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SIMULATING SETTLEMENT PATTERN DYNAMICS BY MODELLING SUBJECTIVE ATTRACTIVITY EVALUATION OF AGENTS

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1– An alternative approach for modelling urban dynamics

1.1 The suburbanization: a complex process

One of the most striking features of urban growth is nowadays the emergence of highly irregular settlement patterns, despite of planners' desires, who tend to canalize suburbanization. Urban pattern formation seems indeed issued from a more and more complex dynamic process: on one hand many individual decisions concerning location contribute to urbanization, on other hand since more and more communities of the urban hinterland are concerned by the suburbanization the number of local decision-makers grows, too. Thus, we may ask the question what is the part of decision in this evolution and the part of self-organization? Do urban structures emerge on their own and do planners may really control the evolution? Another way to deal with this problem is to investigate relation between different type of actors and territory, in urban and suburban areas for getting more insight concerning their respective role in urban pattern morphogenesis. That's the goal of the presented research project. While our research project keeps in tight touch with urban planning, we try to further an approach whose goal is to simulate and to visualize potential impact of planning purposes.

In this context we actually reflect on a tool for simulating urban pattern dynamics. Our approach is based on observations about location strategies of different types of actors and agents, in particular for retail, residential and industrial domains. The present paper tackles notably with the residential behavior.

We start by presenting the general architecture of the model. Then we focus on the residential choice behavior and we show how this knowledge may be used to formalize agents' decision strategy. Finally we give survey on how constructing the model.

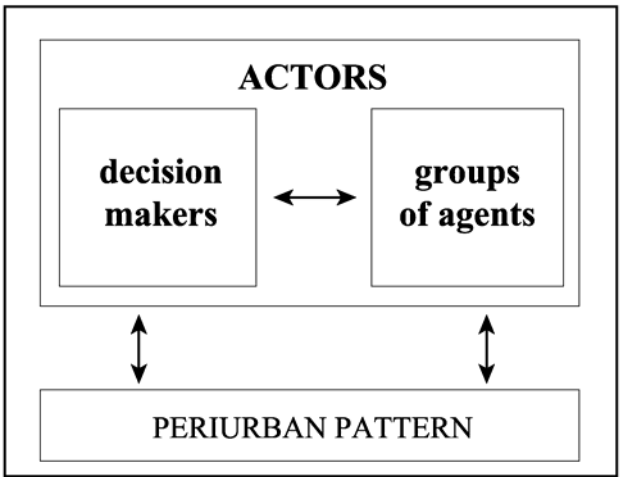
1.2 The general architecture of the model

In order to describe the urban evolution we distinguish different types of actors:

- different kind of agents like firms or residential population. We assume that they form groups of aggregated individuals according to their different objectives. Each group is considered as homogeneous in its behavior. Lobbies can be formed in course of time and thus a social demand can emerge;
- planners, whose decisions and plannings orientations (e.g. land-use plans) constrain the settlement process;
- land-use pattern, which can also be considered as an actor too, because its form represents a constraint toward the action of other actors (spatial inertia). Spatial and socio-economic interactions may occur on different time scales and spatial ranges.

Pattern dynamics is governed firstly by spatial interactions, essentially location strategies of residential population, and secondly by reactions of actors on the gradual transformation of space (retroaction of space on actors' behaviour). So can we observe a feedback between socio-economic actors and their territory (Cf. figure 1).

Figure 1: Feedback between actors and territory



The models general architecture is based on a Geographical Information System. This allows to manage spatial data in a convenient way. Concretely, we set a cartographic representation of space. The scale of the spatial units corresponds to the scale of a land-use plan. We assume that spatial entities are coded as polygons which may be represented on the screen as a cartographic representation of space. According to our previous reflections, the entities correspond to residential, commercial or other types of areas. To each of these entities is assigned a set of attributes relevant for the spatial dynamics. Such attributes could be the accessibility of a zone measured by the time, or/and the distance for acceding to the city centre, or the nearest highway exit, the land rent, different attributes referring to landscape quality, local taxes etc.

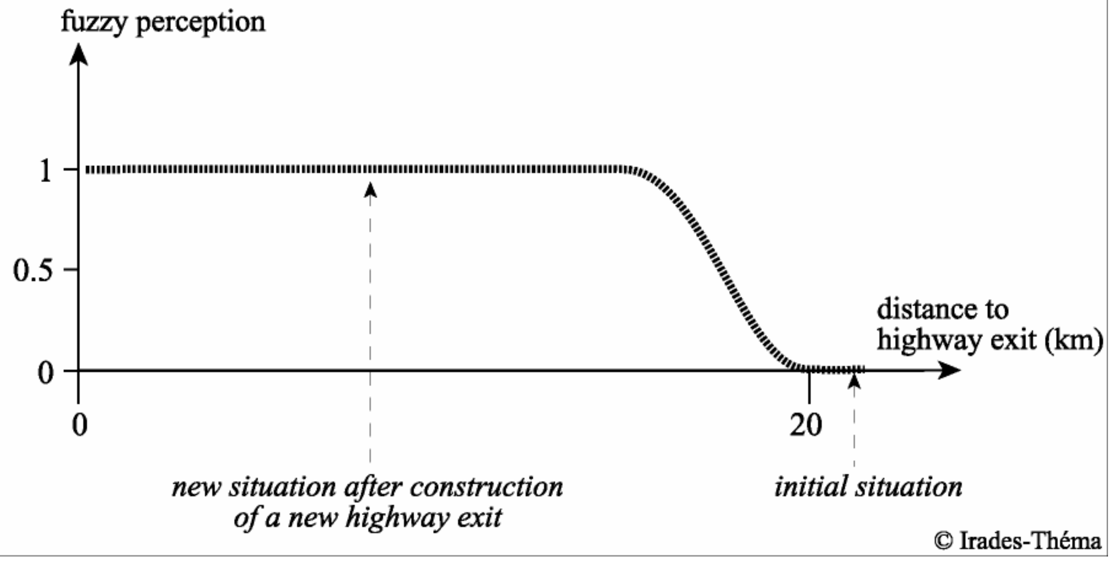
Agents evaluate these attributes. In order to describe their own opinion, we recur to a *fuzzy formalization* (ZADEH, 1965; TONG-TONG, 1995). There are different reasons why we choose this type of approach:

- we think that individuals have a more or less precise opinion about attributes. E.g. an agent will usually not be able to determine exactly if 20 km will be an acceptable distance to go to down-town whereas 20.2 km won't be acceptable at all.
- agents behaviour is often characterized by rather contradictory desires. The German author Tucholsky resumed the antagonistic feature of residential preferences in the following way "Yes, that's what you'd like to have, a villa in the green, with a spacious terrace, the Baltic Sea in front of the house, at the back the Friedrichstrasse (famous avenue in Berlin), with a very fine rural and prestigious view, and from the bathroom you see the Zugspitze (high mountain in the Bavarian Alps)."
- Such thinking is not rational, in the fullest sense of the word. Fuzzy formalization seems more adapted to describe such a behaviour.
- In matter of formalization, fuzzy logic has a considerable advantage since it is possible to develop a clear, robust and mathematical formulation. This doesn't hold completely for rule based approaches as they are used e.g. in expert systems. On the other hand, fuzzy relations may nevertheless transcribe such behaviour

rules. Thus, the observation of agents' behaviour may be first formulated by means of rules, and then be reformulated in a more formal way.

Thus, we introduce fuzzy membership functions for describing the evaluation of agents. Agents may characterize distances less than 20 km as fully in concordance with the notion "good accessibility". We affect to smaller distances the membership value $m_d = 1$. However agents may consider greater distances than less convenient and may judge distances higher than about 25 km as not acceptable. For such distances we suppose a fuzzy value $m_d = 0$. This inspires to suggest for the intermediate distance range a monotone decreasing membership function (C.f. figure 2).

Figure 2: A typically membership function as it should be used e. g. for the perception of distances. By means of the function, a fuzzy value is affected to each value of the support set, e. g. distance. If for a zone the attribute value changes, the new corresponding fuzzy value will be obtained.



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Such a continuous membership function may only be defined for cardinal variables like distances, prices etc. For nominal variables this is not possible. Nevertheless we may introduce fuzzy values to variables which refer to the presence of certain more aesthetic elements in a landscape.

We assume also that agents affect different weights to the attributes. For a shopping centre the vicinity to the potential customers could be more important than the amount of the local tax, at least within a certain range.

Combining both perception and importance we may qualify each attribute by a *partial attractivity*. The agent has now to develop a synthetic appreciation of the zone by taking into account the evaluation of the different attributes. This obliges the agent to arbitrate eventually between them: thus, for a residential zone, the agents will eventually be ready to accept a higher land price if the quality of landscape and accessibility are extremely good, which is trivially the reason why land prices are not uniform. Thus, we may introduce some parameter which describe the predisposition of the agent to come to a more optimistic or pessimistic estimation for some compromise. This arbitration leads finally to a global evaluation of each zone, which summarizes agents' opinion about its *attractivity*. However, we shall be aware that compensation doesn't play the same role for all types of decision processes. E.g. industries or commercial activities apply a precise ranking for importance affected to the attributes. Evaluation should be interpreted as more rational than the residential choice behaviour.

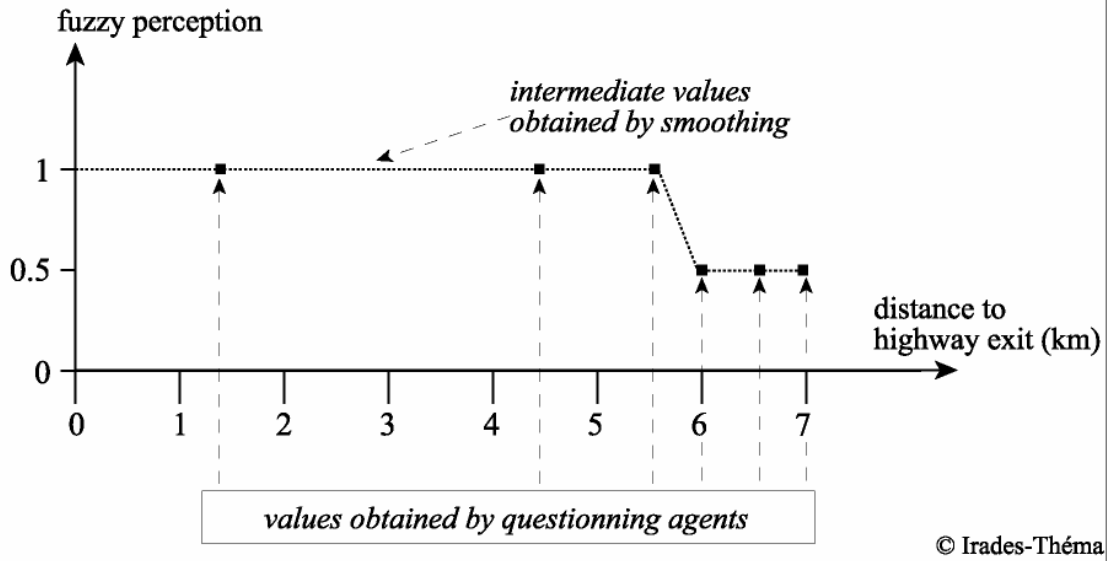
Until now we considered how agents evaluate zones where they are not yet installed. It is however a well-known fact that the evaluation concerning the zone where firms are located or agents live, may differ from the way, they evaluate other zones. Indeed, agents tend to take into account only a restricted number of criteria when comparing zones. Let us give an example. An individual may estimate that a residential zone is very attractive and decide to settle down in this area. However, *a posteriori* he gets aware that there exists no school dinners and that the bus timetable is not convenient. Of course he could have obtained these information before choosing this zone, e.g. the land price was very advantageous and very importance for him so that he neglected other aspects. However land price becomes less important for him when he already lives in the area (except when he will want to sell his house). But there exist also hidden phenomena, like social environment which can hardly be expected *a priori*. Therefore, we suggest to introduce a particular evaluation for different areas, where firms or agents are actually settled. Contrarily to the other zones, we introduce for these evaluation no global attractivity measure, since the non-satisfaction refers usually to particular aspects like the services mentioned. Such a lack of services may lead to the emergence of a social demand, if a critical degree of non-satisfaction is reached.

It is evident that the settlement process causes a progressive transformation of space and may thus influence the future spatial dynamics. We may suppose that landscape quality may be affected by the construction of industries in a site closed to a residential area. We modelize this feedback by modifying the concerned components of the attribute vector according to the changes in space. The new values of the attributes may belong to other values of the membership functions for some component of the perception vector (Cf. fig 2). Due to this link, attractivity of areas may decline or increase with respect to changes of attribute vector. This formalization allows to modelize the feedback between actors and territory, according to the same logic as we described the uncertain behaviour of agents.

1.3 The link to the aggregated level of the society and the calibration of the model

Until now we considered the individual choice behaviour based on plausible arguments. We will now establish the link to the higher organisation level of the society, what allows also to think how the model could be connected to real world data. This relation is formalized by means of a statistic approach based on frequency or respectively, probability. We assume that we carry out a poll in order to obtain some information about the decision process and that the agents act independently when answering to the questions. To give an example, we may ask questions to agents concerning their evaluation of distance criteria and the importance they affect to this attribute. This implies a semantic transcription for distance measurement. So we affect some fuzzy values which refer to the perception. For this aim we may introduce a fuzzy variable for "good accessibility to down-town". Agents have than to decide to what degree they perceive the accessibility as good with respect to their zone. A value close to *one* transcribes that the situation is perceived as good, whereas *low values* refer to a not satisfying quality of accessibility. Since we know the real distance, we may affect the equivalent fuzzy value to the corresponding distance value. This is of course only singular information about the evaluation of a particular distance. However by carrying out polls in different zones we have a set of singular values of the membership function. Based on this knowledge we may construct a smooth curve by interpolation which relates all these special values (C.f. figure 3). Different direct measurement models to obtain membership functions are also described in (ZIMMERMANN 1987, LEUNG 1988).

Figure 3: By questionning agents some discrete fuzzy values are found and we may construct a smoothed function relying these values



In general, agents' opinion may diverge. Then it should be possible to introduce classes of membership functions and to affect to each of these functions the corresponding empirical frequency. *The information about the membership function and the corresponding frequencies is considered as enough general to be used for simulating scenarios at least for comparable situations.*

In a similar way we try to get information about other parameters of the model, like the importance affected to the attributes.

Preliminary tests were realized in Besançon, a regional capital in the East of France of some 120,000 inhabitants. We distributed a multiple choice question paper to firms in different commercial and industrial zones. The real number of the sample (about 140 answers) was too restricted to be reliable under a rigorous statististical point of view. Thus we consider these information "expert opinions". With respect to evaluate accessibility, results made evident that if street network quality is comparable, there exist a simple relation between the distance and their perception. Up to a critical distance, the accessibility is estimated as convenient, beyond this distance, a subsequent decrease of the membership function is observed. However for two zones, the accessibility was perceived as not sufficient, despite of the relative short distance to the highway exit. But in these cases, quality of the street network lied considerably under the standard of the other zones. This inspires to consider rather the time required for reaching the exit than the distance.

According to a statistical interpretation it may also be possible to distinguish different kinds of subpopulations related to specific evaluation criteria. This would be traduced by the observation of a multimodal distribution in the evaluation criteria. In the following, we assume that the different types of behaviour may be strictly separated, i.e. that we may neglect intermediate, hesitating behaviour, what may not be excluded in reality. In the poll mentioned above, it was really possible to distinguish different types of enterprises according to the importance they affected to the attributes. It turned out that they referred to different lines of business.

2– An example of the formalization: the residential choice behaviour

We will now recur to a particular type of decision strategies, the *residential choice behaviour,* in order to illustrate how we may give concrete expression to the general concept of modelization. We choose this example since, on the one hand, a great number of investigations tackled with this topic, and, on the other side the decision process seems rather complex: as pointed out we may expect some compensatory phenomena and a certain arbitration between different attributes. We start by considering the actual state of research in this domain.

In our study, we try to understand which most important actors usually determine choice of residential localization, in order to formalize them within behaviour rules. Residential mobility (without change of employment) results in fact from a modification in the request from housing. Four principal reasons can be evoked:

- the structure of the household evolved (size);
- the incomes of households changed (loss or obtainment of employment);
- the structure of housing is not any more the same one (state, rent, taxes);
- the environment changed (accessibility, landscape, image of the district, etc.).

There are lots of factors determining housing localization strategies. They gave place to many scientific developments[1]. Our object is located downstream from this decision phase and will relate to the determinants for choosing residential localization. Our research is focused on the movements between centres and surrounding areas.

2.1 Three steps in the process of residential localization

Whatever disciplines or scientific streams, many studies allowed to progress in the determination of the factors of residential localization in urban and periurban environment. First, let us point out that the phenomenon of perish-urbanization is, in some manner, durably written in landscape and territorial processes. Many researches, since the beginning of the Seventies, studied these phenomena. The corollary of this vast movement is a relatively homogeneous structuring process of territory, beyond urban borders in a rather loose frame made up primarily individual by housing associated to small private grounds. Perish-urbanization is thus characterized by the subsistence of a large non urbanized space (BAUER, ROUX, 1976).

In fact, it seems that households think in two distinct steps, taking into account localization factors only in second time for their definite choice:

- *the type urban environment (city or periphery ?)*

  For first choice, determinants are simple and founded most of time on the desire to access to home-ownership. This incites households to buy a recent house or to build a new one (BERGER 1993). In this case, it seems that a household with children (this concern main part of the households which choose peripheral areas) would appreciate the advantages of the downtown area to be compensated by those of the life in the countryside. This example enhances the great role of Nature (BAUER, ROUX 1976). Choice is obviously arbitrated by ground price, transport cost, but in this case, searching a natural environment downtown induces a cost related to the purchase of the disconnected to those raised in periphery. Consequently, choice is rather often implicit than really founded on a comparison of the whole advantages and disadvantages according to each type of urban environment.

- *Site choice for housing*

  The first step carried out having made the household towards choose their property in periphery. The precise place location or purchase of housing now will often call a new choice on behalf of the household. The criteria related to the cost are now strongly discriminating, linked with advantages and disadvantages of a possible location, balanced by the importance assigned by different agents (FRANKHAUSER et al., 1996). To traditional criteria of prices related on the cost of the ground or the amount of the taxes, and criteria such as distance and accessibility, are added qualitative criteria like surrounding land-use characteristics (released space, landscape aspect, view).

One can notice that the emergence of a possible social expectation appears at the third step. It results from the weak perception and evaluation of public or private equipment in the second phase. Indeed, equipment presence or its consequences are criteria which are often neglected or undervalued by households. Enhancing these deficiencies is often shifted compared to the second phase. In fact, dissatisfaction encourages the households to gather to make pressure on the proper authorities, in order to obtain equipment considered as essential. In this context, one can quote the case of the school canteens, school bus services whereas the commercial services are not very seldom blamed.

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[1] see the researchs about household strategies (“life cycles ”) (C. BOUVALET, E. LEVEVRE) or about housing market rules (S.-P. LEVY, P. AKIRI, J.-P. SCHAEFFER)

2.2 Key factors for the decision process

It appears clearly that in the second phase of choice, qualitative criteria related to environment constitute an important determinant of the choice for residential localization, thus conferring on urban space a very strong heterogeneity. In certain cases, the importance of these determinants can exceed those related traditionally to the transport cost. An hypothesis can be settled: there would exist a linear relation between an index of amenities and the distance to the centre (GANNON, 1992), according to the low densities residential and reinforced by local specificities. In the same way it is supposed, in an theoretical model (BECKMAN, PAPAGEORGIOU, 1989), that households have heterogeneous preferences for the natural amenities. However, their role could not be highlighted in a model of residential localization in periurban areas (GOFFETTE-NAGOT, 1996).

We consider consequently that the factors determining the residential choice of the households towards the periphery are treated on a hierarchical way:

- ground price remains the main factor, since it calls household capacities to finance their construction project ;
- distance to the centre is important, it is declined of accessibility in a ray of about 20 kilometers around the centre, beyond it is the distance in kilometres which becomes the referent ;
- environment takes today more and more importance, especially if household is located in an periurban area where it could access to home-ownership. For this reason, amongst others, one does not observe any continuity in urban land use, beyond the question of land use regulation (GOFFETTE-NAGOT, 1994). A recent study makes the comparison between social systems and visible forms of landscape (FOLTETE, 1998). Periurban space shows a strong shift between rural landscape forms and urbanized populations. In addition to the price and the distance, sites characteristics themselves must consequently be taken into account (GOFFETTE-NAGOT, 1996). So can we break up this factor into several criteria: density of urban frame, parks, landscape quality, sight and noise, the importance of these factors varying according to the situations as it is explained further in the article.
- equipment presence is not a discriminating criterion. Indeed, movement in perish-urbanization is supported by the increase in the equipment of the households, owning at least a vehicle. For most of them, access to equipment is not presented as being a priority insofar as workers use public or private services during their framework of ‘residence/work site’ moving. To live in periphery of an agglomeration supposes to accept constraints related to the access to the equipment, partially compensated by personal organization of the families.

Of course, hierarchization suggested is not conceived in a strict way. The residential choice results in fact from a complex arbitration between different factors, it exists a compensation which modifies factors weights. Let us take two concrete examples:

- a middle class household decides to invest in a house construction. They choose a ground with a park located near city-centre (5 km far) offering a large view on the valley located downwards. The ground price is high, the distance to the centre is weak and there is no closed public equipment. The household will agree to pay a higher price even if it is necessary to increase the borrowed money, against a nice environment which cannot be faded by ground location. In this case, environment is placed at the head of the determinants, because level of household income allows this choice.

- a lower class household decides to buy a parcel to build its house. They would probably prefer a ground with a lower price, situated quite far from downtown (more than 20 km) and equipment, but located in a nice environment (landscape).

2.3 The formalization of the choice behaviour

The previous analysis made evident that the residential choice behaviour may be dissociated in a hierarchical way. A primary distinction concerns the decision to stay in the centre or to choose a peripheral residential area. The first alternative implies in many cases not to be the owner of a flat. Moreover, landscape quality is certainly considered less important with respect to the cultural offer in the centre. On the contrary, an agent who prefers suburban zones affects a higher importance to the fact that he becomes house-owner and that he benefits of a “natural environment”.

As pointed out, we now restrict our example to agents which in suburban areas. We may consider them as a subpopulation with a clearly defined choice behaviour. We remind also that *four main criteria (attributes)* turn out to be relevant:

- the land price,
- the distance to the centre,
- the landscape quality and the quality of life,
- the accessibility of some services.

Each of these main attributes must be considered as the combination of several sub attributes. In particular we assume that:

- the *distance* refers to the *real distance* but, as we saw, also to the *time (cost)*;
- the *quality of the landscape* includes information about the *angle of the view*, the existence of different elements which *structure the landscape at middle distances*, the presence/absence of particular buildings e.g. industries and eventually further sub attributes, the *density of the build-up area*, the *vicinity to green areas*. The *quality of life* contains particularly information about the degree of *noise* and *pollution*;
- the *distance to equipment* is of minor importance, since individuals are ready to accept higher distances for accessing services if they live in a suburban area. These attributes gain more weight when being confronted with the every day life situation. We think about the distance to some public and private *services*, like post office, shops for daily needs, shopping centres and schools. For schools, the accessibility will be evaluated as “good ”, when there exists a performing school bus system.

We keep this hierarchical structure for the formalization since we think that such a classification transcribes rather good the agents' reasoning: in order to simplify evaluation, the individuals will form groups of key-factors according to some common semantic background.
To each of the sub attributes we affect a membership function. For cardinal variables, like for example the sub attributes of the criterion accessibility, distance and travelling time, we build continuous functions obtained by interpolating polls results (cf. section 1.3). This method can be applied on sub attributes such as the density of the build-up area, the vicinity to green areas, the angle of view, the degree of noise and eventually for pollution, all belonging to landscape quality.

More qualitative aspects like the presence of a good structure at the middle distances or, on the contrary, the presence of some ugly buildings may be characterized by singular values which refer to particular situations. For this aim we should select some striking features like the presence/absence of certain elements and affect fuzzy values to these attributes. Thus we may imagine to recur to multimedial simulations of landscapes for asking agents to evaluate them. Afterwards, we may show the same landscape but after having introduced an industrial building. Such combinations of different sub attributes may help to get information about landscape quality.

In order to value the attractivity of sub attributes, we extract from the empirically determined membership functions the fuzzy values of perception which correspond to the attribute values we consider. Moreover, we know the degree of importance agents affect to these attributes. We should now reflect how perception and importance may be combined in order to get a synthetic measure for each attribute, which we call *partial attractivity* $a_i^{(part)}$ for an attribute i. As pointed out, we assume that the evaluation process follows the introduced hierarchy. Thus in a first step, the agent combines (for each sub attribute) the perception and the importance. For this aim we recur to a type of formalization which has been proposed by Yager when considering multi-objective decision processes (YAGER, 1978). Using Saaty's eigenvector method (SAATY, 1977), he calculates a ratio scale of importance based upon paired comparison of the importance for each pair of attributes. He proposes to take into account the in this way obtained importance that agents affect to a certain attribute by means of an exponent of the membership value. Thus, terms like $m_i^{\gamma_i}$ are introduced, where m_i is the membership value of sub attribute i and γ_i a (non fuzzy) measure for the importance which may vary within a range from *zero* to *infinity*.

$$a_i^{(part)} = m_i^{\gamma_i}$$

Low importances refer to γ-values *smaller than one*, values *greater than one* traduce high importance. Thus membership functions which are not equal to one or to zero are reduced, when the importance is high. This means that the agent is very sensitive to situations which are not perfect i.e. $m_i < 1$. On the other hand, the m_i -values are increased when the agent doesn't affect a high importance

Yager showed that such a formalization makes sence when using different operators for linking membership functions, in particular the interpretation holds for a *MAX/MIN* logic. We remind that Zadeh proposed to transcribe the *AND*-relation by a *MIN* operation: if we require that both attributes A and B should be fully respected then the worst of the two membership values m_A and m_B should be chosen. This means that the presence of a higher value m_B may not at all compensate the bad value m_A . This is a pessimistic evaluation criteria. On the contrary, the *MAX* operation characterizes full compensation: the agent, a “full optimist”, is not affected by the bad value of A but is completely satisfied by the fact that m_B is rather high. This corresponds to *OR*-logic. These operators are non-interactive, since the synthetic value equals one of the input values and is, thus, not at all affected by the other one.

These reflections are important when we consider now the evaluation process which combines different sub attributes in order to establish the link to the next hierarchical level of the decision process. This implies that we describe how the agents arbitrate between the partial attractivities to obtain a synthetic evaluation of the attribute (e.g. how the landscape is globally judged when knowing the evaluation of the different sub attributes using the partial attractivities). In some cases, this link may be thought as a simple operation. For the first attribute, the distance, we believe that a choice based on a simple *MIN*-evaluation holds. If travelling time needed is judged worse that real distance, time prevails over distance, and vice-versa.

$$a_{acces} = MIN(a_{dist} , a_{time})$$

Similar arguments may hold for the accessibility of different types of equipments. However, we may expect that there exists also the possibility of fully compensation. If the distance to a school centre is evaluated by a rather low degree of satisfaction, this may be fully compensated by an existing school bus system.

However, in other cases like global evaluation of landscape quality, we should assume that the evaluation procedure is more complex. Such compensation problems have been tackled by different authors. For example, Zimmermann and Zysno (1983) showed that human aggregation behaviour could be better described by an operator which permits a certain degree of compensation between the “ pessimistic ” *MIN*-evaluation and the “ optimistic ” *MAX*-evaluation.
Therefore they proposed the “*compensatory AND* ”:

$$AND^{1-\gamma} \cdot OR^{\gamma} ,$$

where $\gamma \in [0,1]$ is a parameter, that indicates the degree of compensation. For γ equal to 0Êor 1, the operator is the same as using *AND* or, respectively, *OR*-operators (Zimmermann and Zysno (1983) suggest the use of the probabilistic intersection/union). For $0 < \gamma < 1$ their *compensatory AND* is between these extremes. They showed in empirical studies that this operator might be more appropriate to model human aggregation behaviour. Another operator presented by Yager is the *OWA*-operator (YAGER, 1988), which allows to model linguistic quantifiers like *most* attributes. Recently Torra proposed the *WOWA*-operator (TORRA, 1997), an extension of the *OWA*-operator which is capable to handle different importances of different attributes. Nevertheless apparently neither the *OWA*- nor the *WOWA*-operator have been verified empirically.

The real meaning of these formulations is not always clear. We prefer to try to deduct ourselves propositions for such operators according to a reasoning which refers directly to the evaluation process considered. We should be aware that the dilemma of the agent results from partial attractivities which may lie within a more or less large range. If the range is small, the different sub attributes are obviously judged in a rather similar way that simplifies evaluation. Then, we may expect that the agent can accept some disadvantages as they are traduced by the lower partial attractivities since they are not too much worse than the maximal value of the set of partial attractivity values. Thus, we may suppose that agent judgement will be rather optimistic and tend to *full compensation,* i.e. to $MAX\ (a_i^{(part)}, i = 1,2,...)$

On the contrary, if the range of the partial attractivities is large, the evaluation according to the maximal value may be non convenient. Indeed, if the land price is estimated as not suitable, good attributes concerning the landscape quality may not compensate this disadvantage. In this case the judgement will rather be inspired by the *lowest partial attractivity*; the agent tends to a pessimistic evaluation.

The discussed reasoning may be traduced in a simple way by the following fuzzy operator by means of which we estimate the *attributive attractivity* for the attribute *j*:

$$a_j^{(att)} \quad = \quad DIFF^{\beta} \cdot MIN(a_i^{(part)}) + (1 - DIFF^{\beta}) \cdot MAX(a_i^{(part)}), \qquad \beta \geq 0$$

The logic of this evaluation operator is based on the difference function

$$DIFF = MAX(a_i^{(part)}) - MIN(a_i^{(part)})$$

as discussed and it may be verified that the value obtained shows the evaluation behaviour required for each given parameter value β. This parameter describes how the agents respectively weight the *range between highest and lowest partial attractivity* and seems similar to the importance parameter γ. However, since β does not act directly on an attractivity measure but on the difference, which is rather a control term, the effect is just inverse: β-values greater than one *reduce* this difference; obviously, the agent is not too much affected by the fact that the partial attractivities differ one from the other. Thus, the tendency will be the same as for initially smaller values of the difference, the agent tends to the *MAX*, he is rather optimist. On the contrary, values *between zero and one* make the difference greater. The agent assigns a high importance to the difference of the extreme values of $a_i^{(part)}$. We obtain a *lower* value $a_j^{(att)}$, closer to *MIN*.

The last step would be to aggregate the attribute attractivities in order to obtain a *global attractivity measure* a_k *of the zone k*. We propose to recur to the same logic as discussed before. We should emphasize that it should be possible to estimate the parameters even for such a hierarchical decision process. Indeed, Krishnapuram and Lee showed for Zimmermanns and Zysnos *compensatory AND* respectively, a combination of union, intersection and compensatory operators, how importances and compensation parameters for a multi-level evaluation hierarchy can be found by a backpropagation algorithm using (empirical) training data (KRISHNAPURAM, LEE, 1992).

Let us finally come back to our probabilistic interpretation. The knowledge about different classes of membership functions, of importance values and β-values, their frequencies in the sample of the empirical data, as well, allows to obtain a *frequency distribution* for the corresponding *global attractivity measure* a_k *of the zone k.*

2.4 How to apply this formalization on modelling agents' behaviour

Until now we considered agents evaluation for residential areas, where they don't live actually. But the criteria of the agents may be different for evaluating that where they live actually. Generally, we could consider that even if individuals are unsatisfied by certain attributes, the decision to move is usually perceived as rather difficult, so that an arbitrage between positive and negative aspects will be done. Moreover, a few sub attributes are perceived in the same way (e.g. insufficient bus service), but we may expect that the importance they assigned to these sub attributes, is now different. Thus, by questioning agents, we may know the weight they affect to such services in their actual residential environment and we may determine the *global attractivity* a'_l of the zone where agents live by the same procedure as before. A comparison between these attractivity measures a'_l , a_k $\{k = 1,2,3, ...; k \neq l\}$serves later on to evaluate the willingness of agents to move.

However, the non-satisfaction with respect to certain equipments or services may also lead to the emergence of a social demand. Usually, agents will not move immediately when they are not satisfied, they will eventually try to negotiate a change e.g. by means of pressure group. For modelling the emergence of a social demand we may think to consider the partial attractivity of the sub attributes. For each of them, we introduce a critical threshold. If the value of the partial attractivity lies under this limit, we can expect that the agent is really unsatisfied. Recurring to the frequency distribution of the membership functions of perception m_i and the importance values γ_i we calculate for a zone the mean value of partial attractivity. If this value lies under the threshold, we may expect that a real social demand exists on the scale of the zone.

Instead of using a crisp value for the threshold, one may also think to use a fuzzy transcription of non-satisfaction. Then, we can define a fuzzy measure of non-satisfaction referring to the partial attractivity value. The frequency distribution will be used to determine the degree of possibility that a social demand emerges.

The future task will be to precise the formalization of these processes. Moreover, we should focus on the modelling of the price dynamics which depends, as mentioned, on the one hand on the actual vacancy rate in the zone, and on the other side of the attractivity.

3– Some preliminary remarks for modelling dynamics

Even if the concept of the dynamics of the model is not yet precisely formulated in details, we give a survey concerning the way we should proceed. The time evolution of our spatial system is described by considering the potential evolution of the immigration/emigration of the different zones. We cartography the degree of occupation of each zone in course of time. The dynamics is governed by the following factors:

- the external attractivity function of the different zones;
- the degree of non-satisfaction of the actual zone where agents live or where enterprises are located;
- the vacancy rate in the zones.

The first factor should be considered as a "pull factor" and the second one as a "push" factor. We may moreover assume that the vacancy acts directly on the attractivity of a zone by means of the land-price. If some of the attributes have a high membership value and if the vacancy rate is low, we may expect high land prices. Land price may be directly linked to other attributes and to vacancy.

In a discrete time model, we interpret the settlement process as a sequence of individual decision processes. For these individual processes, we consider:

- that the agent will take its decision to migrate if the attractivity of some zone is superior to that one he is installed actually;
- that he chooses the zone of highest attractivity (what is in concordance with usual assumption in economy). This assumption could be formulated in a more weak way, if we assume that there exists for each alternative a *fuzzy possibility* of choice which depends, however, directly on the attractivity of the zone.
- that there exists a certain willingness to move since agents have often a certain laziness with respect top such a decision. The degree of willingness may depend on the difference between the attractivities of the actual residential zone and the best one. It should be interpreted as a fuzzy measure.

So far, if we exclude the mentioned possibilistic approach and if the willingness would also be equal, the dynamics would be deterministic. However, we remember that we have in reality a frequency distribution for the attractivities of the zones, since we assumed that there exist frequencies for different classes of membership functions, importances and β-values.

Maybe, we should rather recur to a probabilistic modelling. This leads to propose to describe the dynamics by means of a Markoff chain approximation. We assume then that the systems' dynamics is the result of a stochastic sequence of individual decisions. The actual state of the system may then be described by a state vector $\mathbf{n}$, the components identified with the degrees of occupation n_k of the different zones k considered. Then, we introduce a probability $P_t(\mathbf{n})$ to find at time t a certain configuration $\mathbf{n}$. For the initial state $t = 0$ the distribution is sharp, since we know the settlement pattern before running simulation. The dynamics of such a system is completely governed by the conditional probabilities $P_{t+1,t}(\mathbf{n}',\mathbf{n})$ to find a certain configuration $\mathbf{n}'$ at time $t+1$ if the system was at t in state $\mathbf{n}$. [2]

Each of these configurations refers to a potential migration process. The transition probabilities depend directly on the frequency distribution of the attractivities. If there wouldn't exist any overlap between the frequency distribution of the zone with the highest degree of attractivity and other ones, we should expect that all agents migrate to this zone. However this is not probable. Since the evaluation process admits some compensation and since agents will affect different importances to attributes, we may suppose that similar attractivity values are affected to different zones. Then we have a non-trivial evolution: agents still chose the best zone, however since agents differ in their judgement a certain number of individuals will prefer some zones rather than other ones. Immigration rate to a zone depends

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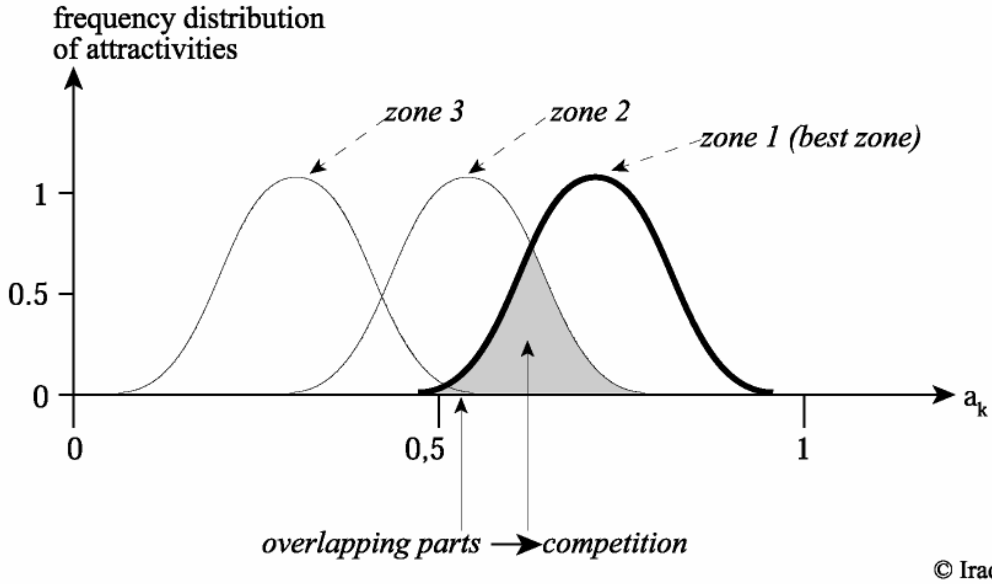
[2] We should emphasize that a time continuous modelization should be possible, too. Then the dynamic description would be based on a master equation approach as it was used by Weidlich and Haag (W.WEIDLICH, G.HAAG, INTERREGIONAL MIGRATION, SPRINGER 1988)

so directly from the relative number of individuals which estimate a zone as the best one (C.f. figure 4).

Figure 4: Frequency distribution of the attractivity of competing zones



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Finally, in order to estimate the velocity of the settlement process, we should scale the time evolution by using the mentioned willingness that we could interpret as a mobility parameter.

Dynamic simulations could not only be used for simulating the dynamics of an agglomeration under a given starting situation. We can imagine to stop simulation and to modify the conditions by assuming that a new road has been constructed near a residential area. Such a decision may affect the attributes vector and we would have to test how agents will react on such a decision. This shows how the tool could be used to apprehend the eventual socio-economic impact of a planning decision.

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