

Figure 1: **Planning as interplay between four spheres and a surrounding society.**



The main lesson to be drawn from this short and sketchy analysis is that the development of a computer based planning support system never can be done in isolation. However, if the development is done with skilful integration of the four spheres, considerable synergy effects can be achieved (Holmberg 1996). At last, the development of new technological infra structure and support systems has to be done with due respect to the completeness paradigm (CP) and the requisite dimensionality model (RDM), (Holmberg 1994).

3 ASSESSMENT IN URBAN AND REGIONAL PLANNING

The need of assessment in URP can be expressed with help of figure 2. According to this figure, the alternative generation phase will be followed by an assessment phase, i.e. a phase during which the outcome of each alternative is evaluated and the best alternative, according to criteria, is chosen. However, as long as the planning is performed manually without computer support, it will in most cases be possible to fully develop just one plan alternative. Minor changes may then be done to that unique alternative during the assessment phase. On the other hand, with appropriate computer support, it will be possible and handy to generate several alternatives in a short time and with limited resources. Hence, the need for a good support also for plan assessment will in this case increase drastically.

Assessment is an utterly complex concept and consequently there are many different types of assessment with different purposes, scopes, methodologies and so on (Agrell 1997). However, it will not be possible to go too far into this vast matter here. Let us just for the coming discussion identify three types of assessment, which have a special relevance in this context.

The first type, according to figure 3 a, can be called internal assessment. Here each feature of the plan will be assessed according to set criteria. However, there will not be any assessment across plan borders. The planned area is considered in isolation. This type of assessment is judged to be well established in current planning practice and will not be discussed further in this paper. The second type, according to figure 3 b, is external assessment. Here the planned area is seen as an open system. This implies that the plan will have an influence on the surrounding area, i.e. the territorial concern in which it is embedded

Figure 2: **Main steps in the planning cycle.**

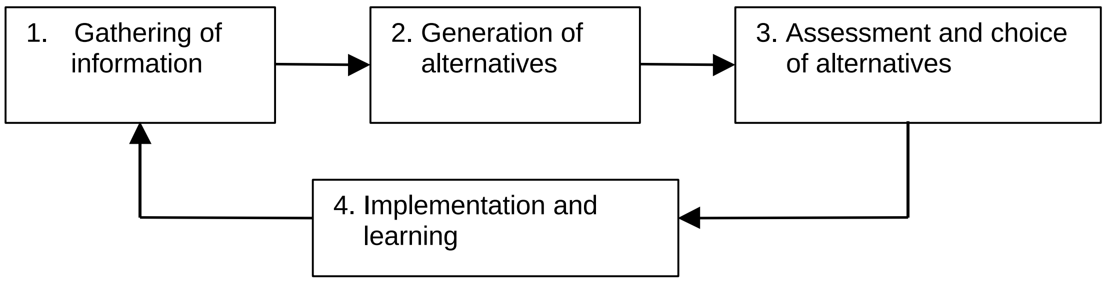
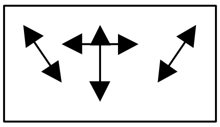
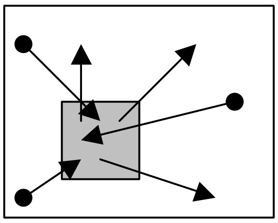


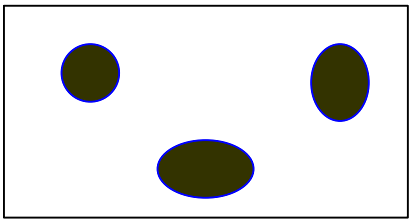
Figure 3: **Different types of plan assessment.**



a. Features internal to the plan are assessed.



b. Assessment of the plan in its environment.



c. Assessment of alternative localisations of an item.

At the same time, the planned area will be impacted by its surroundings. In short, a plan can not be evaluated in isolation. It has to be assessed together with its environment. This type of assessment will be discussed in the next section. The third type, at last, is an assessment between different plan alternatives according to figure 3 c. Here there are several localisation alternatives and the assessment has to tell us which alternative is the best one. An approach to this type of assessment will be discussed in the fifth section of this paper.

4 ASSESSMENT WITH A SPATIO TEMPORAL FUZZY MODEL

The plan to be assessed is embedded in a territorial concern (TC), i.e. a community based organisation for the design, construction, and maintenance of a territory. With other words, a TC is a living system or a society with the responsibility (the concern) to establish and maintain a structure and to keep a set of essential variables within critical levels. Examples of such essential variables may be employment rates, housing standards, education possibilities, health care and other public services, communication and so on. A common goal may be to make improvements on those variables.

Further, the interdependencies among all those variables are very complex and not fully known. In many cases there are also considerable time lags between cause and effects. A common theory, anyhow, is that each area has a direct influence on its neighbours, i.e. the same conditions or states tend to hold for an area and its direct neighbours (Langlois and Phipps 1997).

However, within a TC, let it be a city, a nation, or the whole globe, current states or events at one point also seem to have a direct influence on future states at locations far away, i.e. there will be a global influence. Some examples may help to illustrate this idea. (1) In a city, the separation of housing and business into disjoint areas may increase the risk of riots and social unrest by young people in the city centre. (2) The closing down of a factory in one part of a country will have a positive influence on job opportunities and the same concern's factory in another part of that country.

Yet another point, most entities or aspects of the TC are continuous. For example, the landscape continuously changes from flats to hills or cultivable land gradually changes into sterile ground. With other words, the reality obviously is continuous. Further, if we choose to express the TC as a system model, the system state of that model will be expressed with a set of system variables. Hence, in order to express the continuous character of reality those system variables also ought to be continuous. This is a bit contradictory to classical bivalent logic but fits very well with modern fuzzy or multivalent logic (Klir and Yuan 1995) and the fuzzy principle, i.e. "*Everything is a matter of degree*" (Kosko 1993).

The Space Hypothesis (SH) makes a synthesis of those findings (Holmberg 1998). Hence according to SH, future states of an area within a geographical space will be functionally dependant of earlier states at all other points of the same space, i.e. the local future will already be present at the current time, somewhere within the boundaries of the geographical space at hand.

In the planning case this can be expressed according to figure 4. The planned area will influence all parts of the TC in which it is embedded, but at the same time, it will also be impacted with effects from its surroundings. Hence, a good plan may be ruined if implemented in a bad environment and a mediocre plan may improve if realised in good surroundings.

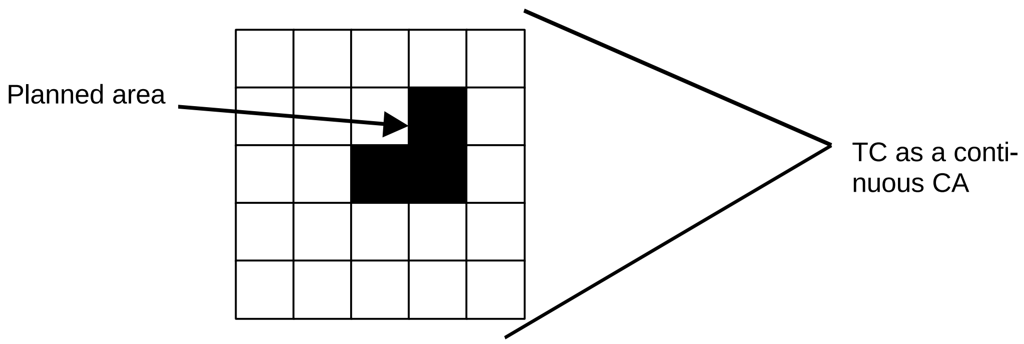
4.1 The STF Model

The Spatio-Temporal Fuzzy Model (STF), as it has been presented by Holmberg (1998), is an attempt to develop an anticipatory tool with properties making it useful also in plan assessment. STF is a fuzzy or continuous cellular automata (CA) designed according to the following points.

The cellular grid

In STF-0 the geographical region in focus is modelled as a two dimensional matrix **S** with $m \times n$ quadratic cells or sites. In order to fit into a natural region with irregular boundaries, a logical matrix **L** will be used to mask out the parts of **S**, which fall outside of the mapped geographical region.

Figure 4: **A planned area seen as cells in a STF modell.**



In addition to the state matrix **S**, there are also impact matrices $\mathbf{I}_{i,j}$, one for each cell in **S**. Hence, $\mathbf{I}_{i,j}$ is the impact matrix of cell i, j in **S**. The purpose of $\mathbf{I}_{i,j}$ is to express the strength of impact on cell i, j from the other cells in the region according to what will be explained under the heading "transition rules" below.

The states

In cellular automata (CA) the state variable s will normally take on discrete, or even binary, values (Rietman 1993, Langlois and Phipps 1997). However, in STF the state variable will be a normalised continuos variable in the interval [0, 1] and indicating to what degree the cell belongs to the fuzzy set of acceptable states.

The neighbourhood

In most CA, local neighbourhoods of the von Neumann or Moore type are employed (Rietman 1993), i.e. just the four or eight closest cells respectively are taken into account. However, in order to accommodate to the Space Hypothesis (SH), a global neighbourhood will be used in STF, i.e., we will have a transition function of the general form.

$$S_{i,j,t+1} = f(s_{1,1,t} \ldots\ldots\ldots\ldots\ldots s_{m,n,t}) \qquad (1)$$

That global neighbourhood is expressed in the right side of equation (1) because here all cells, from the first $s_{1,1}$ to the last $s_{m,n}$, take part in the computing of new values.

The initial state

The S-values, i.e. the values of each cell in the space matrix **S**, can be set manually according to their real world values. However during testing a random number generator with a rectangular distribution can be used to set values in the interval [0,1]. The same with the impact or **I** matrices, there is a manual option but normally even here the same random number generator will be used. The values of the **I**-matrices can be both positive and negative, indicating both positive and negative influence. Numerically, however, they will normally be rather small, i.e., $-0.3 \leq i \leq 0.3$. The only exception being the element $i_{i,j}$ indicating the influence of cell value $s_{i,j}$ on its next generation. This value, being in the interval 0.7 to 0.9 in order to give some inertia to the system.

The transition rules

"Transition rules" is used in normal CA vocabulary for denoting the rules governing the calculation the states of new generations. With a continuous state variable, however, it will be no real "transitions" and it becomes more appropriate to speak about "state calculation rules". Anyhow, in STF for calculating the next value of cell $s_{i,j}$ the impact matrix $I_{i,j}$ is used as a filter. Hence, by multiplying a cell in S, for example $s_{r,c}$, with its corresponding cell in $I_{i,j}$ the impact or contribution from cell r, c on cell i, j will be given. Further, by calculating those contributions from all the cells and adding them together the new value of $s_{i,j}$ will be obtained according to equation 2.

$$s_{i,j,t+1} = \Sigma\, i_{i,j,c,r}\ s_{c,r,t} \quad (:c = 1..n, :r = 1..m) \qquad (2)$$

The general procedure

The simulation develops in the following general steps. First the initial state, i.e. at time t = 0, is set, both for the state matrix **S** and for the impact matrices $\mathbf{I}_{i,j}$ (:i = 1..m, :j = 1..n). This state is produced by a random number generator, but before the simulation begins, individual cell-values can be set manually to any desired value within permissible limits. Next, new states of **S**, i.e. $\mathbf{S}_t$ (:t = 1, tmax), are calculated in succession from its prior state according to the transition rules. Hence, $\mathbf{S}_{t+1}$ is in fact a function of $\mathbf{S}_t$ and the impact matrices as denoted by (3)

$$S_{t+1} = f(S_t, I_{i,j}) \qquad (3)$$

It is worth noting that the impact matrices are not changing during the simulation. Further, a new state of **S** is calculated with help of just the prior generation of **S**, i.e. its immediate predecessor. However, this simplification in temporal dependency is compensated for by the very complicated spatial dependency. Hence, as all cells are related to all other cells there are a very great number of impact routes leading to a cell, some of those are direct one step routes while others can have a length up to the total number of cells in the space. The consequence being that the impact on a cell $s_{i,j}$ is due to values of other cells just one step back up to the total number of cells, due to the length of the impact route.

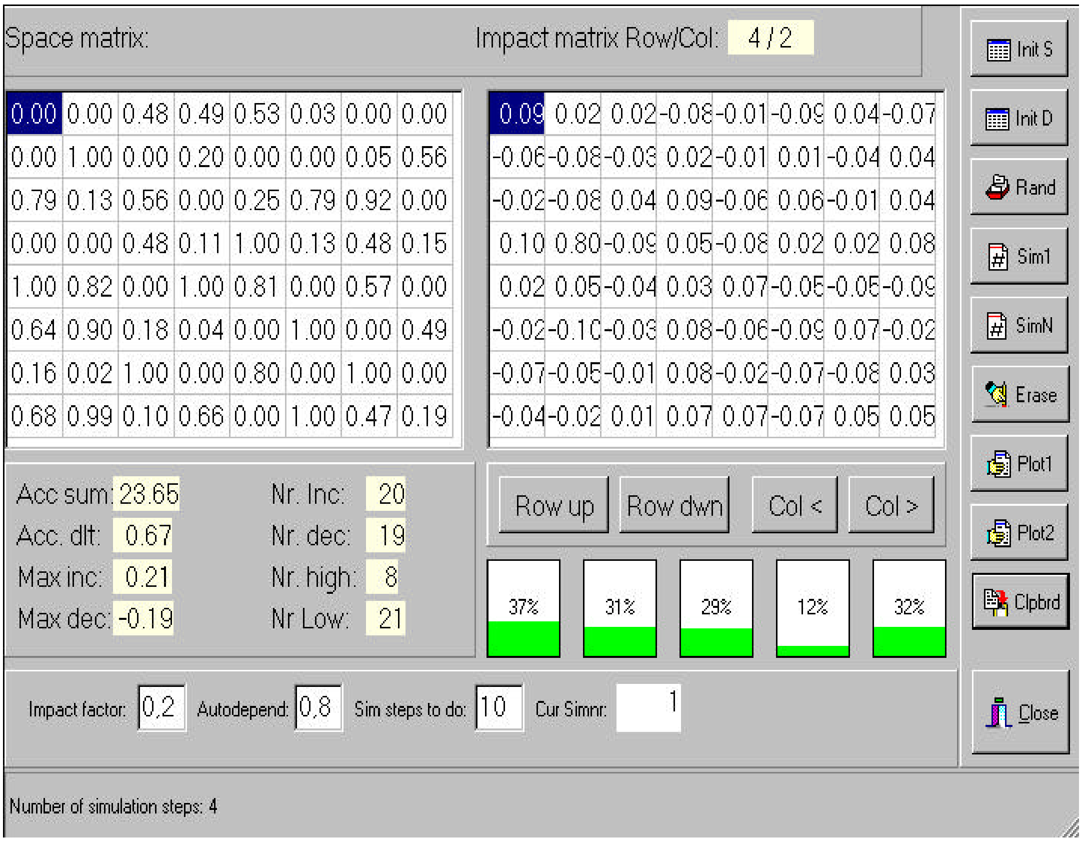
4.2 The STF computer program

The STF has been implemented as a computer program (STFP). With this program it is possible to make simulations according to the rules defined in STF. A print out of the program's computer screen is shown in figure 5. The program is event driven with command buttons for the available operator actions. The space matrix, in this particular case a 8 x 8 quadratic matrix, is displayed to the left while one impact matrix at a time is displayed to the right. By operating the navigation buttons under the display of the impact matrix it is possible to move between the impact matrices. Under the state matrix some essential system state parameters are displayed.

"Acc sum" displays the accumulated sum of the state values of all cells in the space. "Acc dlt" displays the sum of all the changes during the latest simulation step. "Max inc" and "Max dec" is the greatest positive and negative change in any cell during the latest simulation step. "Nr inc" and "Nr dec" is the number of cells which have increased respectively decreased their value during the latest simulation step. At last, "Nr high" and "Nr low" are the number of cells which have reached the max (1.0) and min (0.0) values. The values of "Acc sum", Nr inc", "Nr dec", "Nr high" and, "Nr low" is also displayed graphically.

In figure 5 the impact factor is set to 0.2. This means that the values in the impact matrices in this case will fall in the interval [-0.1, 0.1]. The impact a cell will have on its own next generation, however, is set to 0.8. The actual simulation step is displayed in the lower left corner of the screen. The simulations can be stopped and resumed at arbitrary steps. At each step, the values can be automatically saved into a data base.

Figure 5: **Print out of the STFP computer screen.**



With the current formula according to equation 2, the s-values can grow outside the normalised interval limits [0,1]. In this version of the program, that problem is solved by just clipping the values at the interval limits.

Due to lack of time, so far the program has been used only in a limited number of simulation runs. Those initial simulations have been focused on the following questions:

- Does the results support the space hypothesis (SH)?
- Is the model very sensitive to small changes in its initial conditions?
- Are there any parameter settings which make the model's behaviour chaotic?
- Are there any strange or surprising patterns in the model's behaviour?

4.3 Simulation results

Due to the limited number of simulation data obtained so far, there will still be too early to draw any well grounded or statistically proved conclusions. Anyhow, the current indications point in the following directions:

- Values, which have been introduced into the model by a “plan”, will disappear after just a few simulation steps. Hence, the outcome of a plan seems to be highly dependent on its surroundings.
- A general pattern develops after just a few simulation steps. In following steps interesting and surprising changes will occur in details but the general picture will remain very stable.
- In most cases the model seems not to be unstable or overly sensible to initial conditions.
- The number of cells with intermediate values, i.e., $0.0 < s < 1.0$, will decrease with time, but will eventually stabilise well above zero. However, if the self impact factor is set below a certain limit (often about 0.7), all cells will quickly go down to zero.
- Compared to cellular automata in their traditional form, STF seems to have introduced several new and insight generating dimensions.

To the degree that STF is a true model of a real TC it may also be possible to draw two preliminary and tentative. First, it may be very difficult, even by planning, to obtain the political goal of equal opportunities in all parts of a country or community. In all simulation runs great differences have evolved rapidly. Secondly, any country may collapse if it is not managed properly. However, a suitable anticipatory or early warning system (EWS) may give timely warnings.

In most cases the impact values for a real TC will not be known. However, in principle they can be calculated from historical data. Hence, given that those values or system relationships can be found, STF can be simulated in Model-Time in order to anticipate the Real-Time behaviour of new plans implemented in the TC.

Dubois (1995) has presented hyperincursion in which future states are computed from their neighbours’ states at past, present but also future time steps. In STF future steps are calculated not only from neighbours but from all cells in the system. By combining the two approaches, a spatial hyperincursion will emerge. The anticipated properties of such an operation are enticing, but still they have to be explored.

5 AN ORDERED WEIGHTED AVERAGE (OWA) PROCEDURE

The typical problem here is to find the best localisation for an activity or a building. Multi-Criteria Evaluation (MCE) is a concept which can be used for describing this type of decision problems. In MCE-situations there may be a large number of criteria, which have to be combined according to very complex rules and constraints. For example, the value of a variable v_i has to be greater than a certain limit l_j, i.e. an absolute condition. In other cases a ”bad” value in variable v_2 may be compensated by ”good” values in variable v_3 , i.e., a trade-off condition. A third case may be that it is enough if one variable in a group meets its threshold. Yager (1988) has developed general methods to handle this type of decision problems. Ways to adapt Yager’s methods to a geographical case or a TC have been proposed by Eastman and Jiang (1996) and Holmberg (1997b) and they will be shortly discussed here.

5.1 Crisp procedures

Traditionally two different procedures have been applied in decision processes of this type. First, the criteria are dichotomised into logical suitability values of, for example, “Yes” or “No”. Those logical values are then combined by means of logical operators such as intersection, i.e., logical AND, or union, i.e., logical OR. The procedure is straightforward but, unfortunately, has two severe drawbacks. The first is that irrespective of where we draw the border, an incremental change in input may cause a drastic and big change in output, i.e., a jump from the set of suitable to the set of unsuitable locations will take place. Further, the logical operators are too blunt as instruments for this type of subtle judgements. The intersection, for example, will constitute a too hard condition, i.e., a location which is perfect according to n-1 criteria will be excluded if it fails, due to an infinitesimal step, to fulfil just one of its requirements. The union operation, on the other hand, is far too liberal. Here it is enough if the location meets one of its criteria, irrespective how bad the values of the remaining ones are.

In a second approach, called the Weighted Linear Combination (WLC), continuous criteria are first normalised to a common numeric range and thereafter combined according to their weights of importance according to equation (1).

$$S_{wlc} = \sum wc_n / \sum w \qquad (1)$$

S_{wlc} Suitability index
w Weight of importance
c_n Normalised criterium

Here we will receive a continuous s-value, i.e. we will avoid the abrupt jumps from one set to another. On the other hand, the rationale for just adding together various criteria may be highly questionable. Second, a single extreme value, far away from the common values, may influence the result in a not very logical way.

5.2 Fuzzy procedures

Anyhow, with help of fuzzy measures and fuzzy operations the strength of reasoning will increase and most of the drawbacks discussed above may be overcome. First, if the set of suitable locations is defined as a fuzzy set, a small change in input will just cause a small change in membership grade, i.e. we will avoid the abrupt jumps between extremes.

Second, if the crisp intersection and union operation are replaced with their fuzzy counterparts, i.e. the t-norm and t-conorms, further advantages may be gained. Especially so if they are combined with fuzzy averaging operations, i.e. operations that for any given fuzzy set produces a new fuzzy set which is larger than any fuzzy intersection and smaller than any fuzzy union (Klir and Yuan 1995). Hence, with a proper averaging operator it may be possible to avoid both the hard rigour of crisp AND-operations and the excessively liberal results of crisp OR-operations.

Further, it is also interesting to find a solution which permits tradeoff between criteria, i.e. a good value in one variable may compensate for a bad value in another one.

In this context the averaging operator can be seen as an ANDOR-operator which also provide full tradeoff between criteria. A solution to this requirement is proposed by Yager (1988), who has presented a method called the Ordered Weighted Average (OWA) with continuous control over the degree of ANDOR-ness and with independent control over the degree of tradeoff. In OWA, criteria are sorted according to their rank order and special order weights, to be distinguished from criteria weights, are applied to those ranked criteria in order to achieve the desired degrees of ANDOR-ness and tradeoff. Hence, tradeoff is controlled by the degree of dispersion in the order weights, while tradeoff is controlled by their amount of skew (Holmberg 1997b).

5.3 Example of an OWA-localisation

In this example the decision maker has to choose between four geographical locations (p01..p04) based on four criteria (crit1..crit4) according to table 1. Possible intervals for the criteria are, crit1 from 1 to 10000, crit2 from 1 to 100, crit3 from 1 to 1000 and, crit4 from 1 to 100. Further, criteria 1 and 2 become better, according to the evaluation rules, with increasing values while criteria 3 and 4 ought to be as small as possible. In a first step the criteria values have to be transformed into fuzzy measures according to the rules and principles expressed in table 2 and figure 2.

Having obtained fuzzy numbers for the basic criteria, in the next step there is a need to calculate a crisp total ordering of those numbers. Several ranking methods are available for that calculation (Klir and Yuan 1995). Here we have chosen to sort the fuzzy numbers in increasing order giving the results in table 3. In table 4, at last, the Ordered Weighted Average (OWA) has been calculated for the alternative locations and with five different combinations of order weights. The final results obtained are summarised in table 5 and some of the corresponding maps are displayed in figures 3 to 5.

Table 1: **Criteria values and locations for P01-P04.**

Loc	Crit1	Crit2	Crit3	Crit4	X	Y
P01	8900	70	150	85	26	19
P02	5300	45	600	48	82	21
P03	2800	93	320	15	63	48
P04	7100	20	600	10	23	74

Table 2: **Fuzzyfication parameters.**

Crit	lim1	lim2	increas
Crit1	2000	7500	True
Crit2	15	80	True
Crit3	300	700	False
Crit4	20	90	False

Figure 2: **General form of the membership function used in calculating the fuzzy sets of good locations.**

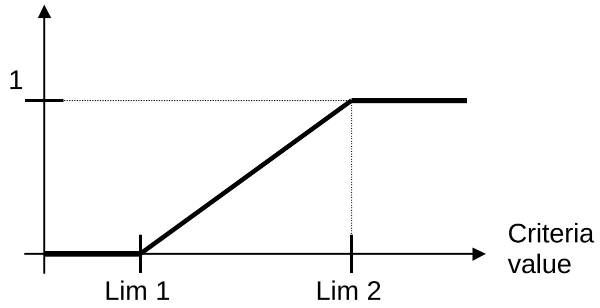


Table 3: **Ranked fuzzy measures for the four locations.**

Loc	RFM1	RFM2	RFM3	RFM4
P01	0.07	0.85	1	1
P02	0.25	0.46	0.6	0.6
P03	0.15	0.93	0.95	1
P04	0.08	0.25	0.93	1

Figure 3: **Map presentation showing results from run 1.**

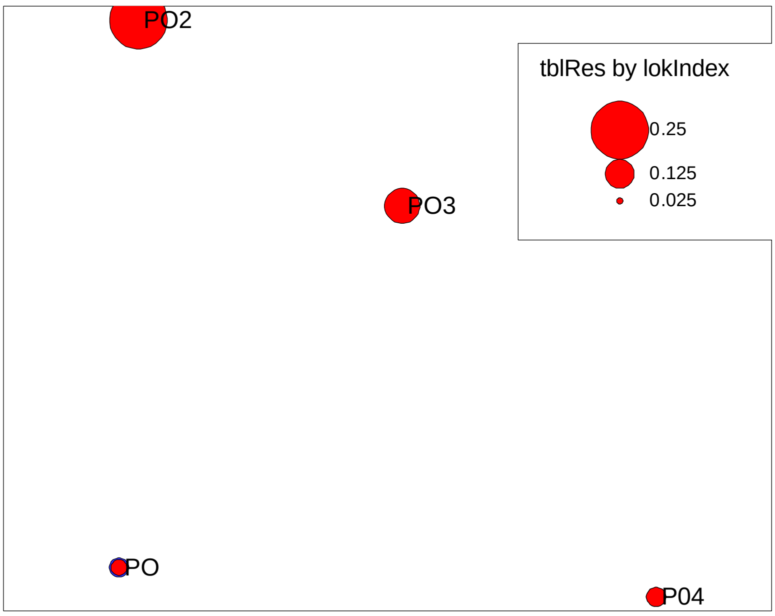


Figure 4: **Map presentation showing results from run 2.**

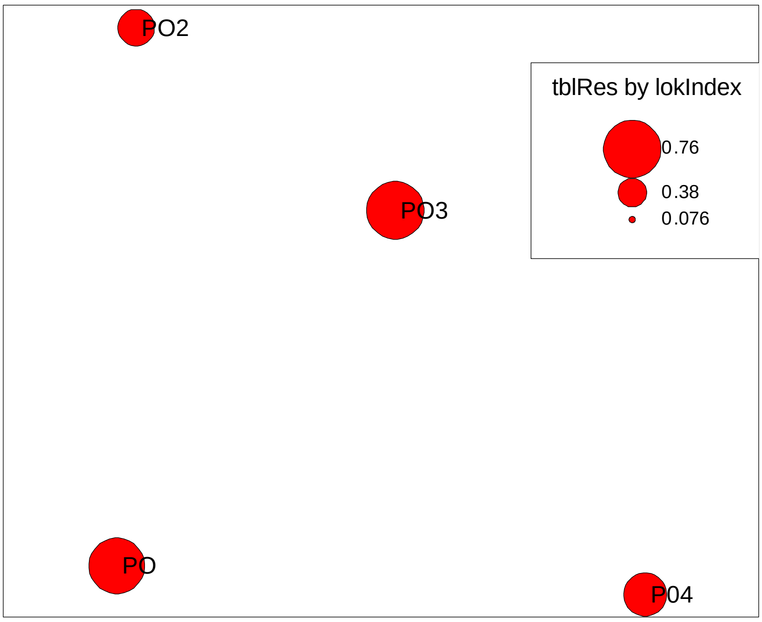
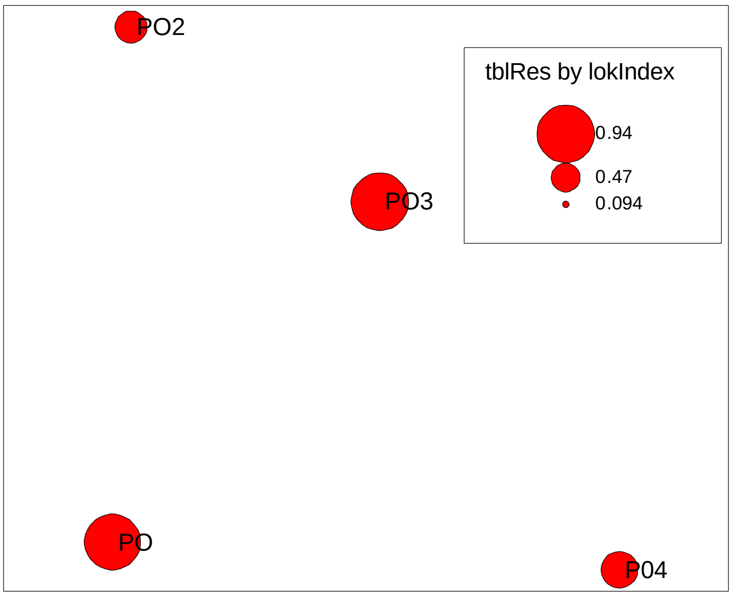


Figure 5: **Map presentation showing results from run 3.**



5. 4 Conclusion from the OWA-example

Already the elementary desktop mapping prototype applied in this short and simplified example has demonstrated the strength and appropriateness of fuzzy measures and the OWA-approach for handling spatial or geographical localisation problems.

Table 4: **Order weights applied in the five calculations.**

Run	OW1	OW2	OW3	OW4
1	1	0	0	0
2	0.25	0.25	0.25	0.25
3	0	0.5	0.5	0
4	0.6	0.2	0.2	0
5	0	0.2	0.2	0.6

Table 5: **Resulting Ordered Weighted Average (OWA) with ordered weights according to table 4.**

Loc	Run 1	Run 2	Run 3	Run 4	Run 5
P01	0.07	0.73	0.92	0.41	1
P02	0.25	0.48	0.53	0.36	0.6
P03	0.15	0.76	0.94	0.46	1
P04	0.08	0.56	0.59	0.28	1

6 CONCLUSIONS

Strong evidences are found that with increasing computer support in generating urban and regional plans there will also be an increasing need of computer based assessment tools. As demonstrated in this paper, theories concerning anticipation and fuzzy logic may be most helpful in designing and developing those tools. However, the solutions shortly discussed here are just prototypes and much research and development work remains before we have fully operational assessment tools for every day use in routine URP.

Even more interesting anyhow, if we, according to Holmberg (1994), changes the main question from, “How can we make use of computers in URP?”, to, “With current and coming information technology given, how do we ought to organise and perform URP in the future?”. The answer, if we decide that the later question is the relevant one, seems to be that the current fragmentation of community development, the gap between planning and realisation and, the alienation of the planning from the real world (Lehtonen 1991) can be overcome if the put URP in a systems context and if we develop URP’2000 according to Synergy-4 (Holmberg 1996) principles. The benefits are obvious, the gap between planning and realisation will decrease, learning and adaptation will increase and, synergy effects will develop between people, doctrine, organisation and, technology.

7 REFERENCES

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