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GÉOGRAPHIE

DUAL-AGENT SIMULATION MODEL OF THE RESIDENTIAL DEVELOPMENT PROCESS
An institutional approach to explaining the spatial patterns of residential developments in France, England and the Netherlands

Présentée et soutenue publiquement par

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Contents

Abstract

The urban form is a major concern for local planning agencies. However, the efficacy of their action depends on the economic, political and institutional context. The context determines how local planning agencies and other actors participate in the housing development process, and how they influence the form of resulting residential developments.

Here it is assumed that an actor's participation in the housing development process depends on the cost and risk involved and the expected return. It is also expected that actors gain bargain power by extended participation. An increased bargain power gives an actor more influence on the housing development process and causes the actor's objectives to be more determinant in the spatial structure of the urban pattern.

The objective of the research presented here is to develop a simulation model that links the urban form to actor's bargain power. Such a model could help explain geographical differences in the spatial configuration of urban development. It could also link changes of the political or institutional context to the emergence of a different form of urban development.

The thesis is built up in three parts. The first part focusses on the local authorities' efforts to intervene in the housing development process. It identifies some crucial possible differences in the local planning authority's impact on the form of urban development according to the country or the local institutional context.

As a result, Part I proposes an Actor-Role model of the housing development process. In this model, a role represents a set of activities that together can be seen as a phase in the housing development process. The roles, which are identified, are landowner, planner, enforcer, land developer, housing developer and financier. Housing development actors aim to adopt one or more roles. This provides them with bargain power that enables the satisfaction of individual objectives. The extent of the bargain power provided by a role depends on the economic, political and institutional context.

The objective of the Actor-Role model is to provide insight in the relationship between the economic, political and institutional context, and the bargain power of development actors. The model is used to analyse the housing development process in France, England and the Netherlands. The outcome is an overview of the distribution of bargain power between the local planning authorities and private residential developers.

The second part of the thesis is dedicated to the conception of a dual-agent simulation model. The model represents the housing development process as a negotiation between two agents: a local planning authority and a private housing developer. The urban pattern is represented by a raster land use map. The modelling is iterative and a simulation runs for a few time steps. At each time step the agents negotiate on the allocation of cells to residential development in the land use map. The new spatial configuration of the map is used as input in the next simulation step.

The agents' objectives are derived from their real-world counterparts. For each agent four spatial objectives are defined. Spatial indexes quantify the extent to which a spatial configuration correspond with the defined spatial objectives. For each spatial index a fuzzy evaluation function represents its evaluation by each agent. An agent's satisfaction function is the weighted average of all the evaluation functions.

The negotiation protocol is based on the Orthogonal Strategy. At the start of the negotiation both agents find a first offer that best respond to their objectives. Then, during the first negotiation round, one of the agents finds a counteroffer that is closest to the last offer of the opposing agent. The satisfaction of the counteroffer depends on the satisfaction from the last offer and the concession strategy. The concession strategy determines the maximum concession each agent is willing to do and depends on the agents bargain power. After the first counteroffer the opposing agent proposes a counteroffer in the same way. The agents continue proposing each other counteroffers until an agreement is reached.

The searches for the optimal first offer and the optimal counteroffers thereafter are formalised as optimisation problems, which are solved using an informed Simulated Annealing algorithm.

The third part of the thesis tests the working of the dual-agent simulation model on three case studies: Lingolsheim in France, Chorley in England, and Malden-Groesbeek in the Netherlands. First the behaviour of the simulation model is tested. The optimal parameters for the Simulated Annealing algorithm are found and the first simulation results are discussed. The following of Part III presents a series of sensitivity analyses, which reveal how the modelling outcomes respond to changes of the model parameters.

In conclusion, the thesis allows a better understanding of the process of residential development control in France, England, and the Netherlands. Some conflicts between the objectives of private residential developers and local public authorities have been modelled and their effect on the form of residential development have been explored. Results obtained suggest that differences in the agents' spatial objectives (i.e. how planning objectives are transcribed into planning rules) influence as much the form of residential developments as differences in the agent's bargaining power.

Chapter 1

Introduction

Residential developments and their form result from a complex, anthropological process. Human behaviour and human decision-making intervene at different spatial and temporal scales related to the urban land use. The spatial and temporal scales of behaviour range from an individu's shop choice for the daily grosseries to the approval of long-term national and international spatial policies. Land use dynamics are reflected in the spatial configuration of residential developments. The multiple scales of human behaviour and decision making is clearly recognised in the form of residential developments (Frankhauser, 1994).

The urban form concerns the spatial configuration of the built area, how it is perceived by those who use the urban space and how it affects their behaviour. The urban form is a multi-scalar concept. Building materials, like bricks, concrete, wood and plants, are the building blocks for buildings (e.g. houses, apartment buildings and office buildings), roads and plantation (e.g. gardens and public green). Buildings, roads and plantation together form streets, alleys, squares and parks, which again create villages, towns, neighbourhoods and open areas. The latter are then the building blocks for and urban region.

The choice of building materials, the size of building plots and the location of houses on the plots, the spatial distribution of houses in a street and the size of squares, the size of a neighbourhood and the availability of commercial services, and finally the distance between a neighbourhood and the city centre and the size of natural parks are all aspects of the urban form. All these aspects define how people perceive their urban environment and affect their behaviour. The urban form also has an effect on biotic and physical processes. Especially at the level of an urban region, the urban form influences the local climate and biodiversity.

In this thesis, we focus on the individual building as a building block of streets and neighbourhoods. Moreover, the spatial distribution of houses and other buildings defines the spaciousness of streets and neighbourhoods, accessibility of services and the availability of open area. The latter are important determinants as to how urban area functions.

The urban form, as in the focus of this thesis, is a major concern for local planning authorities. Especially extensive and low density urban development, i.e. urban sprawl, is seen as having a bad impact on the perception and behaviour of residents and the functioning of the urban area as a whole. The planning authorities' interferences in the urban development process is guided by the authorities' concerns over the impact of the form of urban development on the urban functioning. Their aim is to steer urban developments towards more sustainable shape of urban development.

However, the planning authorities behaviour of steering urban development is often not or only partially implemented in urban development models. Recent efforts in the simulation of urban development (Loibl & Toetzer, 2003; Brown & Robinson, 2006; Loibl, Tötzer, Köstl & Steinnocher, 2007; Miller, Douglas Hunt, Abraham & Salvini, 2004; Semboloni, 2007; Ettema, Jong, Timmermans & Bakema, 2007; Liu, Li & Anthony, 2006) have no or little focus on the role of planning authorities or other development actors. These models rather explain the urban form as the result of the location choices of households and other users of the urban area (e.g. companies and commerce). Households settle at a location that optimises their satisfaction. The aggregate of household location choices lead to the emergence of the spatial configuration of urban development. The effort of the local planning authority to control the form of urban development therefore focusses on restricting the location choices of households through zoning. Households can only settle in the locations allowed by the local planning authority. This alters the location choices of households and hence a different spatial configuration of urban development will emerge.

This approach dismisses the influence of development actors, like commercial developers, who have an interest in the urban development. These actors are actively involved in the urban development process, from which they receive their satisfaction. In an effort to control the urban development, the local planning authority sees itself faced with these development actors. Hence, urban development control in a large part also includes the control of the behaviour and choices of commercial and non-commercial development actors. Moreover, the spatial configuration of urban development is affected by both processes, i.e. household location choices and development actors' decisions. Both processes interact with the urban form (see figure 1.1).

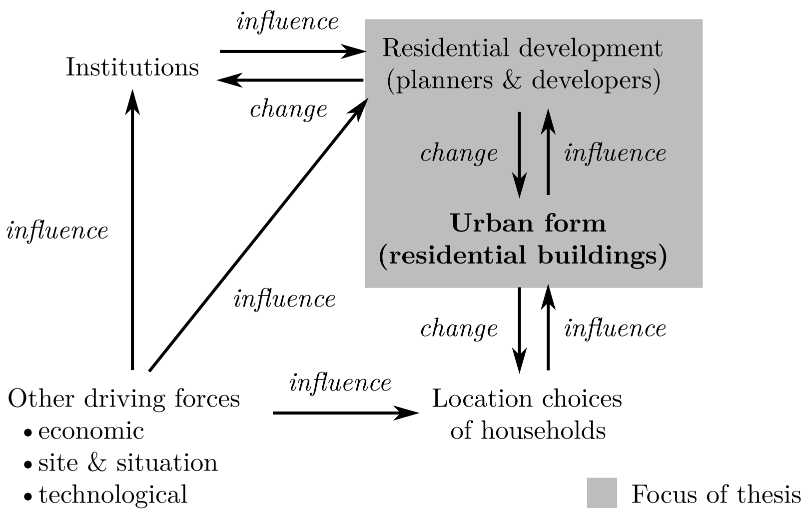


Figure 1.1 *– Context of the urban development process simulated in this thesis*

Human behaviour and decision making, of both land users and development actors, are affected by anthropogenic and non-anthropogenic factors (see figure 1.2). They can be structural. For example, technological developments have led to structural changes in the urban development process. Often used examples are the increased mobility (in combination with increase welfare) and more recently technological developments in tele-communication. At the other hand however, some factors are clearly the result of short term human behaviour. Here is a clear interaction between structure and agency (Healey & Barrett, 1990). Political and legal factors can change rapidly under the influence of political and democratic processes. They also affect the behaviour of actors instantly, moreover, they are often aimed at influencing human behaviour and decision making.

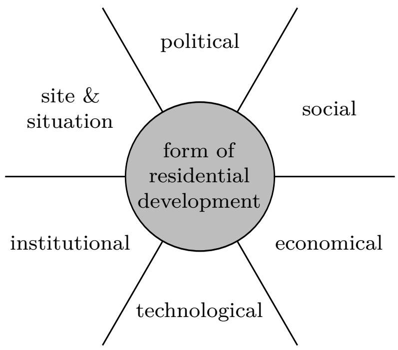


Figure 1.2 *– Driving factors that directly or indirectly affect the form of residential developments*

The latter factors are considered part of the institutions. The institutions are however broader. They include political, legal and also cultural factors that influence the behaviour of actors. Next to behaviour explained by political motivation and legal restriction it also explains certain behaviour because of habits or culture among actors. Institutions are a type of social representations. Intitutions, more or less internalized by individuals, govern social behaviors; they allow the compatibility of all individual behaviors in a given context (Walliser, 1989). Two kinds of institutions can be distinguished: norms (e.g. rules of politeness and courtesy, clothing), which allow coordination between the actors, and groups (e.g. families, associations), which allow coalition between the actors (Walliser, 2003).

We believe that the geographical differences in the form of urban developments can be linked to the differences in institutions affecting the behaviour of development actors. Moreover, the institutions affect the influence development actors have over each other and are therefore responsible for the power balance between these actors. The power balance between development actors also means a power balance between the development actors' objectives concerning residential development.

However, in the urban development process, the institutional relationships also are of significant importance in the urban development process. In the latter process, local planning authorities, and possibly other government agencies, interact, cooperate and compete with private (commercial and non-commercial) development actors. The nature of the interactions and activities of both private and public development actors, which eventually determines the spatial configuration of urban developments, are determined by the institutional context. Hence the nature of the institutional context has an important influence on the form of urban developments.

The institutional context is again the result of the behaviour of the development actors. If actors change their behaviour, it will eventually lead to a change in the institutional context. The nature of the institutional context also depends on other driving forces. Especially, political, legal and administrative driving forces are important to the institutional context. These are driving forces that vary nationally, regionally or even locally, and as a result the interactions between development actors are expected to depend on their geographical location. Which leads to the hypothesis that geographical (national or regional) differences in the form of urban development can be linked to the interaction between development actors.

Hence this research focusses on the influence of institutions on the spatial configuration of urban development by investigating how the institutions affect the negotiation position of development actors. The focus is on identifying the negotiation position of development actors and how variations in the negotiation position result in different urban forms. This information is used to develop a Planning Authority Residential Developer Interaction Simulation Model (PARDISIM). PARDISIM is a dual-agent simulation model, which takes an institutional approach in the simulation of the residential development. Rather than modelling the residential development as the result of residential location choices, PARDISIM models the residential developments as the result of the negotiation between the local planning authority and the commercial residential developer. The objective of PARDISIM is to investigate how differences in the power balance between the local planning authority and the commercial residential developer causes differences in the form of residential developments.

The thesis is divided into three parts, which each consist of three chapters. Part I discusses the link between the form of residential developments and the behaviour of development actors. Herein, chapter 2 gives a review of the importance of the urban form to the functioning of the city. It discusses planning concepts, which are the basis of spatial policies. Planning concepts are aimed at improving the functioning of urban areas. Moreover, the chapter also reviews the complexity of the residential development process. Next chapter 3 discusses the modelling of the residential development process. In chapter 4 we introduce the agent-role model. We use this model to evaluate the residential development process in France, England and the Netherlands.

Part II introduces PARDISIM and is structured as follows. Chapter 5 gives the structure and the progression of PARDISIM. The main focus is on modelling the negotiation between the local planning authority and the private residential developer. Next, chapter 6 defines the objectives of the agents. It derives spatial objectives from the interest and preferences of local planning authorities and private residential developers. Based on these spatial objectives the chapter defines spatial indices that the agents use to analyse the urban spatial configuration. Evaluation functions and a satisfaction function for each agent formalise the evaluation of the outcome of the spatial indices. The implementation of PARDISIM, especially the negotiation process, is discussed in Chapter 7.

Part III presents the results of the first analysis with PARDISIM that aims to investigate the effect of the negotiation position of agent *PA* on the spatial pattern of residential developments. Chapter 8 presents the simulation parameters and the three case studies used to illustrate the working of PARDISIM. Chapter 9 and 10 each present the results of a set of simulations in the three case studies.

The thesis ends with general conclusions and discussions in Chapter 11.

Part I

Urban development as process and result: a matter of space, actors and institutions

Chapter 2

Urban planning and urban form

Form follows function (Batty & Kim, 1992). The way people life, work and trade in cities has dramatically changed over the last few decades. Socio-economic developments, which decreased the size of households and provided people with more welfare and spare time, caused a change in the spatial demands of urban residents. Technological developments, like the decrease of transportation costs, have facilitated the satisfaction of these changing demands. In response, housing developments became less compact, and caused urban sprawl. This change in the urban form has had, in turn, an important impact on the functioning of the city: increased consumption of space, increased distance between homes, jobs and shops, and increased car dependency. All of which has had an impact on the social, environmental and ecological quality of the cities and their surroundings. Hence, the link between form and function is reciprocal. The urban form is a major influence on the functioning of the urban system, and an uncontrolled urban growth is generally believed to negatively affect the functioning of the city.

In Europe, either local authorities or local state agencies intervene in residential development processes in an effort to control, or even steer, the urban growth. Planning authorities indeed consider the control of the form of urban development of paramount importance to ensure the social, environmental and ecological quality of urban developments.

In response to the issues related to urban sprawl academics and planners have developed many planning concepts that aim to counter urban sprawl and positively affect the functioning of the city. Currently, the Compact City planning concept dominates the spatial policies across Europe (Breheny, 1996). It has a presence in the plans of national, regional and local planning authorities. Despite this common point of view, the spatial configuration of urban development differs across Europe. Some factors like, topography, climate and local life styles, obviously influence the form or urban developments. But the existence of geographical differences may also be attributed to differences in the spatial policies (Caruso, 2001). Planning authorities may have a different understanding of the Compact City concept. Similarly, the spatial configuration of urban development may also differ as the result of differences in the context of governance by local planning authorities. The latter is only partly the direct result of national spatial policies.

2.1 Diversity in urban form

Urban form is a broad and complex concept, for which many different definitions exist (Schwarz, 2010). The urban form is multi-scalar (Tannier, Vuidel, Frankhauser & Houot, 2010; Tsai, 2005). It can be viewed and evaluated from the perspective of a single parcel, but also from a more global perspective. The perception and evaluation of the urban form also depends on the number of characteristics used to describe it.

Many indicators have been developed that characterize the urban form. Schwarz (2010) distinguishes between spatial metrics, which describe the physical appearance of the city, and socio-economic indicators. Among spatial metrics, indices of compactness and shape complexity are landscape metrics, that academics have commonly used to describe the urban form (Tannier, Vuidel, Frankhauser & Houot, 2010; Li & Liu, 2008; Stewart, Janssen & Van Herwijnen, 2004). Fractal dimensions are also used to measure the form of urban patterns according to a multi-scale approach (Batty & Longley, 1994; Frankhauser, 2004); they also allow the comparison of the morphology of different urban regions (Thomas, Frankhauser & Badariotti, 2010; Frankhauser, 2004).

Socio-economic indicators take characteristics besides the physical structure into account. They predicate that decisions, actions and interactions of the urban population are part of the urban form. Commonly used socio-economic indicators are street network connectivity, density, land use mix and accessibility (Song & Knaap, 2004; Knaap, Song & Nedovic-Budic, 2007). Other notable indicators are centrality of urban activity (Tsai, 2005) and housing type mix (Yang, 2008).

Both types of metrics have been used to analyse and compare urban patterns. Huang, Lu and Sellers (2007) have performed a comparative analysis of the form of 77 urban areas across Asia, the United States, Europe, South America and Australia. They have measured the urban form using seven metrics, which are a combination of spatial metrics and socio-economic indicators. Schneider and Woodcock (2008) have used four metrics to analyse the form of urban growth in 25 cities across North and South America, Europe, Africa and Asia. Urban form and urban development have also been extensively compared across Europe. Kasanko et al. (2006) have analysed the development of 15 European urban areas. They have evaluated the percentage of built-up area, the growth rate of the built-up area, the share of residential area, the share of continuous residential area, population density and the built area per person. In another study, Schwarz (2010) has compared the urban form of 231 European cities and divided them in 8 clusters.

Physical appearance and socio-economic characteristics of the urban form are both important in the perception and evaluation of local planning authorities and other development actors. Hence both should be considered in the evaluation and comparison of the urban form.

The urban form differs between European cities. However, is the urban form geographically correlated? Europe countries all have their own legislation and institutions concerning the local planning authority's interference in the urban development process. This suggests that the urban forms within the same country are more similar, than the urban forms from different countries. A very extensive study of the urban form across Europe by Schwarz (2010) has found however, that the geographical distribution of the urban form across Europe is complex. No clear correlation between the urban form and the country, in which the city is situated, is found. This seems to contradict with earlier research, like the study mentioned above by Kasanko et al. and a study by Guérois and Pumain (2008). However, Schwarz compares urban areas based on the urban form at one point in time, while Kasanko et al. and Guérois and Pumain evaluate the form of urban developments that have emerged over a specific period of time.

Cheshire (1995) has argued that the development of European urban areas takes place in phases, the timing of these phases possibly being different between areas. In particular, the timing of development phases is different for cities in the north and south of Europe. Cities in the north have started the decentralisation, and later the re-centralisation, earlier than cities in the south. As a result, North European urban areas are generally less compact and have a more complex urban form than the urban areas in the south of Europe, but recent developments of North European cities are more compact. This dichotomy between the North and the South of Europe has been confirmed by Kasanko et al. (2006), Cheshire (1995), and Huang et al. (2007).

A bibliographic research on peri-urbanisation in the Netherlands, Belgium, the UK, Germany, Italy and the Nordic countries shows international differences in the containment of urban development (Caruso, 2001). Even though in all countries there are clear deconcentration trends towards smaller towns and rural area, the residential pattern that has emerged differs between countries. In the Netherlands, at one end of the scale, residential development is very compact. Residential development is restricted to existing residential patterns. This has created a situation of local density, but global openess. At the other end of the scale, residential development in Belgium is strongly diffused due to the peri-urbanisation process. A large part of Belgium is occupied by discontinuous residential patterns. Residences are at a low density, but the global urbanisation is more extensive.

An analysis of 54 urban areas in Spain, Italy, France, Germany and the Netherlands between 1990 and 2000 shows that a clear difference in the extent of urban growth exist between urban areas from different countries (Guérois & Pumain, 2008). Spanish cities have grown considerably over the ten year period, where the urban patterns in The Netherlands and especially in Germany have grown only a little. The same study has also investigated the densification of the urban pattern, and has found that densification of the urban pattern is the highest for the Dutch cities. The densification of the urban pattern in the other investigated countries is considerably lower.

Besides the international differentiations in the urban form in Europe, cities of a same country may exhibit clear differences in their form as each city is a result of a unique urban development process. As a consequence, cities from different countries can be very similar, while cities within the same country can be very different. An illustration of this has been given by Tannier and Thomas (submitted for publication) at the scale of Belgium. In Belgium, the land use policy is regional and not national. However, when classifying the Belgian towns according to a series of morphological indices, the composition of the clusters obtained shows that there is no effect of the region, with no clear-cut Flemish-Walloon difference. Each city is a unique combination of morphological characteristics leading to its present built-up shape. Nevertheless, due to different morphological characteristics, the planning potential of Flemish and Walloon cities seems to be quite different.

On the contrary, Frankhauser (2003) has shown, using fractal analyses, that the diversity of built forms of urban agglomerations appears smaller between cities belonging to the same country than between cities belonging to different countries. Thomas, Frankhauser and Badariotti (2010) have found similar results.

The density, size, dispersion, and complexity of urban development differs between countries. This confirms a correlation between the form of urban development and the country where the development takes place. The differences can in part be explained by geographical differences, like the natural morphology in each country, the climate, the regional economics. But inevitably, an important part of the differences is due to country related driving forces. The urban development process takes place in the national context, which is unique compared to other countries. In particular, political and institutional driving forces are confined to national borders. They are considered as a major cause for the distinctiveness of a country's urban development process.

Alternative driving forces exist. International differences in terms of life styles may also explain the variations of the urban form observed among countries. For instance, Brueckner, Thisse and Zenou (1999) show that it is possible to represent with an urban economic model either an American reality (where high income households are located in the periphery of the cities) or a reality of European cities like Paris (where high income households are located in the city centers) through varying the taste of households for different kinds of amenities. However, the link between the political and institutional context and the form of urban developments is little investigated.

Differences in the urban development process may obviously lead to different urban forms because the form of each urban pattern is the result of the aggregate of annual developments. This idea is supported by the study of Thomas, Frankhauser and Biernacki (2008). The authors show that the built patterns of different neighbourhoods in a given urban agglomeration, built at different times and thus under the influence of different driving forces, may vary much more than the built patterns of different urban agglomerations in a given country.

Focusing on how political and institutional forces affect the behaviour of the actors in the urban development process can help explain geographical differences in the form of urban developments. Differences in the rules, regulation and other institutions overseeing the urban development process and regulating the behaviour of the local planning authority contribute to differences in the form of urban developments. For example, Cheshire (1995) indicates that a pro-active policy could help steer developments towards re-concentration. This suggests that, in a country, where a pro-active involvement by (local) planning authorities is more common, planning authorities are more likely to see urban developments conform strict Compact City policies. Moreover, differences in institutions, even those that are only remotely related to urban development (e.g.

tax system), have an impact on the local authorities' intervention in the urban development process, and hence on the form of urban developments (Borsdorf, 2004). Governance and spatial policies play a great role in the development of urban patterns. The analysis of differences in governance and spatial policies therefore help to explain the differences in the form of urban developments (Caruso, 2001).

2.2 Impacts of urban form on urban functioning

The relationship between the spatial pattern of housing developments and its impact on the functioning of the urban system is complex. A spatial pattern can affect the urban system in multiple ways at the same time, both positive and negative.

According to Tobler's first law of geography 'everything is related to everything else, but near things are more related than distant things' (Tobler, 1970, p. 236). Hence any new residential development will have an impact on its surrounding; conversely, the behaviour of the residents in the new development will be affected by the new development's surrounding.

The influence of the form of residential developments on their functioning as well as on the rest of the urban system is a major concern for planners. Extensive residential development, as part of urban sprawl, is often regarded as having a negative impact on the urban system. Both planners and researchers investigate the effects of different forms of residential development on the functioning of the residential developments themselves as well as on the entire urban system. These effects are central to the definition and choice of spatial planning concepts. However, the relationship between the form of residential developments and the functioning of the urban system is complex. The identification of the effects of a certain form depends much on which perspective is taken. The perspectives evaluated here are: space consumption and fragmentation; cost reduction; energy consumption; quality of life.

Space consumption and fragmentation

Urbanization means land for agricultural production and nature preservation is lost and the land that remains gets more fragmented. Whether the focus is on the loss of agricultural production or the loss in natural quality differs between countries. In some countries the loss of land for agricultural production is important; in other countries the focus is more on the preservation of the quality of natural areas (Millward, 2006).

Human activity, related to urbanisation, results in an impact on natural areas that goes far beyond the areas that are converted into urban area (Alberti, Marzluff et al., 2003). It generally changes the flux of energy, matter and species (Zipperer, Wu, Pouyat & Pickett, 2000). The proximity of human activity modifies the local physical conditions. It generates the deposition of anthropogenic pollutants changing the chemical composition of soil, air and water (Berling-Wolff & Wu, 2004). It also results in the change of natural drainage systems and the emergence of heat islands (Zipperer et al., 2000). Furthermore, urbanization results in the introduction of exotic species (Gonzalez-Abraham et al., 2007; Alberti, 2005). It also changes the extent and frequency of anthropogenic disturbances, which results in the change of the species composition. The transformation of land cover favours species that more easily adapt to human interventions at the expense of species that have difficulty adapting (Alberti, Marzluff et al., 2003).

Urban developments have a direct impact on the quality of natural areas by the elimination and fragmentation of habitats (Berling-Wolff & Wu, 2004). It causes links between habitats to lengthen or break, which leads to the (local) extinction of species and the loss of biodiversity (Kong, Yin, Nakagoshi & Zong, 2010)

Urban development not only causes fragmentation of natural habitats. It also increases the interaction between urban areas and the remaining natural habitats. Increased interactions causes more disturbances as mentioned above. It is also a source for wild fires (Syphard, Clarke & Franklin, 2005). The stronger the interactions between a habitat and the surrounding land uses the more it is difficult to maintain the richness of species in this habitat (Saunders, Hobbs & Margules, 1991).

The form of urban developments determines how productivity, hydrology, nutrient cycles, material cycles and disturbance regimes are changed (Alberti, 2005). The form of urban developments also determines the quality and connectivity of the remaining ecological habitats (Bierwagen, 2005; Tratalos, Fuller, Warren, Davies & Gaston, 2007).

Urban characteristics, like density or housing type, have indeed an effect on the availability of landscape patches that can function as habitats (Tratalos et al., 2007). Increasing the availability of these patches (i.e. their ecological quality) has a positive impact on the biodiversity.

The loss of connectivity depends on the extent and importance of connectivity prior to the urban development and the intensity of the urban developments. Small urban developments spreading through disaggregated habitats have less impact than large urban developments spreading through highly aggregated and connected habitats (Bierwagen, 2007). Moreover, the connectivity of natural habitats is sensitive to the quality of the landscape (e.g. urban land uses and urban land cover types) between them (Rayfield, Fortin & Fall, 2011). Tannier, Foltête and Girardet (2012) have also found that the loss of connectivity between natural habitats depends on the intensity of the urbanisation and the dispersal distance of animal species considered. Like Bierwagen (2007) they conclude that the relationship between urban form and ecological processes is equivocal; it seems impossible to identify a single threshold or a unique rule for residential development with which one can conserve all species living in a landscape.

The impact of urbanisation on agricultural production is similar to the impact of urban development on natural areas as discussed above. The conversion of rural land uses to urban land uses leads to the loss of land, but the conversion of land has also an indirect effect that exceeds the impact of diminished agricultural production land. Urban development has a preference for the best agricultural lands. The proximity of new urban developments can impede agricultural production due to constriction on nuisance and shortage of land.

Emerging urban developments can cause the general belief among farmers that agricultural production will diminish (Lockeretz, 1989).

Alig and Healy (1987) have argued that, although eventually relatively little land is converted into urban use, urban sprawl still has an impact on the rural production process. The anticipation of the conversion of rural land use into urban land use causes the price of rural land to increase. The increased rural land value results in higher property taxes. The authors have also point out that rural activities represent either amenities for the urban land users (e.g. open landscapes) or annoyance (e.g. noise and smell). The first leads to appreciation of rural activities, while the latter leads to conflict between urban and rural land uses.

Cost reduction

The link between the urban form, especially the urban density, and the costs induced by urban development is one of the foundation of current spatial policies (Sauvez, 2002). The conception that low-density urban developments are more costly than high-density, compact urban developments is common among professional planners.

Studies have been conducted, which have aimed to show a link between decreasing urban density and increasing public costs (Camagni, Gibelli & Rigamonti, 2002). A lower urban density causes the costs for the provision of public services to rise.

A study in the United States has concluded that the costs for water and sewer lines are related to the size of building plots (Speir & Stephenson, 2002). In another study in the United States, Carruthers and Ulfarsson (2003) have examined the influence of the spatial structure of urban development on the public expenditure. They have analysed twelve measures of public expenditure among which, roads, transportation, police and fire protection, and education. The results of their study shows that the costs of public service provision increases with decreasing density and that a policy of compact urban development contributes to reducing public expenditure.

De Sousa (2002) has concluded from an economic analysis of the costs and benefits of brownfield development in the Greater Toronto Area, that overall compact urban development is economic viable for the society at large. Compact development leads to a more sustainable urban area, which results in less costs incurred by society.

Similarly, in the case of Europe, studies have shown the relationship between urban density and the costs of public service provision. Camagni et al. (2002) have found that public transport is strongly influenced, in terms of efficiency and competitiveness, by the structural organisation of an urban area. From a more recent study in Spain follows that the relationship between cost and the extent of urban sprawl is not linear, the cost of public service provision accelerates at very low and very high levels of sprawl (Hortas-Rico & Solé-Ollé, 2010). With increasing sprawl the costs of more and more public services start to rise. And if urban sprawl advances considerably over a short period of time, the increase in costs of service provision becomes an important concern for the local authority's budget.

Studies on the costs of urbanisation in France point however in the opposite direction. Guengant (1992) has found that the development costs of the road network increase with an increasing urban density. Furthermore, the costs for the provision of public services in low density urban areas seem to be lower than in high density areas (Fouchier, 2001). More recently, Castel (2006) has found that density has little effect on the costs for the local planning authority, but low-density developments can result in higher tax revenues.

However, the same research is also put in perspective. Fouchier (2001) argues that high-density urban areas often function as the centre for a larger region and provide public services to the surrounding low-density urban areas. Also, high-density urban developments result in a spatial structure that is more valued than the alternative (Castel, 2006).

Urbanisation also has an impact on society in the form of externalities. Extensive urban developments could result in higher expenses to provide the same level of public services (Guengant, 1992), but could also lead to a lower level of public services (Camagni et al., 2002). The latter implies that residents depend on their own means to access services. This results in, among other things, increased households' expenses and more car dependency.

Energy consumption

In urban areas, energy is mainly used in buildings, for transportation of people and goods, for industry, and for waste collection (Ishii, Tabushi, Aramaki & Hanaki, 2010). Reducing the consumption of energy is becoming more and more a policy objective in an effort to reduce the emission of greenhouse gasses. The main energy needs, that are affected by the urban form and can be influenced by spatial planning, are transport and energy used in buildings (Owens, 1990; Ewing & Rong, 2008; Ewing, Bartholomew, Winkelman, Walters & Anderson, 2008). In buildings, energy is used for heating, cooling and electricity supply, and accounts for about 40% of the total energy consumed; transport makes up a third of the total energy need (Brown, Southworth & Sarzynski, 2009; Steemers, 2003). Measures that help reduce energy consumption for either transportation or for the use in buildings are expected to significantly contribute to the reduction of greenhouse gas emissions.

The vast growth of car use over the last decades has caused environmental issues, like greenhouse gas emissions, congestion and health issues. Hence, the reduction of car use has been, and still is, actively pursued by governments. Based on the premise that urban sprawl increases car dependency and thus causes a growth in car use, part of the solution is sought in urban planning. Moreover, urban planning is a necessity in dealing with the increasing car dependency. Car use cannot be reduced by economic measures alone (Dupuy, 1999).

Travel demand is for the largest part driven by people's participation in activities separated in space and time (Schwanen, 2004). Hence, attempts to reduce the distance traveled in general, and the car use in particular, focus on bringing different activities closer together. A strategy, which appears to be effective. Land use policies that are designed to put residents closer to their destination, increase accessibility and provide alternatives to car travel will lead to less car use (Handy, Cao & Mokhtarian, 2005). Multiple urban forms exist, that bring residents closer to their activities.

Most prominent is the establishment of a more compact urban form and a general increase of the urban density. Schwanen, Dieleman and Dijst (2001) have studied the relationship between travel behaviour and the urban form in the Netherlands. They have found that the deconcentration of urban land use appears to lead to more car use for different purposes. Compact urban development, however, leads to an increase in the distance traveled by car. This indicates that a negative correlation between the population density and car use exists (Cervero & Murakami, 2010).

A compact urban form in a mono-centric urban area causes a reduction in car use. However, many urban areas, that are close to each other, interact with each other, creating a large polycentric urban area. Also, in many major urban areas, suburbs have grown into sub-centres. Polycentric urban areas lead to a decrease of commuting towards the main urban centre (Helminen, Rita, Ristimäki & Kontio, 2012). However, they lead to commuting between sub-centres, which eventually cause the commuting distance to increase (Aguilera & Mignot, 2004; Schwanen, Dieleman & Dijst, 2001).

Next to the reduction of the length of trips by car, the use of alternative modes of transport is stimulated. The use of the car and the traveled distance by car depends on the household characteristics, the characteristics of the residential environment and the trip purpose (Meurs & Haaijer, 2001; Dieleman, Dijst & Burghouwt, 2002). The provision of public transport has an important role in the choice of transport mode. Studies conducted in the Netherlands (Dieleman et al., 2002) and China (Qin & Han, 2013) have clearly found that the supply of good public transport contributes to the reduction of car use.

Also, the use of non-motorised modes of transport, like walking or cycling, is stimulated. Although the urban form is expected to have an impact on the choice of transport mode, density does not seem to have a significant effect on the distance traveled by non-motorised modes of transport (Forsyth, Oakes, Schmitz & Hearst, 2007). Alternatively, the physical appearance of the urban environment seems to be more important. An attractive urban environment, especially attractive public open space, induces alternative, non-motorised modes of transport (Giles-Corti et al., 2005).

Moreover, Saelens, Sallis and Frank (2003) have found that a combination of higher density, land use mixity and connectivity is important to stimulate non-motorised transport. An urban environment with a single land use (e.g. housing) does not promote non-motorised transport, however, a mix between residences and shops stimulate walking and cycling (Cao, Mokhtarian & Handy, 2009). Especially, since the choice of mode of transport for shopping trips is most affected by the characteristics of the urban environment (Meurs & Haaijer, 2001). Yet, in case of commuting trips the environmental characteristics have little influence on the choice of mode of transport, as this choice mostly depends on personal characteristics.

The amount of energy used for the operation of buildings in the urban pattern is affected by the urban form. Hence urban planning can help increase the efficiency of energy use in buildings. Ewing and Rong (2008) have argued that buildings in a low density urban pattern have a higher energy need than buildings in a high density urban pattern. Firstly, homes in extensive urban developments are often bigger than homes in dense urban developments. The former require more energy for heating, cooling and electricity supply. Secondly, low-density urban structures profit less of the urban heat island effect, and thus require more energy for heating. Ewing and Rong have concluded that a high density urban pattern indeed results in a more efficient energy use in urban buildings.

Many authors have confirmed the existence of a relationship between the urban density and the energy efficiency of urban buildings. A study for Beijing (Qin & Han, 2013) has found that the compact urban form contributes to the reduction of energy use, because, among other things, higher building density reduces the energy used for heating and cooling of indoor spaces. Brown, Southworth and Sarzynski (2009) have found that a compact urban pattern results in less energy use, primarily due to less use of electricity. And also Sovacool and Brown (2010) have concluded that the use of energy could be reduced by a more compact urban development.

However, the conclusion that urban density has an impact on energy use in buildings also finds some opposition. Holden and Norland (2005) have argued that the difference in energy use between single family homes and multi-family residential buildings has been strongly reduced since the 1980's. Also, the energy saving potential of multi-family residential buildings is often not achieved due to poor building quality (Rickwood, 2009). Finally, Perkins, Hamnett, Pullen, Zito and Trebilcock (2009) have concluded that the energy use per capita is similar for a city centre resident and a suburban resident, since the average household in a city centre apartment is smaller than a household in a suburban single family home.

Moreover, in an attempt to reduce the residential energy use, appliances and building design seem to be as important as the urban form (Rickwood, Glazebrook & Searle, 2008). For example, the installation of air-conditioning in offices results in an increase in energy use which is larger than the variation in energy use as the result of different urban densities (Steemers, 2003).

Yet, the urban density still has an impact on the energy used in indoor spaces. An optimal urban density exists, beyond this optimal density the energy use will rise again (Holden & Norland, 2005). Rickwood (2009) has found that multi-family residential buildings do not necessarily lead to a more efficient energy use; but terraced houses appear to be more efficient than detached homes. Finally, a study in Japan (Ishii et al., 2010) has concluded that a medium urban density, which holds the middle between a high density centralised urban pattern and a low density decentralised urban pattern, has the best potential to install energy saving technologies. Thus, medium urban density appears to result in the most efficient use of energy in urban residential and commercial buildings.

The overall conclusion is that urban sprawl increases the use of energy, and thus causes more greenhouse gas emissions. From the perspective of promoting energy use efficiency, academics indicate that a moderately compact urban pattern is preferred over urban sprawl as it helps to reduce the use of energy for both transportation and indoor use.

Quality of life

Besides personal factors, the quality of life depends on the urban environment (Yang, 2008). The planning authority's concern is with the influence of the urban form on the residential's quality of life. Implementing measures, that elevate the quality of life, can augment the attractiveness of the neighbourhood and increase or maintain the settlement of people (Brueckner et al., 1999). The urban environment's influence on the residential quality of life has a spatial, human and functional dimension (Bonaiuto, Fornara & Bonnes, 2003).

The spatial dimension refers to architectural and urban pattern characteristics. An aesthetic urban landscape is viewed as an amenity (Brueckner et al., 1999). Low density residential developments are often associated with low aesthetics. This idea, is both confirmed and disputed (Burchell et al., 1998).

The human dimension focuses on socio-relational features, like civility, security and sociability. An important issue is social segregation. Urban sprawl, especially the development of low density residential areas and peri-urbanisation, is believed to contribute to social segregation (Pendall, 2000).

Research on density of US cities and segregation of income has found a relationship exists (Pendall & Carruthers, 2003). Although Pendall and Carruthers have stated that the relationship is more complex than usually perceived, they have found that cities with increasing residential density have less income segregation than cities with constant or decreasing residential density. Galster and Cutsinger (2007) have stated that increasing density of urban development leads to less social segregation. If, however, urban development becomes too dense, social segregation is again reinforced.

Finally, the functional dimension concerns the access to amenities (e.g. shops, services and green areas). Several studies have shown that accessibility to services and facilities is one of the factors that cause residential satisfaction (Bramley & Power, 2009). Access to services and facilities is often better in dense urban forms; both the availability of services and facilities and the variation in services and facilities lessen as residential areas become more remote. Thus from the perspective of the provision of services and facilities, the compact urban form seems most preferable.

Even so, the proximity of green and natural areas contribute to the quality of life of residents (Kweon, Ellis, Leiva & Rogers, 2010). The conversion of agricultural or natural land to urban area causes the loss of open space and can cause the loss of cultural heritage (Levia & Page, 2000). Compact urban development limits the loss of rural and natural open areas. However, compact urban development does not leave room for urban open area, like urban parks.

Alternatively, a fractal urban form allows for a high accessibility to services and facilities, but also manages to maintain the proximity of green and natural areas (Frankhauser, Tannier, Vuidel & Houot, 2010).

2.3 Classical urban planning concepts

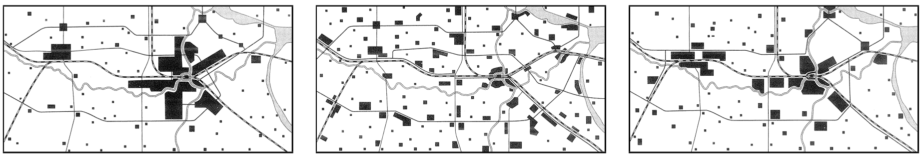
Extensive urban development proves to have a genuine impact on the urban functioning. It results in the consumption of scarce and non-renewable resources, especially open space and energy (Camagni et al., 2002). Planners and academics have responded to the trend of extensive urban development with urban planning concepts and urban models. This section discusses six major planning concepts: Concentrated Decentralisation, Compact City, Urban Growth Boundary, Green Belts, Green Alleys and infrastructure network.

Concentrated Decentralisation

Concentrated Decentralisation is a response to the rapid growth of the urban population. Its objective is to direct urban growth away from major cities towards regional growth centres (Schwanen, Dijst & Dieleman, 2004). On the other hand, urban sprawl is concentrated in a few locations; rural and natural areas remain relatively open.

In the 1970s and 1980s the Dutch national planning authority based their spatial policy on the Concentrated Decentralisation planning concept (see figure 2.1). Concentration of the population in existing cities did not meet the mode of living demanded by society and it was expected to lead to, among other things, congestion and reduced accessibility (Hidding & Van den Brink, 2006). The planning concept has also been applied in other countries, like the United States, France, the United Kingdom and Sweden (Cervero, 1995).

Although most planning authorities have moved away from the Concentrated Decentralisation planning concept, it is still relevant as it still explains major parts of today's urban structure. Moreover, at the local level, the planning concept is at the basis of the spatial policy set out in the SCOT of Grand-Besançon (Spatial Plan for the coherence of the urban area of Besançon).



(a) concentration **(b)** deconcentration **(c)** concentrated decentralisation

Figure 2.1 *– Illustration used in the* Tweede Nota Ruimtelijke Ordening *to explain the Concentrated Decentralisation planning concept, source: Ministerie van VRO (1966).*

Compact City

The Compact City concept, in North America often referred to as smart growth, envisages urban development in compact built patterns. These patterns are characterised by high built densities, uniformity and sharp, distinctive boundaries (Geurs & Van Wee, 2006). The idea behind this is that urban sprawl affects the urban-rural gradient, creating a zone which is neither urban nor rural. A clear transition between the urban pattern and the rural surrounding, with a distinctive urban boundary is often desired over a gradual transition (Hidding & Van den Brink, 2006).

Advantages of the Compact City, commonly agreed upon, are: better opportunities for public transport, decreased energy consumption for heating of residences and less segregation (Koomen, Dekkers & Van Dijk, 2008). Furthermore, De Sousa (2002) has shown that a smart growth approach proves to induce more benefits than greenfield residential development. He has argued that smart growth is the more sustainable solution. Also, it is often suggested that the Compact City concept results in a reduction of commuter travel. Finally, the use of the Compact City concept at the basis of spatial policies and their implementation is effective at restricting urban sprawl (Geurs & Van Wee, 2006).

Next to the Compact City concept, many related planning concepts exist. They complement the Compact City concept by contributing to the objectives of the Compact City. The increasing density concept, the mixed land use concept and the location policy are discussed below.

Densification of urban land use is seen as an integral part of the Compact City planning concept. In order to come to a more compact urban development, the urban density needs to increase. Two scenarios are possible: first new residences are developed at a higher density than existing settlements, and second, existing residences are replaced by denser new settlements. Densification does not necessarily mean an increase in the building density. It can also be achieved by increasing the density of activities and the frequency of use (Williams, 1999). Densification is at the basis of what is referred to as urban renaissance. A decrease in income segregation and less environmental pressure are argued to be attributable to denser urban development (Ghorra-Gobin, 2010).

Mixed land use, also multiple land use, is a planning concept that attempts to promote mixing urban living and working (Stead & Hoppenbrouwer, 2004). The objective is to improve quality of life in urban areas. Combining residences, shops and offices in one location could increase safety, as it increases the presence of people throughout the whole day. It also gives the opportunity to residents to live close to work and shops, and thus to transit by foot, bicycle or public transport. Similarly it gives the opportunity to companies to profit from the proximity of clients and suppliers. Different land uses can be combined spatially, e.g. living over shops, or temporally, e.g. using a school building at night for meetings of local associations or clubs, or even using a car park for office employees during the day and for local residents at night (Van der Valk, 2002). This way, mixed land use contributes to an efficient usage of the available space.

As part of the Compact City planning concept the Dutch national government has imposed a location policy on companies and organisations, dubbed the ABC policy (Dijst, 1997). Its objective is to limit the growth in car use and provide an alternative in the shape of public transport. Locations are given a qualification of A, B or C, based on their accessibility by car and public transport. An A-location has an excellent accessibility for public transport, however the accessibility by motorised transport is poor. Such a location is considered ideal for offices, business services and public amenities. A B-location is easily accessible by both public transport and motorised personal transport. It is ideal for agriculture and extraction, car-dependent offices and intensive manufacturing. Finally, C-locations have a poor accessibility for public transport, but a good accessibility for motorised transport. Extensive industries are envisaged at these locations. A similar concept is found in Germany, where cities aim to concentrate development around hubs in the public transport network.

Urban Growth Boundary (UGB)

A planning concept that is much older than the Compact City planning concept is the Urban Growth Boundary. The Urban Growth Boundary divides land into two zones: one where development is allowed and one where it is not (see figure: 2.2). Between urban areas the restrictiveness can vary from strongly bound, strongly bound with satellites to moderately bound, weakly bound or unbound (Millward, 2006). A strongly bound Urban Growth Boundary shows resemblance with the Compact City policy.

The Urban Growth Boundary has been heavily criticized (Tayyebi, Pijanowski & Tayyebi, 2011). The concept depends very much on conformity by the local authorities, which, in case it lacks, renders the Urban Growth Boundary inefficient (Han, Lai, Dang, Tan & Wu, 2009). A prominent result of the Urban Growth Boundary is an considerable increase in land and house prices (Anas & Rhee, 2006). Also, the planning concept proves to be a rather crude measure, that allows little flexibility (Anas & Rhee, 2006) and that only works when it is strictly maintained and adapted only occasionally (Ding, Knaap & Hopkins, 1999).

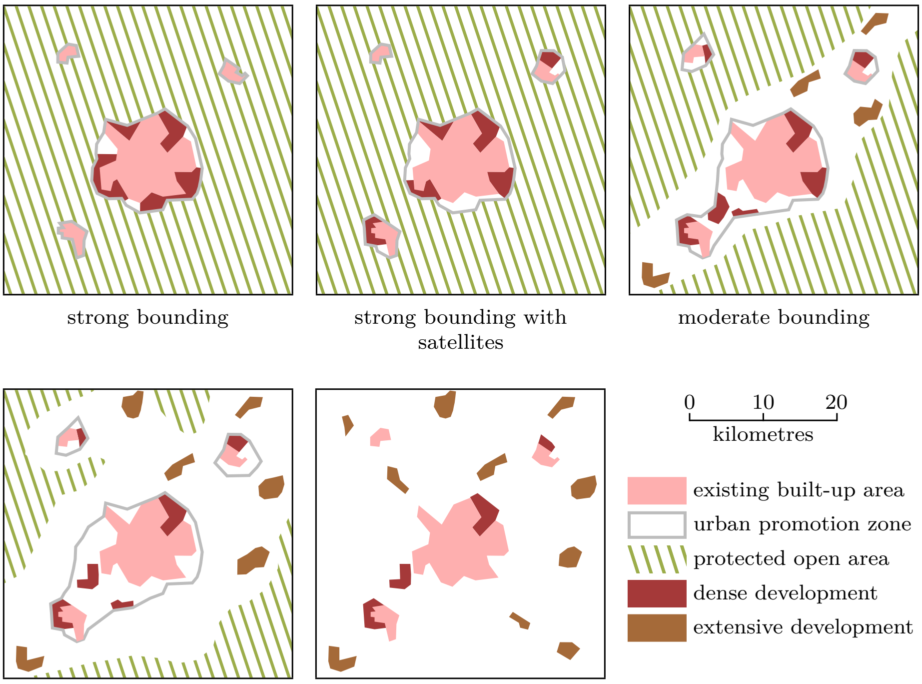
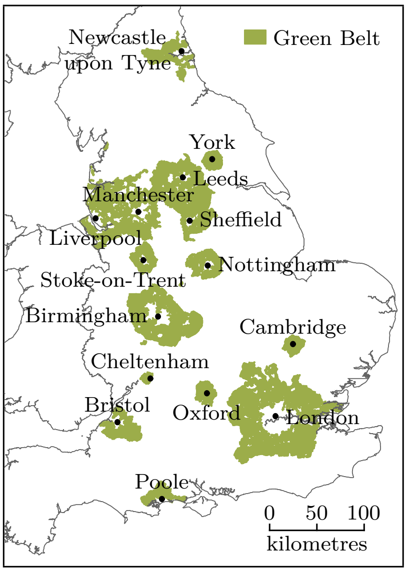


Figure 2.2 *– Varying restrictiveness of the Urban Growth Boundary in a conceptual urban pattern, adapted by author from Millward (2006).*

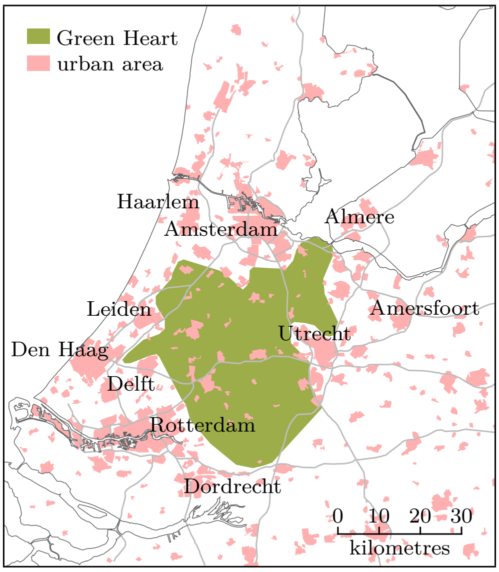
Green Belts

The green belt planning concept can be seen as a complement of the Urban Growth Boundary. The concept of Green Belts originates from Ebenezer

Howard's Garden City. The idea behind it is that belts of green and open, i.e. non-urban, land encircle major cities and embrace small and medium-sized settlements in the cities' hinterland. Severe restrictions on urban developments in the green belt are put in place. The purpose of a green belt is to stop the outwards growth of the major city it encloses, preserve open land and prevent the major city and the surrounding towns and villages to coalesce (Longley, Batty, Shepherd & Sadler, 1992). The Greenbelt concept has been developed and applied mostly in the United Kingdom (see figure 2.3a), however, it has also been applied in other countries around Europe, as well as in North America and Asia (Maruani & Amit-Cohen, 2007; Li, Wang, Paulussen & Liu, 2005; Van Rij & Korthals Altes, 2008).



(a) Green Belts



(b) Green Heart

Figure 2.3 *– (a) Green Belts around English cities prevent the expansion of these cities, source: Survey (2009). (b) The Green Heart at the centre of the* Randstad *prevents the inwards urbanisation of the outer urban ring, source: Meijers, Romein and Hoppenbrouwer (2003).*

A special case of a greenbelt can be found in the Netherlands (see figure 2.3b). The Green Heart (*Groene Hart*) is very similar to the Green Belts that are found around London and other cities in the UK (van der Valk & Faludi, 1997; Mori, 1998). The term Green Heart came to light in the early 1950s and refers to the relatively open area between the urban regions of Rotterdam, the Hague, Amsterdam and Utrecht. The latter are all part of the *Randstad* (border city), which edges the Green Heart. Since the Green Heart planning concept of the Green Heart emerged, Dutch spatial planning policies have aimed at keeping the Green Heart open. It avoids that the west of the Netherlands evolves into a large urban area. At the same time, it provides a location for outdoor recreation for the people from the Randstad.

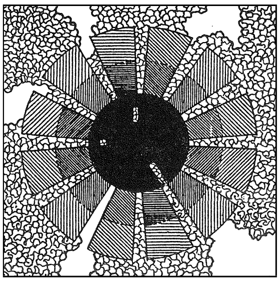
Green Alleys

The Green Alleys, or Green Ways, planning concept is a strategy based on the characteristics and advantages of integrated linear systems (Ahern, 1995). It aims to realise a synergy across spatial scales. Green ways are primarily linear, multifunctional and consistent with the concept of sustainable development.

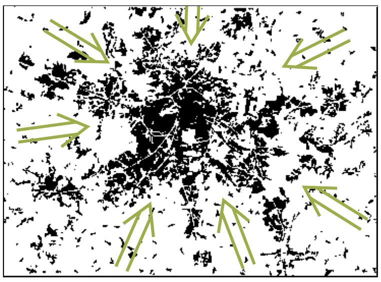
Green Alleys have a strong resemblance with Green Belts. They are by some viewed as the offspring of one and the same planning concept (Van Rij & Korthals Altes, 2008), however there is a main difference in the function between the two (Kühn, 2003). In the case of Green Belts, urban green functions as a separator between the urban pattern and the rural hinterland. Next to the general functions of urban green, its purpose is to confine urban growth. Green Alleys, at the other hand, focus on the integration of urban patterns and open area. The Green Alleys planning concept reckons the dynamic character of the urban pattern.

Green Alleys have often been designed as the link between natural habitats in a nature preservation network (Linehan, Gross & Finn, 1995). They allow species to transit from one habitat to another. Although in many instances, species and habitat conservation is an objective of green ways, it is not always the primary objective (Von Haaren & Reich, 2006). The linear character of Green Alleys contribute to the control of the urban micro-climate. In warm areas, Green Alleys can lower the temperature in residential areas (Crewe, 2003).

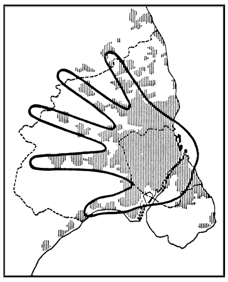
Finally, the Green Alleys planning concept increases the provision and accessibility of outdoor recreational space. The penetration of Green Alleys into the core of the urban pattern results in a structure that allows easy access to green and open area (Frankhauser, Tannier, Vuidel & Houot, 2008). The Green Alleys planning concept has been at the basis of the spatial policy of several cities in the North of Europe. Figure 2.4 shows how Green Alleys have been at the basis of the spatial development plans of Berlin and Copenhagen.



(a) Planning concept for Berlin



(b) Green Alleys in Berlin



(c) The *finger plan* of Copenhagen

Figure 2.4 *– The Green Alleys planning concept has been applied in European urban regions. (a) An old planning concept for Berlin reveals the objective of letting Green Alleys penetrate the urban area, source: Eberstadt, Möhring and Petersen (1910), image taken from Frankhauser (1994). (b) The current urban pattern of Berlin reveals how green and open area penetrates towards the urban centre, source Kühn (2003) and (Frankhauser 2011, oral presentation). (c) The finger plan of Copenhagen leaves the open area between the 'fingers' green, source: Knowles (2006).*

Infrastructure Networks

In relation to urban planning and development, many relevant Infrastructure Networks can be identified, that accommodate the flow of traffic, people, information, goods, water, and species. The network planning concept takes these networks as the basis for spatial planning (Hidding & Teunissen, 2002).

The Infrastructure Networks planning concept is currently the basis for Dutch national spatial planning. The idea behind it is a layer approach of space (Priemus, 2007). According to this approach, three layers can be identified: first, the *substratum*, which comprises the soil system, the water system and the biotic system; second, the *networks layer*, which mainly comprises infrastructure networks; and third, the *occupational pattern* comprising human activities (e.g. living, working and recreation). The substratum and the networks layer condition the occupational pattern. Therefore, the networks layer should be at the basis of spatial development plans of the occupational layer.

The network planning concept takes a more functional approach than the concepts that are discussed above and considers the dynamics of the driving forces of urban development. The spatial organisation that results from spatial planning based on the network concept is more complex (Hidding & Teunissen, 2002). It adapts a more polycentric approach to urban development (see figure 2.5).

2.4 Alternative planning concepts

The Compact City, currently the dominating planning concept, has been heavily criticised. It has been found to be leading to congested roads, higher house prices, reduced living space and reduced access to open and natural areas (Breheny, 1996; Gordon & Richardson, 1997; Burton, 2000). The implementation of the Compact City planning concept has also resulted in a large drop in the housing provision (Korthals Altes, 2006). The Compact City policy has been responsible for inducing traffic, as it has resulted in uniform development and thus households cannot find amenities close by (Frankhauser, 2004; Schwanen, Dijst & Dieleman, 2004). Finally, in compact cities, different types of land uses have found themselves sharing an increasingly confined space. This has resulted in more environmental conflicts between environmentally sensitive and environmentally intrusive land uses (De Roo, 2000).

In response to the critical analysis of the Compact City planning concept, academics have searched for alternative models of the urban form that better meet the requirements for sustainable urban development. A brief overview of some of these alternative urban form models is found below.

The New Urbanism model has been developed, primarily in the United States, in response to low-density suburbanisation (Calthorpe, 1993). In this model, cities, towns and neighbourhoods combine clear centres and edges, compact development, interconnected streets in grid or web-like patterns, mixed land uses and parks to define and connect neighbourhoods (Ellis, 2002). The touted benefits of New Urbanism are reduced land consumption, more public green space, and less transportation related pollution and energy use because of cyclist and pedestrian friendly design (Conway, 2009).

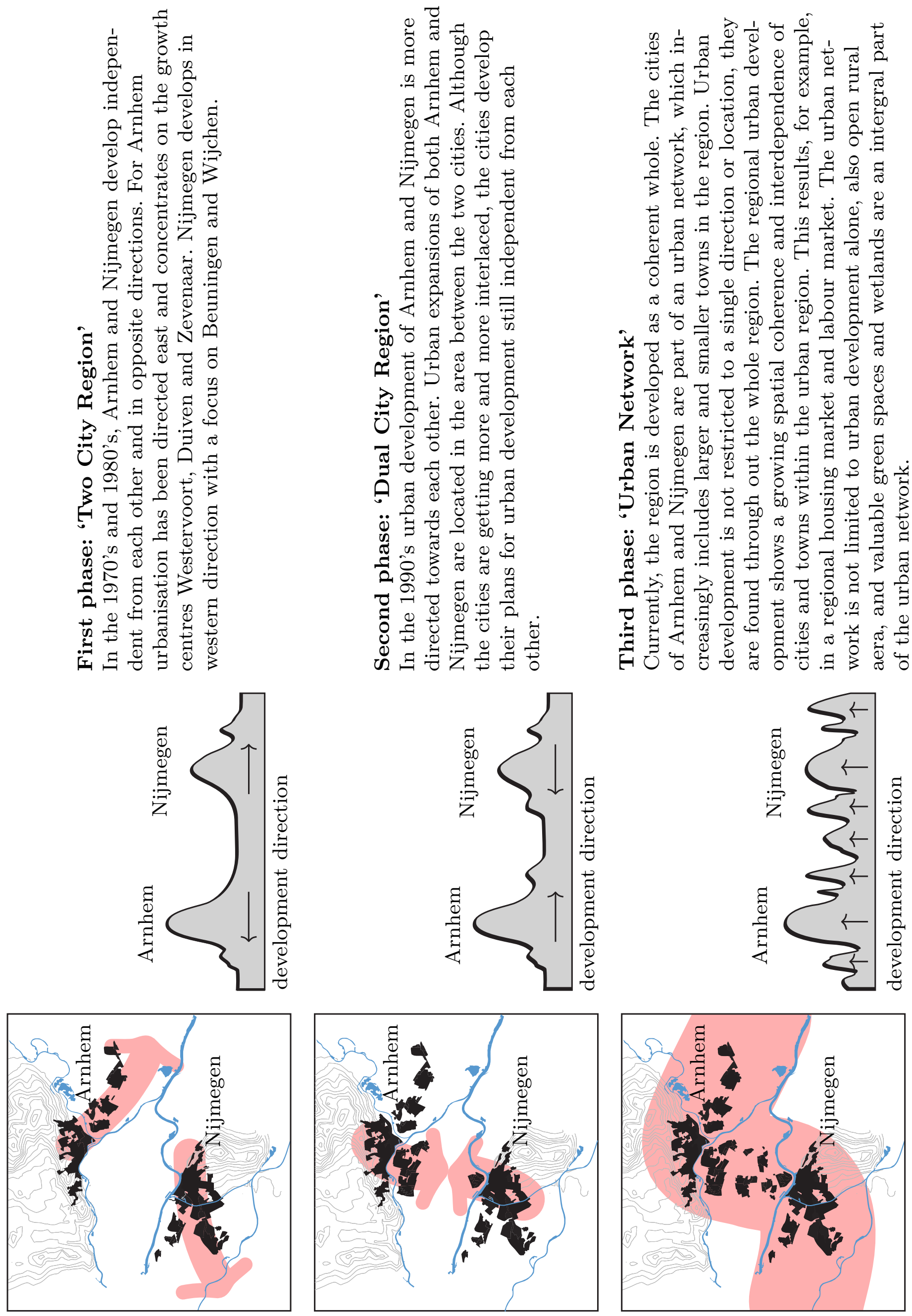


Figure 2.5 *– Arnhem and Nijmegen are two Dutch cities, near the German border, situated close to each other. The two cities are enclosed by pushed moraines in the north and south-east, which restrict urban development because of the preservation of pushed moraine landscapes. The development of the urban region during the last decades can be divided into three phases, where the last phase has been planned conform the urban network planning concept, source: College van Bestuur Stadsregio Arnhem Nijmegen and Gedeputeerde Staten van Gelderland (2006).*

Urban Village is a planning concept, which is quite similar to New Urbanism (Pacione, 2004). They both build on the organic metaphor, which aims to view the world as a whole of connected elements, rather then a collection of separate elements (Thompson-Fawcett, 1998). Urban Village is based on a theorisation of the historic, pre-industrial urban form, which promotes compact, human scale urban developments with mixed land use and mixed tenure. Physical qualities and building design are important features in Urban Village, as well as in New Urbanism, that arrest urban sprawl and maintain urban quality (Jabareen, 2006). Figure 2.6 compares traditional urban developments with New Urbanism and Urban Village.

In response to the Compact City metaphor, which has been considered too broad, generic and ideological, an alternative urban model, the 'Wisely Compact City', has come to the fore (Camagni et al., 2002). It combines a reasonable densification and a polycentric urban development. The urban pattern comprises small and medium-sized compact centres, which are well connected through an efficient network of public transport.

The Fractal City model follows from a multi-scalar approach (Frankhauser, 2004; Cavailhès, Frankhauser, Peeters & Thomas, 2004). The penetration of open area and built pattern should be multi-scalar, resulting in both small and larger open areas in the built pattern (figure 2.7). Fractal urban patterns are intrinsically non-uniform across scales, and exhibit longer and more sinuous boundaries than compact patterns (Frankhauser, 2004). In the Fractal City model, various urban and rural amenities have a high accessibility, and hence result in a reduction of transportation needs. Various planning concepts and real world implementations approache the logic of the Fractal City model (Frankhauser, 2004), like for example the Urban Village planning concept, concepts from the School of Le Corbusier, the green area concept of Stuttgart, and the real world urban patterns of Copenhagen and Berlin.

Alternatively, at the inter-urban level, multiple cities can be organised in a polycentric urban region (Davoudi, 2003). The latter refers to historically and politically separate cities, within a reasonable proximity from each other and with a high degree of functional inter-dependencies, that form a functional unity. Well known examples are the Randstad in the Netherlands, the Flemish Diamond in Belgium and the Rhine-Ruhr in Germany.

These five alternative urban forms each present an alternative solution to the Compact City planning concept or a response to problems that exist in the Compact City planning concept. They are based on existing planning concepts and hence occasionally one of the models, that are presented above, is the underpinning concept of an urban plan in stead of the Compact City planning concept.

The overview of the planning concepts that is presented here and in the previous sections is not exhaustive and merely aims to show some of the responses to issues that have risen due to urban development, especially urban sprawl. The Compact City planning concept appears to be currently the most implemented planning concept (Breheny, 1996).

Planning concepts for the urban form are the basis of spatial policies of local, regional and national planning authorities. Similar to the authorities who adopt them, the planning concepts themselves differ in scale. Some planning concepts,

(a) Housing development in San Jose, California, USA, by Sean O'Flaherty

(b) Cul-de-sacs in Colorado Springs, Colorado, USA, by David Shankbone

(c) De Held in Groningen, the Netherlands, by Kevster

(d) Prospect New Town in Longmont, Colorado, USA, by Decumanus

Figure 2.6 *– The design of traditional residential developments is dominated by uniformity as illustrated in (a) and (c) and by car possession and car use. The latter appears from (b), showing the lacking possibility to use alternative modes of transport. New Urbanism is characterised by diversity (d) and the space reserved for alternative modes of transport (e). Similarly, Urban Village is characterised by more pedestrian-friendly design (f) and (g). The planning concept also features a focus on physical quality and building design (f), (g), (h) and (i). All photos are licensed under a creative commons license* BY-SA.

like the polycentric urban region and the Green Belt planning concept, are large scale concepts oriented towards the urban form at agglomeration level. While other concepts, like the Urban Growth Boundary and the Compact City, can be implemented at the city level. The New Urbanism and Urban Village planning concepts include views concerning the form of individual neighbourhoods. In contrast, the Fractal City planning concept can, by definition, be implemented at different scales.

Differences in the scale of planning concepts, but also the involvement of multiple planning authorities, result in the combination of planning concepts. Moreover, national governments can impose planning concepts on local governments. In England, the national government imposes the Compact City planning concept on local planning authorities, by requiring a minimum share of urban development to be brownfield developments (Adams, 2004). But at the local level an additional spatial planning concept can be implemented, as seen for example in Leicester (figure 2.8), The spatial plans of Leicester combine the

(e) Willowgrove in Saskatoon, Saskatchewan, Canada, by Daryl Mitchell

(f) De Veste in Brandevoort, the Netherlands, by Peter H.

(g) City centre Radovish, Macedonia, by Pulvis Angelus

(h) Jakriborg in Hjärup, Sweden, by Johan Magnus

(i) Saifi Village in Beirut, Lebanon, by James Gallagher

Compact City planning concept with Green Lanes. Contrary, in the Netherlands, previous spatial policies set out in the '*Vierde Nota Ruimtelijke Ordening Extra*' (Ministerie van VROM, 1991) contained detailed plans for urban developments. This has left local planning authorities little room for the implementation of alternative planning concepts. However, since the publication of the '*Nota Ruimte*' (Ministerie van VROM, 2004), local planning authorities have more room to implement additional planning concepts in their spatial development plans.

The presented overview illustrates that spatial planning concepts are the concepts behind spatial policies. Spatial planning concepts, through the execution of spatial policies, have an important impact on the form of residential developments and urban developments in general.

2.5 Assessment of the efficiency of different planning concepts

The shape and spatial configuration of residential development have a significant impact on the functioning of the urban system. Urban sprawl, characterised by dispersed low density residential developments, is generally considered to have a negative impact. Section 2.2 illustrates however the complexity of the relationship between the form of residential developments and the functioning of the urban system. Especially, high residential density has proven to be a double-edged sword.

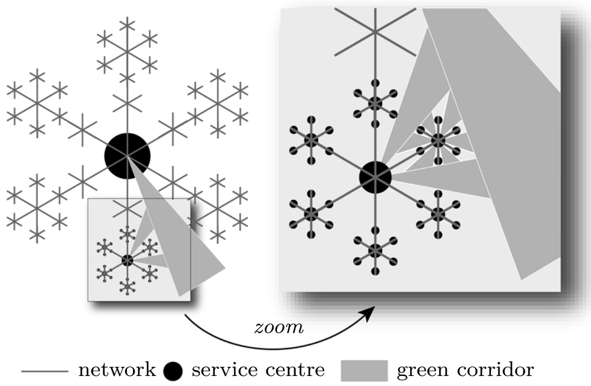


Figure 2.7 *– The multi-scalar approach of the Fractal City results in many small and a few larger open areas in the urban pattern, source: Frankhauser, Tannier and Vuidel (2007).*

The planning concepts discussed in this chapter have been developed in response to the issues that have risen due to extensive residential developments, i.e. urban sprawl. The Compact City currently is the most implemented planning concept (Breheny, 1996). However, many planning concepts, e.g. New Urbanism, Urban Village and the Fractal City, are a reaction to social and spatial issues related to the implementation of the Compact City planning concept.

Most research that links urban processes and characteristics to the spatial pattern of residential developments is still on-going. Similarly, spatial planning concepts, especially their efficacy and their impact on the behaviour of households and the development industry, remain a subject of research.

Some research has investigated the environmental impact of planning concepts (Geurs & Van Wee, 2006). It concentrates on how the Compact City planning concept limits the fragmentation and the degradation of natural habitats. Similarly, Conway (2009) has looked into the environmental impact of New Urbanism. Planning concepts that limit urban sprawl generally also limit fragmentation of natural landscapes. However, some planning concepts limit fragmentation less than others. Tannier, Foltête and Girardet (2012) have shown that, in some cases, fractal forms of residential development cause less fragmentation of natural habitats than non-fractal moderately compact urban forms.

Another string of research has focused on the effect of spatial planning concepts, more specifically the Compact City planning concept and the related green belt planning concept, on residential developments. By restricting the residential growth in an urban area, it either flows to areas beyond the restricted growth area, or green belt (Schwanen, 2004). Alternatively the number of residential developments decreases, which results in an increase in house prices and a housing shortage (Korthals Altes, 2006).

There is an enormous body of research focusing on the relationship between the spatial pattern of residential developments and the travel behaviour of residents (Priemus, Nijkamp & Banister, 2001; Handy, 1996). Researchers have

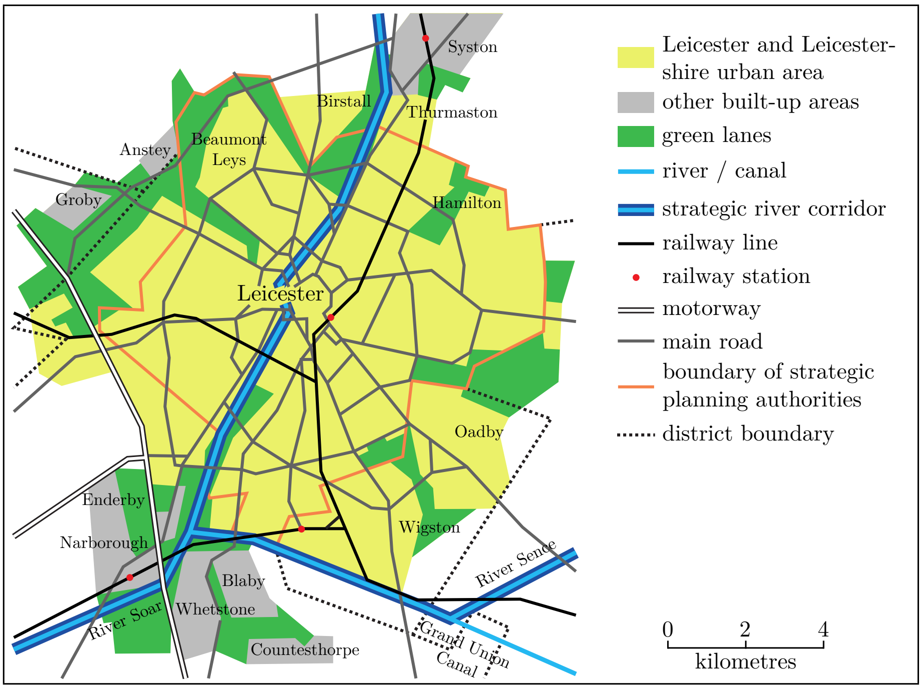


Figure 2.8 – *The urban development plan for Leicester shows a compact city, but it also includes green lanes that penetrate the urban pattern, source: Sinnott, Green and Franklin (2005).*

evaluated the travel behaviour of residents in view of different planning concepts.

Cervero and Murakami (2010) have investigated the link between travel behaviour and the urban density in the USA. They have found that a dense urban form results in less car travel. In addition, research in the Netherlands has evaluated the changes in travel behaviour as the result of different planning concepts, among which the Concentrated Decentralisation and the Compact City planning concept (Schwanen, Dieleman & Dijst, 2001; Schwanen, Dijst & Dieleman, 2004). The planning concepts have contributed to an increase of the use of alternative transportation modes, like walking and cycling. However, they have been less effective at reducing travel times.

Aguilera and Mignot (2004) and Helminen et al. (2012) have investigated the travel behaviour in polycentric urban areas. In these areas residents commute and travel from the centre to sub-centres and back, but also between sub-centres and from the urban periphery to both the centre and sub-centres and back. This pattern shows great resemblance with the network planning concept as illustrated in figure 2.5. Results from these studies show that polycentric urban areas appear to lead to a decrease of the distance travelled towards the centre, however this is replaced by travel between sub-centres.

Alternatively, Tannier, Vuidel, Houot and Frankhauser (2012) have review planning concepts based on a fractal approach and compare fractal planning concepts with non-fractal planning concepts. They have argued that a fractal approach does not necessarily increase the accessibility of amenities in comparison with non-fractal planning concepts. Fractal planning concepts perform better than non-fractal planning concepts when accessibility of non-urban amenities is considered, but they perform worse when accessibility of urban amenities is considered. However, the fractal approach results in the maintenance of urban quality and accessibility, even after continued development (Tannier, Vuidel, Frankhauser & Houot, 2010).

2.6 Impact of the implementation of spatial policies on the form of urban developments

The planning concept and the derived spatial policy are only part of the response to urban sprawl related issues. The efficacy of spatial policies and policy decisions, hence the efficacy of spatial planning concepts, depends on the planning authority's ability to implement their spatial policies and policy decisions.

A planning authority is charged with the development and implementation of spatial policies, by steering the urban development process. Herein the planning authority sees itself confronted with other social actors who have their own objectives and behaviours. The objective of the planning authority's planning and development activities is to influence the social actors' behaviour such that the latter results in a sustainable urban development that conforms the planning authority's spatial objectives. The effectiveness of the planning and development activities determines the planning authority's success at implementing planning concepts.

The role of the local planning authority: more than plan definition

Hidding and Van den Brink (2006) have shown that a local planning authority needs to influence actors' behaviour and development processes in order to have its objectives (i.e. the planning concept) implemented. They have defined the role of the local authority's planning and development activity as one of influencing existing processes of reciprocal adaptation of space and society. The authority's role in the urban development process is one of stimulation and steering—not necessarily initiation and fully controlling—in the interest of the general public.

A pivotal underpinning to the above definition is a clear distinction between defining and shaping the public objectives, which results in a spatial policy or plan, and promoting the implementation of these objectives. Both processes are however strongly linked. The completion of shaping a spatial policy and the adoption of that spatial policy mark the start of the processes of steering and promoting development (Sabatier & Mazmanian, 1980). Planning authorities need to consider how to implement the spatial objectives when defining them.

Based on this dichotomy Hidding and Van den Brink (2006) have qualified the public planning and development activity as a search with two aspects:

1. the *design task* constitutes finding solutions for the reciprocal adaptation of space and society. The outcome of this search is often laid down in a spatial plan or policy;

2. the *control task* constitutes finding means, within the existing legal, administrative and political context, to steer and coordinate the behaviour of actors who are involved in the urban development process.

In its design task, the local authority faces the population in its jurisdiction, or their elected representatives. Spatial plans and policies are the result of a democratic process. However, for the control task, the planning authority faces private initiative, i.e. actors, mostly private companies, with an interest in land development and housing construction. The planning authority finds itself in an arena with banks, investment companies, private land developers, builders, etcetera, all with their own objectives, plans and perception, and with whom it needs to interact.

In addition to Hidding and Van den Brink's dichotomy Healey and Williams (1993) have proposed a trichotomy to define European spatial planning systems:

1. a *plan-making function*, in which the planning authority defines strategies and principles for the spatial organisation and land use;
2. a *developmental function*, which includes measures to promote development in general or specific developments (e.g. land assembly, land servicing or development, infrastructure provision, financial aid); and
3. a *regulatory function* relating to the control of building location and form, and activity change within existing buildings.

The plan-making function corresponds with the design task of Hidding and Van den Brink. However, their control task correspond both to the developmental function and the regulatory function. In the developmental function, the local authority focuses on stimulating spatial developments that conform the objectives set out in the plan-making function. While in the regulation function, the local authority evaluates if proposed developments are in accordance with rules and regulations set out in legislation, local ordinances, spatial plans, etcetera. Across Europe, major differences exist between the exact definitions of how the local authority should execute the regulatory function (Healey & Williams, 1993). Beside these differences, this function also differs in how the local authority executes their regulatory function. The latter is especially noticeable when comparing countries in the South of Europe eith countries in North-West Europe.

Adams et al. (2003) have added the institutional capacity as a fourth element to the trichotomy of Healey and Williams. Institutional capacity, or social capital, refers to features of social organisation, such as appreciation, trust, norms and communication networks, that facilitate cooperation between stakeholders (Putnam, Leonardi & Nanetti, 1992). Building an institutional capacity means strengthening these features. It enhances the interaction between the local planning authority and stakeholders like residents and developers. It improves the relationship between the local authority and stakeholders along three dimensions: knowledge resources, relational resources and the capacity for mobilisation (Healey, 1998).

The presented typology helps to analyze the planning authority's tools and how they contribute to the implementation of the planning concept. Table 2.1

gives an overview of the four types of tools commonly used by local planning authorities. To achieve a successful implementation of its objectives the planning authority needs to have access to a balanced set of tools from all four types of functions (Hidding & Van den Brink, 2006). Each type of tool aids the local planning authority in a different way.

Function	Tools
Plan-making	Statutory plans Non-statutory plans
Regulatory	Planning (development) control
Developmental	Subsidies Taxes Direct action within the market Public development Public private development
Institutional capital building	Consultations Public private partnerships

Table 2.1 *– Typology of the planning authority's implementation tools (based on Adams et al., 2003)*

In the planning function, or design task, the planning authority's objective is to apply the general planning concept to the unique situation the authority is facing. It entails a process of analyses, formal and informal consultations and political debate. This process results in concrete objectives concerning the development of the spatial structure. Furthermore, the planning authority needs to communicate these concrete objectives. Hereto the planning authority can, but is more often required to, define one or more statutory or non-statutory plans. Especially for statutory plans legal requirements exist for both the content of plans and the procedure of plan development.

At the local level, most planning authorities define statutory plans indicating the local planning authority's objectives, e.g. *local development scheme* and *local development documents* (United Kingdom), *projet d'aménagement et de développement durable* and *schéma de cohérence territoriale* (France) *ruimtelijk structuurplan* (Flanders), *structuurvisie* (the Netherlands), *Flächennutzungsplan* (Germany) and *kommuneplan* (Danmark). The exact content and the detail of the content is different between countries (Davies, 1988). Also, depending on the legal context of the country, the content is either purely indicative or can contain legally binding elements (Healey, 1992b; Spaans & De Wolff, 2005).

The purpose of the planning process is the formulation and communication of the authority's objectives concerning the spatial development. Yet the resulting plans also have a controlling function. The communication of statutory and non-statutory plans changes the mindset of social actors and results in anticipating behaviour.

As a regulator the planning authority aims to enforce spatial policies defined in the planning function. Probably the most important tool is the requirement of a permit or permission to change the land use at a certain location (Needham, 2007). This can take many shapes.

In England anyone seeking a major land use change at a certain location is required to seek a planning permission (Cullingworth & Nadin, 2006). A planning permission could already be required for changing the use of a building, thus the development of a new housing site certainly requires a planning permission.

In the Netherlands, the allocation of land use is presented in the legally binding land use plan (*bestemmingsplan*). Every change in the land use needs to be conform with the land use plan. Permits are required for any major demolition, construction or ground work necessary for the land use change as well for the environmental impact or nuisance caused by certain land uses.

Both planning systems seem very different, but one amounts to the other. The result is that, if sufficiently enforced, it allows the local authority to block the development of land and the construction of buildings, if they deem undesirable.

A planning authority has access to several different types of tools (see table 2.1). With these tools a planning authority intervenes in market and development processes. The purpose of which is to gain control over the location and various other aspects of the character of urban development (Adams et al., 2003).

Local authorities often have the possibility to directly intervene in the market for development land through compulsory purchase and pre-emption right. These statutory tools assure that development projects can continue, even if landowners are unwilling to sell their property. These tools are often limited to locations where concrete development projects exist.

However, a planning authority often requires a more general control over the land market and the urban development process. Such control is aimed at limiting negative externalities and ensuring that public interests are taken into account. Hence, the planning authority might want to control land or house prices, avoid land speculation, stimulate or discourage (residential) development in general or in certain areas, or stimulate compact urban development over extensive development. Depending on the institutional context, authorities can chose between several tools, e.g. land banking, house price regulation (Barlow, 1993), voluntary land purchase, subsidies (Needham, 1992), taxes (Korthals Altes, 2009; Bento, Franco & Kaffine, 2006) or, even though it is an improper use of the tool, pre-emption right (Vilmin, 2008). Finally, to gain more control over the urban development process, the planning authority can also engage in public or public-private developments.

Building institutional capacity is a recognition of the interdependence of social actors. The local authority depends on the cooperation of, among others, developers and investors to implement their objectives. This has become more and more relevant over the last two decades, which coincides with the move from government to governance (Stoker, 1998). Several definitions of governance exist. However, it is often described as the 'self-organised steering of multiple agencies, institutions, and systems which are operationally autonomous from another yet structurally coupled due to their mutual interdependence' (Jessop, 1998, p. 29).

The move from government to governance has become evident with the emergence of public-private partnerships. In a public-private partnership, planning authorities enter into an agreement with one or more social actors (e.g. developers, investors) to execute a development project. In some countries, a formal structure exists for the public-private partnership. The *zone d'aménagement concerté* in France is an example of such a structure. In many cases the agreement between the planning authority and the social actors is a private agreement. Such an agreement is the result of negotiations between the planning authority and the social actors. However, sometimes the local planning authority has the ability to use public tools to gain aditional bargain power in the partnership.

A local authority's ability to control the urban development process, and influence the urban form that emerges, depends on how the authority executes each of the four functions. All four functions have a role in the control of urban development. Moreover, a local authority needs to focus on all four functions in order to effectively control urban development (Hidding & Van den Brink, 2006).

How successful a local authority can execute the four functions depends on planning rules and regulations, the availability of development tools in each function, the effectiveness of development tools, and the willingness to use these tools. These factors are determined by national legislation and the institutional context. But also the political, economic and social context have a major influence. Since the institutional and political contexts, and often also the economic and social contexts, differ between countries, the local planning authority's ability to control the urban development is different between countries.

Effects of the application of development control tools on the form of urban developments

Analysing the effect of the local planning authorities' application of various development control tools on the urban development process is subject of research. For instance Cheshire and Sheppard (2002) have investigated the effect of zoning, where developments are restricted to designated areas. They have concluded that zoning better helps containing residential developments than development taxes. However, zoning also causes, among other negative impacts, increased house prices and can lead to social segregation. Similar results were found for Houston (Texas, USA), which is known for the lack of zoning (Qian, 2010). The planning authority may substitute zoning with public investments and private contracts. However, the planning authority cannot prevent the mixing of land uses, notably industrial developments near residential areas, and thus prevent the degradation of the spatial quality.

Needham (1992) has illustrated how subsidy of land development gives the local authority more control over land developments. The authority can set criteria that indicate when residential development, or any other type of development, is eligible for subsidy. Also, subsidy, in combination with sufficient land provision, causes low land prices. The latter causes land development to become a public activity, as seen in the Netherlands until recently. A related development control tool is public land ownership. A study of public land ownership in

Manchester (UK) has shown that public land ownership has had a substantial effect on the morphology of urban developments (Kevill & McKay, 1988).

Also a more structural context contributes to the planning authority's ability to control residential development. Aspects from the legal or administrative context can eventually result in more or less control. Sellers (2002) has compared the administrative systems of France, Germany and the United States. He has concluded that due to the administrative and institutional context German authorities locally implement national spatial policies more consistently than their counter parts in France and the United states. Webster and Wu (2001) have compared two hypothetical planning systems. In one the community has the development rights, similar to the British planning system. Authorities use planning conditions, planning gain, etcetera to ensure social development. In the other planning system, developers own the planning rights and authorities can steer developments through financial stimulation. Webster and Wu have found that the planning authority is more effective in the former planning system.

Spatial patterns clearly affect the spatial quality of urban areas. Spatial planning concepts and spatial policies that govern the spatial pattern of residential and other urban developments are therefore important means to control the spatial quality. However, some of the research discussed above has shown that the spatial pattern also depends on the context of the planning authority's governance and planning tools used to implement planning concepts. A planning authority's decision to either use or not use planning tools like zoning, development taxes and subsidies eventually has an effect on the spatial pattern of urban developments.

The planning authority's decisions as to which planning tools to use is important since it determines the efficacy of the planning concepts and the spatial policies. At the same time this choice is politically loaded. Planning tools, like zoning, are sometimes seen as government interference in, and thus a restriction of, the free market (Qian, 2010). Opponents to government intervention in the urban development process argue that it limits economic development and causes a mismatch between supply and demand (Holden & Turner, 1997). The latter results in increased social and environmental issues like longer commuting distances. Whereas at the other end of the spectrum, proponents of government intervention argue that it is necessary to compensate for market failures that contribute to urban sprawl (Pryce, 2003). The planning authority's participation in the urban development process finds itself at the centre of this debate.

However, besides the political debate on the use of planning tools, planning authorities might see themselves restricted in their interference in the urban development process and the use of planning tools. Planning tools are not always available to planning authorities, this depends however on the context in which they operate. National legislation on spatial planning might not have foreseen the use of certain planning tools. Local and regional planning authorities might use planning tools differently than intended, which can cause undesired side effects. What is more, spatial planning and governance is a complex process (Silva, 2002) involving many actors with different objectives, unclear outcomes of policy measures and planning tools, and a mismatch between policy objectives and measures.

This suggests that, next to spatial planning concepts, the capability of local planning authorities and the context, in which they govern urban developments, play an important role. Moreover, the geographical differences in the pattern of urban developments is expected to be partly the result of differences in the context of the local planning authority's governance of the urban development process. The geographical differences in the spatial pattern of urban developments is linked to national borders, which confirms that the national context is an important factor.

The influence of the context of governance on the implementation of planning concepts and spatial policies, and thus on the spatial configuration of urban developments, suggests this influence should be part of simulation models of urban growth. Therefore, the next chapter investigates how planning authorities are part of the urban development process, concentrating on residential development. It discusses how the implementation of spatial policies is important and which factors affect the planning authorities' behaviour in this process.

Chapter 3

The process of residential development: micro-economic versus institutional economic modelling

The number and form of residential developments are a major interest to local planning authorities and local state agencies. This interest is apparent in their behaviour; they direct a lot of their effort to steering the residential development process in order to control the form of residential developments. The local authority's success of controlling development depends on many factors. Among them are the national and regional settings of the development process, which are expected to affect the behaviour of local planning authorities. Hence to better understand geographical differences in the form of residential developments the focus should be on how the national setting, local authority behaviour and the form of residential developments are related. These links are not present in the micro-economic approach of residential location dynamics, which rather focuses on the location choices of households. Alternatively, institutional economic modelling provides a link between the national setting and the behaviour of local planning authorities. An institutional approach could therefore help explain geographical differences in the form of residential developments.

3.1 Micro-economic modelling of residential location dynamics

Three main economic theories are behind the land user behaviour modelling approach based on the location choices of households and other actors (Koomen & Stillwell, 2007; Arguea & Hsiao, 2000): the land rent theory (Alonso, 1964), the hedonic price theory (Lancaster, 1966; Rosen, 1974) and the discrete choice theory (McFadden, 1978). These three theories explain location choices of residents and are the basis of the decision rules of agents representing residents in simulation models of the residential development process.

In the land rent theory, a household's choice of the location of residence is a trade-off between the cost of residing at the location of choice and the accessibility of the central business district and local service centres (Fujita, 1988; Page, 1999; Henderson, 1974). The central business district and local service centres provide households with employment and the possibility to buy goods. Hence, households aim to settle close to the business district and local service centres to reduce the costs of transportation. However, the costs of residence, i.e. land rent, increase as a household settles closer to the central business district.

Besides the accessibility of the central business district and local service centres, the presence of cultural and social amenities (Brueckner et al., 1999) and the accessibility to permanent open areas (Irwin, 2002) are also factors that increase the land rent. Households finally settle at the location that provides the optimal trade-off between the cost of settlement and the accessibility of the central business district, local service centres, permanent open areas and other amenities. Differentiation between location choice of households is due to the differences in the importance of the location characteristics (Fernandez, Brown, Marans & Nassauer, 2005) whereas differences in the urban form are explained by differences in the economic production in cities (Henderson, 1974).

Hedonic price theory simplifies the analysis of markets by viewing the demand for goods, i.e. locations of residence, as the demand for amenities (Arguea & Hsiao, 2000). It assumes that consumer satisfaction is not obtained from the location of residence itself, but rather from its characteristics (Gorman, 1980). The hedonic price refers to the monetary value attributed to an amenity at a given location, for instance the neighbourhood quality and the accessibility of shops, schools and other services. The satisfaction perceived from a residential location is the result of the satisfaction perceived from all amenities at a location (Rosen, 1974).

Hedonic price theory has been used to link economic values of locations to the outcome of spatial analysis using spatial indices (Geoghegan, Wainger & Bockstael, 1997). The price of houses has been correlated to the outcome of indices measuring the presence of open areas, their quality (diversity, fragmentation), as well as the quality of the built environment. The link between spatial indices and hedonic prices allows a simple modelling of the locational preferences of households based on spatial characteristics.

Discrete choice theory represents an actor's decision as a choice between a limited set of mutually exclusive alternatives (Bierlaire, 1998). When addressing residential mobility, discrete choice models allow the modelling of mainly two kinds of choices: the choice to move or not, and the choice of a new residential location. One of their main advantage is the introduction of greater flexibility in the way of, among other things, taking into account bounded rationality (De Palma & Thisse, 1989; Verburg, Schot, Dijst & Veldkamp, 2004). For instance, it is well known that households are unable to evaluate all characteristics of all possible locations of settlement. Hence in discrete choice models, households evaluate a limited number of potential residential locations based on a limited set of characteristics.

Finally, micro-economic models of residential location dynamics focus on the household behaviour in a given (pre-defined) housing market. Household behaviour can be very finely represented: utility functions introducing preferences for a large spectrum of characteristics (hedonic models), probabilistic choice and bounded rationality (discrete choice models), etcetera. However, interactions between different types of actors are not modelled.

3.2 Introducing the role of private development actors and planning authority in the modelling of residential location dynamics

Multi-agent simulation (MAS) techniques have emerged in the research of urban development, because they, sometimes used in combination with cellular automata, are well suited for the simulation of urban processes at micro level (Benenson & Torrens, 2004). MAS models have very useful characteristics (Parker, Manson, Janssen, Hoffmann & Deadman, 2003): they are capable of representing complex systems and are easily adapted to changing circumstances; they closely mimic the dynamic paths of the system; they simulate and help explain emerging phenomena. MAS models simulate real world processes rather than produce results that can be fitted to empirical data sets (Brown, Walker, Manson & Seto, 2004).

An important application of MAS models is the simulation of the change of spatial patterns as a result of the behaviour of (spatial) actors. Models, that have been developed for this purpose, have been used to simulate urban sprawl as a result of the location choices of households and private companies (Loibl & Toetzer, 2003). Similarly, they have been used to simulate migration within a city and explain the distribution of social classes (Benenson, 1999; Omer, 1999).

One interesting feature of MAS models is the easy introduction of heterogeneous behaviour into the simulation of urban processes. An example is the creation of different types of residents, with different preferences for the location of settlement (Brown & Robinson, 2006). Loibl, Tötzer et al. (2007) have also described a multi-agent simulation of a polycentric urban agglomeration in which each city has its own characteristics, such as for example growth velocity.

The role of the planning authority is, however, rarely found in multi-agent simulation models of the urban development process. Rather, the residential location choices are pivotal to the simulation of the residential development process. Residential developments are modelled as the result of the aggregate location choices of households.

Some authors (Miller et al., 2004; Semboloni, 2007) have proposed models that include the behaviour of private developers; households and private companies depend on developers for the construction of new urban areas. Household agents and company agents demand urban development through a system of simulated markets. If sufficient demand for development exists, it is profitable for a developer agent to develop a new urban zone.

Other authors have also included local authority agents. For instance, Ettema et al. (2007) have proposed a model which includes agents that represent local authorities. The behaviour of such authority agents has most similarities to non-profit developers. Alternatively, the behaviour of the local planning authority can be confined to the acceptance or rejection of development proposals made by a developer agent (Liu et al., 2006). The location choice of households remains, however, the basis of all simulations based on the land user behaviour modelling approach.

A more realistic simulation of the role of (local) authorities has been introduced by Arentze and Timmermans (2003b). Their model framework allows authority agents to endorse certain development proposals of developer agents. As a result it permits the modelling of a more pro-active role of planning authorities in steering the development process. This was however not yet integrated into their model.

Negotiations between the private and public actors have been integrated in urban growth models relatively recently. Webster and Wu (2001) have included a negotiation between a planning authority and a private developer in their urban growth model. Ligtenberg, Wachowicz, Bregt, Beulens and Kettenis (2004) have chosen to simulate the planning process itself rather than the development process. The influence of interest groups on the decisions of local authorities is simulated as negotiations between the different agents. The authors have discussed three scenarios in which the agents have different decision powers. Rather than modelling the local authority's influence on the residential development process, the model simulates how interest groups influence the planning process.

Finally, only a few models focus on the relationship between the behaviour of development actors and the urban spatial configuration. These models take into account the complex interactions between development actors.

3.3 Complexity of the residential development process

Classically, residential location modelling takes a demand side approach. In these models, building provision is assumed to follow demand (Healey, 1992a; Van der Krabben & Lambooy, 1993). This approach dismisses however the complexity of building provision. It cannot explain how differences in the supply-side complexity can cause differences in the spatial pattern of residential development. Residential location modelling does not foresee the modelling of the local planning authority's pro-active behaviour aimed at controlling the urban development process. As shown in section 2.6, the local planning authority's effort to control the residential development process focuses on the provision of residences, rather than on the demand for residences. Hence to model the effect of the planning authority's behaviour on the spatial pattern of residential developments the focus should be on the supply side, i.e. the provision of residences. A supply side approach allows the modelling of the impact of different factors on the provision of residences. Moreover, it enables to typify the pro-active behaviour of the local planning authority and other development actors. Several descriptive models already exist that illustrate the complexity of the provision of residences and the pro-active behaviour of development actors. We present here two of them: event-sequence models and behavioural models.

Event-sequence models

Event-sequence models help understand and illustrate the complexity of the process of provision of residences by unpacking it into its constituent events. Probably the most straightforward event-sequence model has been introduced by Cadman and Austin-Crowe [1] (as cited by Gore & Nicholson, 1991, p. 706; Healey, 1991, p. 223). Taking an approach which represents the perspective of the developer, they have divided the development process into four distinct phases: evaluation, preparation, implementation and disposal. Alternatively, Goodchild and Munton [2] (as cited by Healey, 1991, pp. 223–224) have depicted seven stages (table 3.1). Similar to the model by Cadman and Austin-Crowe, the model by Goodchild and Munton starts with the identification of development potential of a parcel, and ends with the (re-)occupation of the parcel. However, the stages in the latter model better represents critical events and decisions. These two models already illustrate some of the potential complexity of the process that leads up to the provision of residences (Healey, 1991).

	Phases of the property construction process
1.	The 'maturing of circumstances' which permit the change of the land use, e.g. housing development on a previously agricultural terrain.
2.	The purchase of the land by an actor with an interest in its development.
3.	The preparation of the land for development, this includes both 'physical' construction work and 'abstract' operations such as the establishment of the legal title to the land.
4.	The preparation of the development scheme, this includes obtaining all the necessary consents, especially planning permission.
5.	The arrangement of the development scheme.
6.	The construction of the development scheme.
7.	The occupation of the new development by either the developer, a new owner or a tenant.

Table 3.1 *– Event-sequence model of the property construction process, source: Goodchild and Munton (1985) as cited by Healey (1991, pp. 223–224)*

Ratcliffe [3] (as cited by Gore & Nicholson, 1991, pp. 706–707) has defined a detailed model of the development process, that consists of the same four stages as the model by Cadman and Austin-Crowe. It sets out the construction process in a flow diagram of events from the perspective of a developer (figure: 3.1). This model illustrates the complexity of the process. Similarly Punter (1988) has presented a flow diagram that models the construction process in France from the perspective of the local authority. Although this presentation is now

1. Cadman, D. and Austin-Crowe, L. (1978). *Property development.* London: Spon.
2. Goodchild, R. and Munton, R. (1985). *Development and the landowner: An analysis of the British experience.* London: Allen & Unwin.
3. Ratcliffe, J. (1978). *An introduction to urban land administration.* London.

somewhat outdated, this model defines the process as a sequence of a vast number of events and decisions that lead up to the actual construction, illustrating the complexity of the process. Despite criticism, linear flow diagrams representing the construction process, like the Ratcliffe model, illustrate that actors take decisions throughout the course of the construction process. These decisions affect the outcome of the process and thus the spatial pattern of residential developments.

A verbal description of the process, like in the models by Cadman and Austin-Crowe and by Goodchild and Munton, are rather crude and provide a very general depiction of the development process. The flow diagram models, like the models by Ratcliffe and by Punter, allow a more precise description of the process. However, they postulate the property construction as a rigid process, with a definite beginning and end. Moreover, such models are exclusively project-based, and describe the trajectory of certain types of property construction projects. Hence both types of models fail to capture the diversity and complexity of the construction processes. They lack the iterative nature of the property construction process (Gore & Nicholson, 1991). The property construction process is indeed dynamic and continuous: new property construction projects may start at any point in time. Projects can be executed simultaneously or not, and in different manners.

The 'pipeline model' by Barrett et al. [4] (as cited by Gore & Nicholson, 1991, pp. 709–710; Healey, 1991, pp. 228–229; Adams, 1994, pp. 45–46) integrates these characteristics of the construction process as mentioned above. It describes the property construction process as a circular process, rather than a linear sequence of events (figure: 3.2). Moreover, the urban development process is considered continuous; developed land will at some point in time be subject to redevelopment. Albeit, in some cases, especially city centres, this might take a very long time. The 'pipeline model' also includes external factors that have an important influence on the outcome of individual events in the property construction process. These include the global socio-economic context in which the construction process is situated. They also include economic sectors, like the financial sectors and the construction industry, who have a major interest in the construction process, but who are not directly involved in the principle decisions.

The model by Barrett et al. divides the development process into three phases, which show clear resemblance to the four phases of Cadman and Austin-Crowe. The evaluation phase consists of the simultaneous identification of social demand, development pressure and prospects by both private and public development actors. The events in this stage lead up to plans for residential construction. In the next phase development actors test the feasibility of their plans and prepare the implementation of the plans in separate parallel events. These include land acquisition, going through public planning procedures, funding the land acquisition, land development, and the physical constructions at the development site. If all the conditions in the preparation phase are met, the process

4. Barrett, S. M., Stewart, M. and Underwood, J. (1978). *The land market and the development process: a review of research and policy* (Occasional paper No. 2). School of Advanced Urban Studies, University of Bristol.

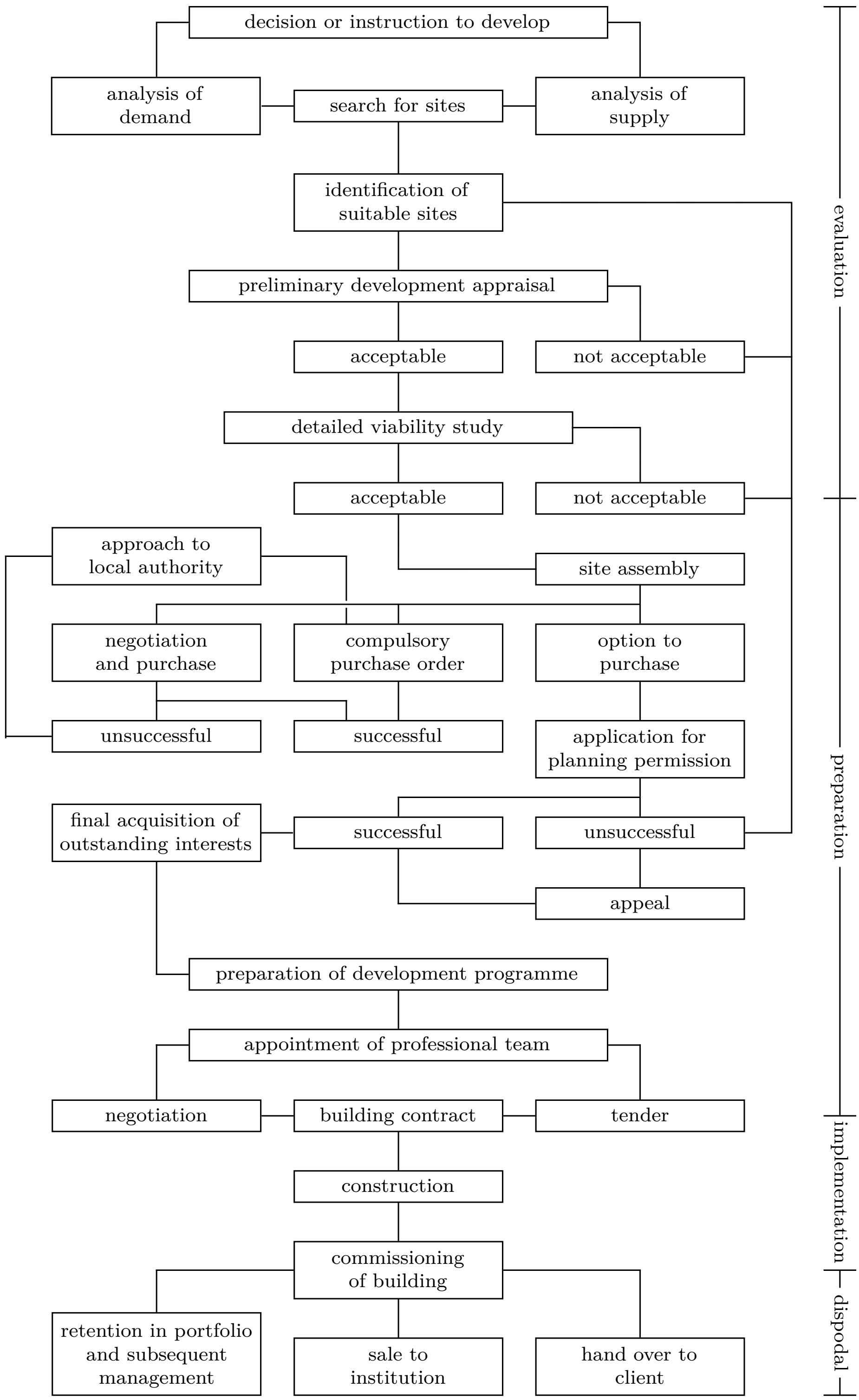


Figure 3.1 *– Linear model of the property development process in the British context, source: Ratcliffe (1978) as cited by Gore and Nicholson (1991, pp. 706–707).*

moves to the implementation phase. This phase combines the implementation phase and the disposal phase from the model by Cadman and Austin-Crowe. It consists of the physical construction of property, the disposal to the final owners and the use by the end user.

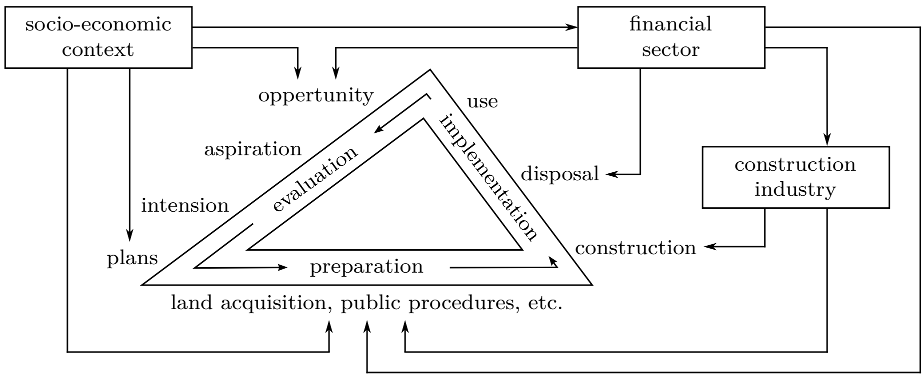


Figure 3.2 *– An event-based 'pipeline' model of the commercial property development process, source: Barrett et al. (1978) as cited by Gore and Nicholson (1991, pp. 709–710), Healey (1991, pp. 228–229) and Adams (1994, pp. 45–46).*

Similar to the model introduced by Barrett et al., Gore and Nicholson [5] (as cited by Gore & Nicholson, 1991, pp. 711–712; Adams, 1994, pp. 47–48) have also depicted the development process as a circular process. Their model describes the public sector development process (figure: 3.3). The evaluation phase is replaced by a policy phase, indicating the perspective of a government agency. More importantly, however, is the addition of a fourth leg, which is the vacancy phase. This phase links the use of a development to the policy or opportunity to (re-)develop the same area. Evolving demands of users and the deterioration of built and spatial structures cause a growing user dissatisfaction. For government buildings and office buildings this results in the abandonment by its users and buildings become vacant. In case of residences, privileged tenants move to other areas, leaving behind underprivileged residents. The latter process eventually leads to social segregation and related social issues (Buisson & Mignot, 2005; Wacquant, 2006).

The fourth leg in the model by Gore and Nicholson of growing dissatisfaction and eventually abandonment, could be viewed as the emergence of a social demand for change. The extra leg completes the model and makes the model fit the basic model of the urban development process in which residents and other land users demand a spatial structure, and development actors provide a spatial structure. What the models by both Barrett et al. and Gore and Nicholson illustrate is the complexity and the large number of decisions involved in the provision of the spatial structure.

5. Gore, T. and Nicholson, D. (1985). The analysis of public sector land ownership and development. In S. M. Barrett and P. Healey (Eds.), *Land policy, problems and alternatives* (pp. 179–201). Aldershot, UK: Gower.

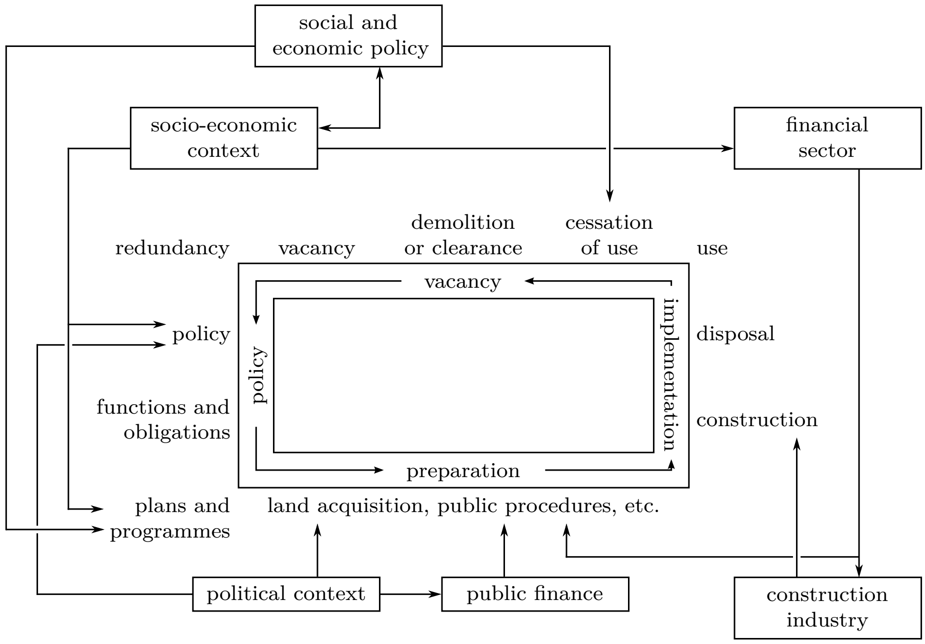


***Figure 3.3** – An event-based ‘pipeline’ model of the public property development process, source: Gore and Nicholson (1985) as cited by Gore and Nicholson (1991, pp. 711–712) and Adams (1994, pp. 47–48).*

Behavioural models

Compared to event-sequence models, behavioural models (also called agency models) concentrate more on the actors and their interactions in the development process.

Ambrose (1986) has distinguished three main ‘fields’ in the development process, the state, the financial sector and the development industry (see figure: 3.4). The state includes both the public authority and other public agencies, also referred to as the public sector. The financial sector consists, inter alia, of banks, pension funds and insurance companies. The development industry consists of commercial actors involved in the construction of property. Residents, or land users in general, are the fourth field, which, in contrast to the first three fields, is less cohesive.

In their interactions with financial institutions, like banks, insurance companies and pension funds, the residents’ actions are individual. Residents and other land users are the principle supplier of funds for the residential and other urban developments through the financial sector. However, they have little influence on how the money is spend. Furthermore, Ambrose has argued that the influence of residents on spatial planning policies through public participation is limited.

Bryant et al.[6] (as cited by Gore & Nicholson, 1991, p. 713; Healey, 1991, pp. 225–227) have recognised the multiplicity of actors involved in the residential

6. Bryant, C. R., Russwurm, L. H. and McLellan, A. G. (1982). *The city’s countryside: land and its management in the rural-urban fringe.* Harlow: Longman.

development process. Their model links the event-sequence approach and the agency approach (figure: 3.5), and thus illustrates who dominates the decision process at the different stages of the development process. Similarly, Drewett [7] (as cited by Gore & Nicholson, 1991, p. 714; Healey, 1991, pp. 224–225) has also contended that the residential development process is an aggregate of many decisions by a multiplicity of actors. However, he has placed the developer at the centre of the development process (see figure 3.6). The developer is the link between 'social and economic determinants of housing demand and supply' (Drewett, 1973, p. 163).

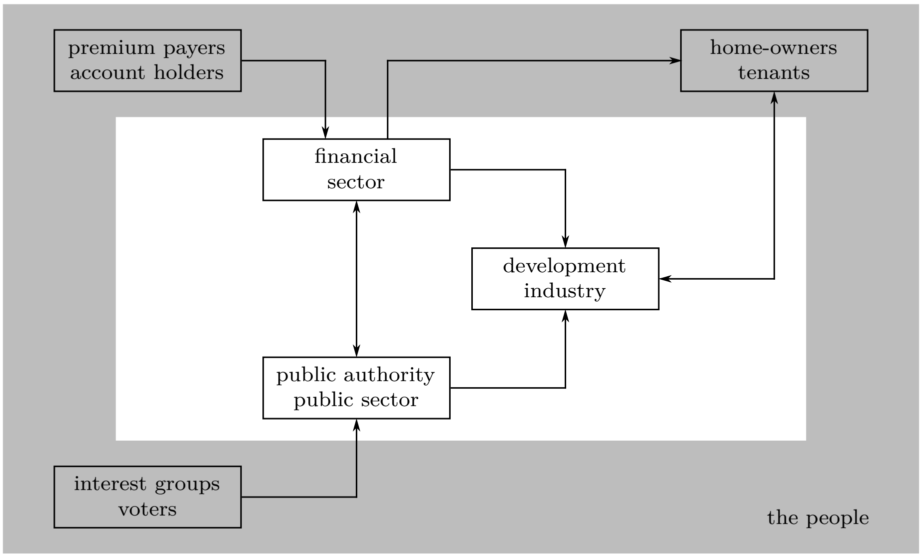


Figure 3.4 *– Behavioural model of the property development process. The process is dominated by three main 'fields': the financial sector, the public sector and the development industry, source: Ambrose (1986).*

An important conclusion from the two latter models is that the residential location choice is only part of the residential development process.

3.4 Institutional approach

Residential location choice modelling, presented in section 3.1, and the event-sequence models and agency models from section 3.3 do not attempt to explain the link between the national setting, in which the residential development process comes about, and the form of the resulting residential developments. Dynamic residential location choice modelling focuses on links between the form of residential developments and the location choice of households and firms. The latter depends again on the spatial configuration of the urban structure. In this approach the spatial preferences of households would be the link between the

7. Drewett, R. (1973). The developers decision process. P. Hall, H. Gracey, R. Drewett and R. Thomas (Eds.), *The planning system: objectives, operations, impacts* (Vol. 2, pp. 163–193). The containment of urban England. London: Allen & Unwin.

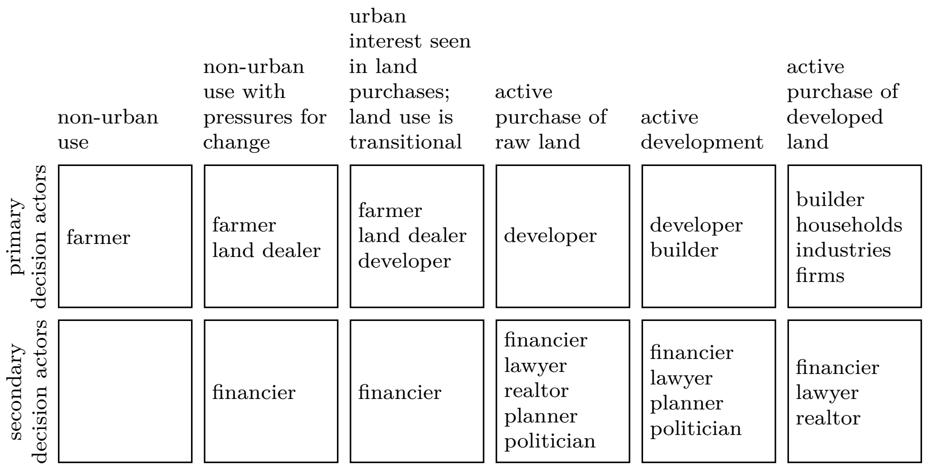


Figure 3.5 – *The conversion process of land from non-urban land use to urban land use, source: Bryant et al. (1982) as cited by Gore and Nicholson (1991, p. 713) and Healey (1991, pp. 225–227).*

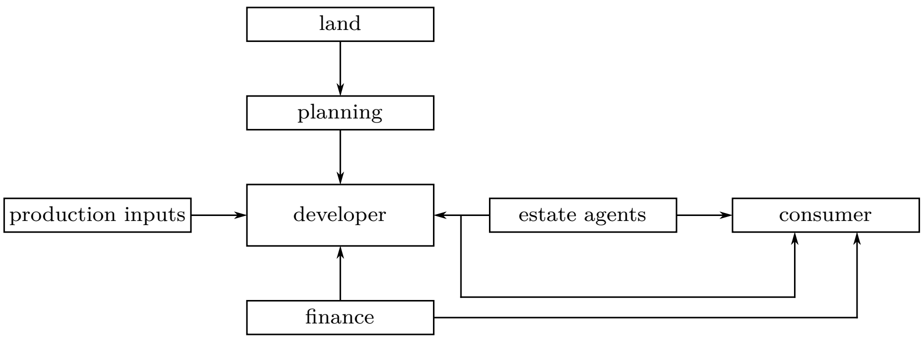


Figure 3.6 – *Decision actors in the land development process, placing the developer in the centre of the process, source: Drewett (1973) as cited by Gore and Nicholson (1991, p. 714) and Healey (1991, pp. 224–225).*

national setting of the residential development process and the form of residential developments. It is however the question if geographical variations in households' spatial preferences are responsible for the geographical differences in the form of residential developments. Alternatively, attributing the geographical differences entirely to spatial plans dismisses the pro-active role of planning authorities in the residential development process.

The Cadman and Austin-Crowe model and the Goodchild and Munton model are both very generic. Residential development processes from various planning systems fit their description. However, both models do not describe how the national setting of a planning system affects the stages in the development process. On the other hand, flow diagram like models, like the Rattcliff model, are fitted to a specific planning system. Similarly, agency models focus on the relationships between social agents and do not elaborate how the national setting of the development process affects the social agents' relationships and behaviour.

The event-sequence models of both Barrett et al. and Gore and Nicholson include external factors determined, by the national setting, that influence decision-making at the various stages in the residential development process. However, they do not explain how the national setting is linked to the form of residential developments. The models do not show how the context structures the residential development process. Moreover, they do not define how the strategies and behaviour of social agents are different in the various planning systems.

Structure of building provision

A structure of building provision refers to a network of historically specific relationships between social agents associated with the provision of specific types of buildings (Ball, 1998). Part of the structures of building provision, the markets within them have a prominent place in these structures, as the markets and the network of social agents mutually influence each other. The interactions between the agents help determine the market and its nature, while the market affects the nature of agents and their relations and interactions. The current pattern of social agents and their relationships and interaction also depend on historic institutional and other social relations, and how these relations have evolved under the influence of market changes.

Ball (1986) has identified three forms of social struggle over building provision. First, the structures of building provision approach depicts a conflict between social agents within the building provision process. Analysing a structure of building provision therefore involves the identification of the economic roles of social agents, the influence of social agents on each other and the factors that determine these mechanisms. Second, a conflict exists between social agents in a structure of building provision and wider social and economic processes. Structures of building provision are not closed systems and outside processes affect markets and social agents within a structure. The third conflict is between different structures of building provision, when different types of structures of building provision compete over resources.

The outcome of the residential development process depends on how these three types of conflicts are resolved. This again depends on the structures of building provision as each structure deals differently with these conflicts. Since structures of building provision are location specific and likely differ between countries (Ball, 1998), they provide a link between the national setting of the residential development process and the form of the resulting residential developments.

Modelling the relationship between the structure of development control systems and agent behaviours

Healey and Barrett (1990) have argued that the residential development process should be viewed in the light of the relationship between structure (e.g. rules, laws, administrative and financial organisations) and agency (i.e. agent behaviour). The structure drives the development process and produces distinctive behaviour patterns in particular periods and locations. The structure is the framework within which social agents make their decisions. It also shapes the social context of the agents: their perception of the resources that are available to them, the social rules that govern their behaviour and the ideas on which to base their strategies. In retro-action, the structure is transformed by agent behaviour, i.e. the way agents deploy, acknowledge, challenge and potentially transform resources, rules and concepts in the pursuit of their strategies.

The spatial configuration of residential developments are the result of decisions and actions of social agents in the development process; it also depends on the relationship between social agents (Van der Krabben & Lambooy, 1993). Whereby, the social agents' decisions and actions stem from their interests and strategies. A key idea to the structure-agency approach is that decisions, actions, strategies and interests of the social agents relate to the structure, i.e. the setting of the residential development process (Healey & Barrett, 1990). This setting defines the value of building land, buildings and other parameters that structure the social agents' decision-making. The social agents' decision-making and their consequent behaviour provide a link between the setting of the residential development process and the spatial configuration of residential developments. As a consequence, a geographical difference or a temporal change in the national setting of the residential development process results in a different pattern of the decision-making and behaviour of social agents (Van der Krabben & Lambooy, 1993).

Similarly to the structure of building provision, the structure-agency approach makes a distinction between social agents and the economics roles they play in the residential development process (Healey, 1992a). In this context, the social agents' economic roles can be seen as a classification of the social agents' strategies and consequent behaviour. Hence the pattern of the decision-making and behaviour of social agents can be depicted as a network of social agents and the economic roles they play. The roles agents play in the residential development process is driven by their interests in the development process.

Both the structures of building provision and structure-agency approache acknowledge the effect of institutions on the residential development process (Ball, 1998). The national and regional settings of the development process affect agent behaviour and agent interaction. Agents develop different strategies; they pursue and play different roles in the residential development process. As a consequence the residential development processes in alternative planning systems are characterised by a different pattern of agents and the roles they play. A different distribution of roles among the agents ensues a decision-making with different agencies, who have different interests.

3.5 Agent-role approach

The institutional approach, as discussed in section 3.4, distinguishes between agents (i.e. groups of actors also called 'agencies') and the roles they play in the residential development process. Two important assumptions are behind this:

1. the roles agents play depend on the context of the development process, and
2. the differences in how the adoption of roles affect the power relations between agents.

In the case of structures of building provision, the network of social agents and their economic roles are defined as the result of historic institutions and the working of markets. A change of one or more markets will lead to a change in the network of social agents and their economic roles. Hence the network of social agents and their economic roles can be viewed as an indication of the historic and current state of institutions and markets. In comparing different networks of agents and their roles, the difference between them can be an indication of how markets and institutions have evolved differently.

A change in the markets will change the competition between social agents. Agents might become interested, or might lose interest in the case of a market change. Hence, a market change can cause economic roles played by certain social agents, to be played by other social agents. This is viewed as the evolution of structures of building provision. Social agents play the economic roles from their personal objective, hence different social actors means different performances. If markets become more volatile, the difference over time in land prices becomes larger, land banking becomes more attractive. This results in housing developers, whose main objective is to make a profit from the construction and disposal of houses, to move out, while housing developers or hybrid developers, whose strategy includes the creation of a land bank (and who make a profit from the difference in land price between the moment of acquisition of the land and the moment of disposal of the houses) move in. The difference between both developers is that the former has a strong preference for profitable types of houses, whereas the latter's preference of certain types of houses is far less dominant.

In the structure-agency approach, a change in the structure causes a change in behaviour if agents perceive that resources become available to them, or are taken from them. If they perceive an increase or a decrease of restrictions, they will adjust their behaviour accordingly. In the structure-agency approach, the power relations between agents have a prominent position. According to their economic roles, agents affect the strategies, decisions and behaviour of other agents in the residential development process. Agents define the power relations by playing economic roles and, at the same time, the power relations define which roles each agent can play.

In this context it is possible for an agent to play a role, because, although it does not bring profit, it might cause the power balance between agents to change in its favour. For instance, housing developers might play the role of land assembler. They buy the land from the first landowners, usually farmers. Their objective is not to reap the planning gain, or profit from the inflation of the land prices. Their objective is rather to assure a building claim, i.e. the right to construct residences in part of the development project. This happens in the Netherlands, where the local authority is (one of the agents who is partly) responsible for the development of building land. This is deducted from the fact that housing developers sometimes lose money through these transactions and housing developers who do not have this strategy have less opportunity to acquire the option to construct housing. As a consequence the housing developer who has this strategy gains more influence on the residential development process. It eventually leads to the development of more commercial housing.

If an agent plays more roles, it will start to dominate more and more stages of the development process. However, there are differences in ideas concerning how and why social agents play economic roles, and under which circumstances.

The analysis of the social agents and their economic roles in the residential development process can provide insight, both into the interests that dominate the residential development process and how these interests influence the spatial outcome of the process.

Chapter 4

Agent-role model of the residential development in France, England and the Netherlands

The agent-role approach has already been used for the analysis of urban development and planning process (Healey, 1992a; Guy & Henneberry, 2000; van der Krabben, 2009; Schmidt, 2009). In these studies, the agent-role approach allows an in depth analysis of the power relations between the agents involved in a certain project or a certain section of the planning and development process. These analyses help explain how a pattern of roles played by agents has resulted in the specific functioning of the spatial development process. The objective here is to take a similar approach in the analysis of the residential development process in France, England and the Netherlands to illustrate how the different institutional settings eventually cause the power relations to be different.

Both England, with a strict green-belt planning concept and a market-led land development process, and the Netherlands, famous for the state-led land development, are known for their tight control of the development process. Albeit both countries have their own way. This obviously leads to different agency-role patterns. France knows a less strict control of the form of urban development. Residential development in France is a mix of market-led and state-led developments. French local planning authorities have, however, several powerful planning tools that help to exercise control over the land development process.

This chapter aims to identify and compare the agent-role patterns of the residential development processes in France, England and the Netherlands. The objective of the comparison is to see if differences in the agent-role patterns also results in different power relations between public and private agencies. A secondary objective is to determine how the roles fit into the strategies of the public and private agencies.

For this, the chapter analyses the residential development process separately for each country, after which it compares the agent-role patterns. Before, let us begin with a short description of the roles an agent can adopt in the course of the residential development process.

4.1 Identification of six possible roles

In the framework of the agent-role model, any agent can adopt one or more roles in the development process. Let us remind here that the outcome of the development process, including the spatial pattern of developments, depends both on who exercises power of resources and on the negotiation process between agents (Ambrose, 1986).

Land acquisition and Land assembly

Land acquisition and land assembly represent a crucial role in the urban development process:

– To enable urban development, land is needed. Land supply and land assembly is therefore an essential part of the development process.
– Furthermore, the landowner needs to be willing and able to make land available for the purpose of urban development, Otherwise, the landowner needs to sell the land to someone who can and will make it available;
– Also, since the landowner has an important role in the development process and in determining the course of the development, the objectives of the agent who adopts the role of landowner are deemed to have a significance for the final result of the urban development process.

The first landowner with an interest in urban development, i.e. with an intention to change the land use from the current, most often agricultural, land use to urban land use, has a great impact on the development process. Indeed, the first landowner with the intent to perform urban development has the initiative and can decide what to do. If there are no public regulations that allow public authorities to overwrite any decisions, the first owner can decide on what course the development should take. He can decide on who is to perform the development. He can propose the development plan. Or, in the case of land speculation, he can profit considerably from the planning gain. Finally, he can set condition for the sale of land to other development actors.

The first landowner with an interest in the residential development process impacts the process in several ways that eventually affect the spatial configuration of the developments. Indeed, the landowner decides what type of development it allows on its land. In practice this means that the landowner proposes or supports plans that will best meet its objectives. Next, it affects who ever executes the land development and the housing development and under which conditions. The latter affect the spatial configuration. Local authorities can control the behaviour of landowners and the effect of their behaviour on the spatial configuration through several means, but most notably through expropriation rights and pre-emption rights.

Several factors determine whether an agent decides to become landowner. First, the costs of land ownership is directly related to the land price, which is the result of the market forces (demand and supply of land) that form the land market. In the same way, the land market is influenced by planning (the more restrictive planning, the higher the prices) and the public planning tools (expropriation, pre-emption, etc.).

The institution of the role of landowner in a planning system gives an indication of the power balance between the private and the public agencies. Thereby understanding the institutionalisation of the role of landowner, and the related land market and development models, contributes to the understanding of the power balance in the development process.

Land development

The role of land developer can be adopted by both private and public agents, who, in this role, are responsible for the physical and legal activity needed to create plots of land suitable for housing construction. The land developer is therefore responsible for the removal of structures of previous land use, the construction of on-site infrastructure, the creation of building plots, the connection to existing infrastructure, the provision of on-site (and off-site) service provision, and more. In French, a land developer is referred to as '*aménageur*'.

The local authority performs the land development for the same reasons it performs the land acquisition. The role of land developer is, similar to the role of landowner, important to the local authority to support its objectives and complement its roles as planner and enforcer (see below). Indeed the roles of planner and enforcer alone do not allow a planning agency to completely achieve their objectives.

Planning

The role of planner is mostly seen as a public task. The (local) planning authority evaluates economic and social developments and determines the desired development in light of the expected economic and social developments. Although, in theory, planning is a purely political process and a process of interaction between the planning authority and society, civil and informal elements are part of this process. With the transition from government to governance, non-democratic actors (e.g. housing associations or private developers) get influence on the planning process and the resulting plans.

It is not clear if we can speak in terms of the influence of the role of planner on the urban development process, where planning is defined as the formalisation of public objectives in spatial plans and policies. Where local authority's objectives might not be realistic, spatial plans and policies usually are. They are concrete intended measures, that already have taken into account the objectives of others and how much they can influence the outcome of the urban development process. The effect of planning is mostly the publication of the targets. In this way the (local) authority determines the general thinking of the actors and the direction of the urban development process. How well the objectives of the planning authority get implemented in the final result of the urban development process depends on the influence the planning authority can exercise through the other roles it adopts.

Enforcement and Supervision

In the context of this research, the role of enforcer is viewed from the perspective of the public authorities and thus seen as a purely public task. The objective of a public authorities in the role of enforcer is to steer the urban development process into the direction envisaged in spatial plans and policies. Hereto, the public agent often has a set of public tools, i.e. tools only a public authority can use (e.g. expropriation, building permit). These tools provide planning authorities with a means to locally force residential development into a certain direction.

Housing construction

In the context of this research, the housing constructor is the agent who organises the construction of houses on the building plots created by the land developer. The housing constructor is responsible for the activity needed for construction of houses, including the design, finding financing, acquiring building permission, the construction and the disposal to the end-user or letting agency.

Financement

An actor in the role of financier is responsible for the provision of the money needed for the urban development. Money can be provided in different ways, e.g. a loan, investment or subsidy.

A distinction is to be made between urban development aimed at the provision of housing and development aimed at the construction of office space. The latter case is more than the housing development subject to speculation and other market forces.

As shown by this description of six possible roles in the housing development process, each of them has a different effect on the actor's bargaining position. The bargaining power perceived from the adoption of roles differs per role. For example, the adoption of the role of land developer provides an agent with more influence on the final spatial configuration than the adoption of the role of housing developer would. Yet the effect the adoption of a role might have on one type of agent is not the same as the effect it has on another type of agent.

4.2 Residential development in France

An important moment in the institutional history of residential development in France is the decentralisation during the 1980s. During this period the responsibilities for local planning, and especially housing provision, devolved to the regions. And, although French local authorities have often less autonomy from the national government compared to Dutch and English local authorities (Kübler & Piliutyte, 2007), the change had an effect on the control of residential developments. The regions, the new local planning authorities, and also communes became better capable at identifing location specific objectives and considerations. They determine the local planning and development agenda.

Spatial plans and policies concerning residential development at the local level are henceforth formulated by the local planning authorities. At the agglomeration level, the *Schéma de Cohérence Territoriale* (SCOT), which replaces the *Schéma Directeur* (SD) and the *Schéma Directeur d'Aménagement et d'Urbanisme* (SDAU) since the introduction of the Loi SRU, globally defines the location of residential developments. The *Plan local d'urbanisme* (PLU), previously the *Plan d'Occupation du Sol* (POS), forms the local adaptation of the SCOT and identifies in detail the locations of residential developments in the communes. The PLU has to strictly conform the SCOT.

But more importantly, the PLU also functions as a planning tool for the control of residential developments. The PLU sets out the locations available for residential development and the conditions for development. Residential developments that do not conform the PLU are not permitted.

The initiative to construct at the available location comes from both private and public actors. France has a mixture of state-led developments and market-led developments. Vilmin (1996) distinguishes four different strategies or frameworks of urban development: diffuse development (*développement diffus*), supervised mutation (*mutation encadrée*), negotiated urban planning (*aménagement négocié*) and public urban planning (*aménagement public*). While public urban planning and development is usually reserved for developments of public use, e.g. hospitals, residential development projects commonly fit into one of the other three frameworks.

In case of diffuse development, urbanisation takes place along existing infrastructure, and is as such foreseen in the land use plan (i.e. PLU). The development related costs, that are imposed on the planning agency, are financed with the increase in local taxes. This increase results from the increase of the number of residents and companies. Mainly small and private actors operate within the diffuse development. Moreover, these developments usually concern single houses or small groups of houses built on demand. Hereby should be noted that in France relatively many houses are built on demand by relatively small and regionally operating private developers or housing constructors.

Similarly, in case of the supervised mutation the initiative of the development lies with the private actors, like with the diffuse development. The difference, however, is that the supervised mutation often applies to larger developments that therefore require a change in the urban landscape or a change in the land use. As a result additional regulations often exist in comparison to the diffuse development. For example, it is necessary to adjust the existing infrastructure, which will be financed through the *programme d'aménagement d'ensemble* (PAE). The local planning authority remains responsible for the construction and maintenance of the infrastructure. Within this framework mainly professional, private actors dominate.

Diffuse developments and supervised mutations are both market-led. Private agents play many roles, like land assembly, land development and housing construction. These agents therefore have a major influence on the role of planning. Although the local planning authority defines the possible location for development and the conditions of development, the developer takes the initiative in the design. The design is then presented to the local planning authority in a permit (most notably a *permis de lotissement*). The spatial configuration of the development proposed in the building permit application forcefully conforms to the developer's objectives.

In case of negotiated urban planning, both private actors and public actors can take the initiative, however the local planning authority or another public actor, e.g. a *société d'économie mixte* (SEM), is actively involved. These co-operations between both public and private actors can be understood as public private partnerships, as they also exist in other countries. They exist both in urban renewals and greenfield developments. Normally, the result of the negotiation is implemented in a legal framework called the *Zone d'Aménagement Concerté* (ZAC), which also regulates the developers' contribution to the development of public services and infrastructure.

Next to the private and public development actors, landowners can also be part of the negotiations. It is possible that at the stage, at which the development is negotiated, land is still owned by third parties. This usually does not cause any issues with the progress of the development, since public actors have the possibility of both expropriation and pre-emtion. Especially, the pre-emption rights of local planning authorities, and other public actors, are quite powerful. Public actors can put a *Zone d'Aménagement Différé* (ZAD) in place, which gives them pre-emption rights for a period of maximum 20 years, with the possibility to extend this period with an additional 10 years (Vilmin, 2008). In 2010 the maximum duration was reduced to 14 years with a possibility to extent for an another 6 years. In comparison, in the Netherlands, the maximum period is 2 years. This hugely affects the property market, and contributes to the elimination of land speculation. Planning authorities often use pre-emption rights in order to retain control of the local property market (Vilmin, 2008; Goodchild, Gorrichon & Bertrand, 1993).

Since its inception, the ZAC has been a popular planning tool. Many residences have been constructed within the context of a ZAC (Merlin & Choay, 2010). Because of the active involvement of public agents, like the local planning authority and social housing associations, the distribution of roles differs from purely market-led developments, although most of the land development and housing construction, except for social housing, is executed by private agents. However, the local planning authority, with the implementation of the ZAD, has an important role in the assembly of land necessary for the intended residential development. Also, the local planning authority, or any other public agent, is actively involved in the planning and design process of the development. And finally, developments in a ZAC are also partly financed with public money. This different pattern of agents and roles gives the public agents, the local planning authority and others, more influence on the spatial configuration of residential development, than in case of private developments.

Thus far the evaluation of the French planning system has focused on the interactions between the local authorities (and other public actors, like social housing associations) and private developers. However, characteristic for France is the scale of the actors. Where countries like England and the Netherlands have had constant reform of the local authorities, French local authorities remained largely untouched. French local authorities are therefore relatively small and consequently high in number. Private developers on the other hand sometimes operate at the national level. Despite that private developers can be very big, small and dispersed private residential development projects dominate the residential development process. Moreover, residential development projects are small but many. This provides opportunity for other agents like businesses, who intend to become the user of the property.

Moreover, with the devolution of the control over spatial development to the local authority, the state also conceded control over the local economy (Nicholls, 2005). The national state reduced the financial support and French local authorities have become increasingly dependent on local taxes. Especially taxes levied on enterprises settled within the territory have become important. This affects the position of the local planning authority, as it provides local authorities with a financial incentive to allow, or even attract, development within their jurisdiction. Especially, since local tax-incomes are an important source of income for the local planning authority.

In particular, developments for commerce, business and industry have been lucrative for a local authority. Next to the increase in employment, commercial land users have also caused an increase in revenue for the local planning authority. Yet the '*Taxe Professionnelle*' currently no longer exist. This has caused a situation where end users, especially commercial end users, have had considerable influence on the spatial policy of a local authority. Many communes adapted spatial plans to facilitate the development of commerce, business or offices, if they were requested to do so.

4.3 Residential development in England

Spatial planning and residential development control in England differs from France and the Netherlands because it is based on the British legal system, and not on the Napoleonic system. The differences manifest themselves in the position of spatial plans. Local planning authorities in England do not design a legally binding land use allocation plan. Where certain land uses are permitted, and where they are not is ultimately defined by the granting of planning permissions. For the evaluation of the requests for planning permissions, necessary for the development of land and the construction of housing, a local authority needs to consider current spatial policy and plans. However, a planning authority has the ability to deviate from these policies and plans if it has valid motivations to do so. Also, the evaluation and subsequent issue or refusal of planning permissions is considered an administrative decision. The possibilities of appeal by third parties against a local authority's decision are limited. The issue of planning permission is for a fair part at the discretion of local planning authorities.

In France and the Netherlands, because they both are planning systems in a Napoleonic legal system, land owners are entitled to bear the fruit of their land. That means, that if due to an administrative decisions, the land value increases, this increase, also known as planning gain, belongs to the property owner. This is often the case when permission is given to construct housing on the land. In England, the planning gain as the result of a planning permission to construct housing, is seen as the effort of society and hence belongs to society.

This provides the local planning authority with an important tool. Local planning authorities can require, as part of a planning permission, to transfer some of the planning gain towards society. In most cases this means the local planning authority. These transfers take the form of developers executing some developments on the local authority's public or social agenda. This can include social or affordable housing, or public infrastructure as part of the development. Planning agreements allow the planning authority a negotiation position which helps them realise several social objectives.

More importantly, in England, the residential development process is market-led. Local authorities in England do not have a pro-active role in the residential development process. Land assembly, land development and housing construction are in large part executed by market actors with the use of private investments. The initiative for the development planning and design is therefore with private developers and investors. Investors are important agents, as the vast majority of residential developments are speculative. The construction of housing is initiated by developers, who try to sell these houses for a profit.

The local planning authority's involvement in the planning and design of residential developments limits itself to the evaluation of requests for planning permission. Hence, the initiative for the planning and design of residential development is with private agents, giving the local planning authority limited influence on the spatial configuration of residential developments. English planning authorities have to control the spatial configuration of residential development through restrictions of the developments they allow. Spatial policies based on the green belts planning concept (see section 2.3) and its strict application to planning permissions is part of the tight control. Moreover, spatial plans and policies of the national planning authority, and thus also local plans and policies, require that large amounts of residential developments are built as brownfield developments, i.e. on previously developed land.

The vigorous restriction of residential developments on greenfield sites contributes to the control of the shape of urban development. However, the strict control of residential developments has also led to fewer homes being constructed, resulting in a housing shortage and increased house prices. Also land prices have increased, as local authorities have no means to control the local land market, leading to land speculation. English planning authorities have received a lot of criticism for their restriction of greenfield residential developments. This illustrates that a limited involvement in the residential development process leads to less control, although the local authority has managed to control the spatial configuration of residential developments. The lack of control is expressed in social issues.

4.4 Residential development in the Netherlands

In the Netherlands, like in France, the roles of land assembly, land development and residential development are often not played by the same social agents. Land assembly and land development have been important tools to the local planning authority's control of the residential development process. Land development in the Netherlands is state oriented. Local authorities have dominated land development, and currently still have a prominent presence in the land development process.

Like France, the Netherlands has a Napoleonic legal system (Bontje, 2001). Spatial planning and the position of local authorities herein is strongly embedded in national rules and laws. Also, planning and control of urban development is hierarchical. National plans set out the broad strokes and local authorities fill in the details. A special position is reserved for the land use allocation plan (*bestemmingsplan*), which is legally binding. It sets out, often in great detail, the location of different land uses, but it does not contain any spatial policies. The land use allocation plan is not so much a tool that helps the promotion and control of residential developments, but it rather helps preserve the existing situation (Needham, 2007).

Similar to the local authorities in France and England, Dutch municipalities have public instruments to control the urban development process, of which the legally binding land use allocation plan (*bestemmingsplan*) and the building and construction permits are the most important. They allow a municipality to restrict undesired developments by imposing constraints or a ban on undesired developments. However, these instruments do not provide the means desired by municipalities to actively steer the urban development process towards a favourable spatial implementation of necessary land uses (Priemus & Louw, 2003). In contrast, involvement in the land market permits a municipality to actively govern the urban development process. Municipalities use their position in the land market to assemble land and provide building plots in an effort to attract the development of especially industry and offices (Needham, 2007).

Until the 1990s, the national government has provided subsidy on both land development and social housing development. Furthermore, there has been a policy of making a lot of building land available to housing development (Needham, 1992). This has caused the land prices to remain low, moreover the planning gain on land development was small. Private parties have been uninterested in performing land assembly and land development. Land assembly and development have thus been totally in the hands of local planning authorities. The execution of land assembly and land development has provided the local planning authority with the ability to control the housing development process. First of all by performing the land development, the local authority has been able to define the spatial characteristics, up to the size of individual parcels. Moreover, the local authority has been able to set up requirements for the housing developments in the sales contracts of the individual parcels. Also the planning authority has had control over the timing of residential developments (Louw, van der Krabben & Priemus, 2003). Finally, by buying undeveloped land and selling serviced building plots a municipality has seized profit from the planning gain. This has allows the municipality to cross-subsidise non-commercial land uses like social housing and schools (Needham, 1992). Also, it has allowed the municipality to contribute to off-site provision or improvement of public services (Needham & Verhage, 1998), and to cover losses incurred in previous, unprofitable development projects (Priemus & Louw, 2003).

At the end of the process, the developed land has then been transferred to private developers, who played the role of housing constructors. Since the local planning authority determined who had access to developed land, social housing associations, who construct social and affordable housing could easily obtain land for housing development. This practice has provided the local planning authority with an enormous control over the planning and design of residential developments. The result of which is compact urban developments, yet without land prices and housing prices spinning out of control or a housing shortage.

During the 1990s the above practice changed however. The national government has updated their spatial policies, which it has published in the *Vierde Nota Ruimtelijke Ordening Extra* (VINEX). This plan, however, indicates in great details the areas that have been allocated to residential development for everyone to see, including private developers. In addition, the national government ended most of subsidies on social housing development, social housing associations no longer receive government funding and need to finance housing development themselves. These two measures of the national government, in combination with economic change that has caused an increase of land and house prices, has resulted in the local planning authority's loss of control of the residential development process.

The increase in land and housing prices resulted in an increase of planning gain on residential development land. Commercial housing developers gained interest in land assembly, because the planning gain became worth the risk. Moreover, due to the publication of the exact location of future residential developments the risks for developers actually decreased. Developers became active on the land market and started to buy land within the zone allocated to residential developments by the national government. Due to the decreasing subsidy from the national government public land acquisition became more and more difficult. The role of both financing and land assembly shifted more and more from the national government and the local planning authority to private residential developers (Needham, 2007).

Private developers still have, however, no interest in land development. Land development is still largely controlled by the local planning authority (Groetelaers & Korthals Altes, 2004). Private residential developers use the role of land assembly to influence the planning of residential development projects. Private developers buy undeveloped land with the intention to sell the land to the local authority, who then develops the land. Private developers do often not make a profit from these transactions, they however claim the right to construct houses on the terrain once the land development is completed (Priemus & Louw, 2003). Other forms of public-private cooperation between the local planning authority and private residential developers have emerged (Needham, 2007). The local planning authority eventually has lost a lot of its original influence in the residential development process. Dutch local planning authorities continue however their practice of public land development.

The public private partnerships in the Netherlands show some resemblance with the ZAC in France. However, Dutch local planning authorities do not have the same means to control the negotiation and land assembly (Verhage, 2002). Dutch planning authorities have to buy land on the land market, which became a lot more expensive. In contrast the risk taken by Dutch local planning authorities to maintain control of the residential development process are rather high (Needham, 2007).

In summary, until the early 1990s, the local planning authority has played the role of land assembly and land development. Private developers, which included many not for profit social housing associations, have played the role of residential development. Due to this distribution of roles, the planning authority has also played the role of spatial planner. As the whole process has been controlled by the local planning authority until the housing development, almost all decisions concerning the spatial configuration have been taken by the local planning authority. However, since private developers have started playing the role of land assembly, they have also gained an interest in planning. Through demands as they exist in the public private partnerships that has become more common since the 1990s, they have had an influence on the spatial planning and thus on the spatial configuration of residential developments.

4.5 Comparison

The patterns of agents and their roles differ between the three countries analysed in this chapter. The adoption of roles allows the local planning authority to control the spatial configuration of the residential development in different ways. The way the local authority can control the residential development process depends on how much power the authority perceives from the adoption of the different roles. Also, private residential developers aim to influence the spatial configuration, as it provides them with a means to increase profit gained from the residential development process.

Table 4.1 and table 4.2 provide a qualitative overview of the influence each type of agent perceives from the different roles in the residential development process. Herein a '+' indicates no to a little influence, '++' indicates a relevant influence, whereas '+++' means the agent perceives a lot of influence on the spatial configuration through the adoption of this role. For the Netherlands a distinction is made between the period of state-led land development and the period in which land development became more and more a mixture of state-led and market-led development.

From the overview it becomes clear that local planning authorities in England and France influence the spatial configuration of residential developments through public planning tools, e.g. planning permissions and public-private agreements (ZAC). The French planning authority also perceives some influence through the role of land assembly due to the powerful tool of pre-emption. As a result, private residential developer have more influence through 'market-controlled' roles, like land development and housing construction.

In the Netherlands, the local planning authority controlled the spatial configuration of residential developments through market mechanism. However, when the local planning authorities lost control over these mechanisms, their control has diminished. Especially because the local planning authority does not have powerful public planning tools available like for example French local planning authorities do.

The bargaining position provided by the adoption of roles depends on the (administrative, economic, political, etc.) context. Hence the bargaining position provided by the adoption of a certain role is different from one country to the other. Three possible scenarios exist: an agent fully adopts a role, an agent partially adopts a role or an agent does not adopt a role. It should be noted that an actor needs to accept at least one partial role in order to participate in the housing development process. Examples of a partial adoption of a role are the acquisition of part of the development terrain, the participation in a public-private partnership on either planning or land development. Apart from this, bargaining power that is provided by the adoption of roles is not linear. If an agent adopts a second role, which has identical power to the first role it adopted, the bargaining power of this agent not necessarily doubles. The adoption of roles is also interdependent; the complete adoption of one role might imply the adoption of other roles either because the adopting agent has first choice or because other agents loose interest in the adoption of roles.

Thereby, both the role adoption and the bargaining position obtained consequently are complex to model especially when modelling the dynamics of the residential development process.

	France	England	the Netherlands	
			< 1990s	> 1990s
Land acquisition - Land assembly	+++	++	+	+++
Land development	++	+++	+	+
Planning	+	++	+	++
Enforcement - Supervision	n.a.	n.a.	n.a.	n.a.
Housing construction	++	+++	++	+++
Financement	++	+++	++	+++

Table 4.1 *– The influence private residential developer perceives from the adoption of the roles (n.a.—not applicable)*

	France	England	the Netherlands	
			< 1990s	> 1990s
Land acquisition - Land assembly	+++	+	+++	+
Land development	+	+	+++	++
Planning	++	+++	+++	++
Enforcement - Supervision	+++	+++	+	+
Housing construction	+	+	+	+
Financement	++	+	++	+

Table 4.2 *– The influence local planning authority perceives from the adoption of the roles*

Part II

Housing development simulation model

Chapter 5

PARDISIM: a two-agents simulation model

Part I of the thesis put forward the interest of an institutional approach of the residential development. The central idea is that geographical differences in the form of urban developments result from national and local differences in institutions because:

1. besides the residential location choices of households, the form of urban developments is influenced by the behaviour of development actors; residential development actors are responsible for decisions that affect the location and the spatial structure of residential development.
2. the behaviour of development actors is influenced by the institutions (e.g. local governance, national rules and administrative organisations). Institutional and administrative differences between countries or even regions, might cause difference in the bargaining power between actors. These differences could help explain the spatial differences between cities. In particular, the implementation of spatial policies by (local) planning authorities depend on the influence those authorities have on the housing development process.

These two premises are the underpinnings of PARDISIM, a simulation model of the residential development process, which is proposes in this chapter.

5.1 Proposed simulation model

Although the power balance between the agents in the residential development process is important to understanding and modelling the emergence of the shape of urban development, only a few simulation models link the form of urban developments to the power balance between development actors. Webster and Wu (2001) have simulated the urban development process under two different planning regimes. In one, the planning authority has development rights and can use planning conditions, planning gain and impact fees to control urban developments. In the second simulation, the developers have the development rights and the planning authority controls urban development using subsidy payments. Ligtenberg, Bregt and Van Lammeren (2001) have introduced a simulation model that models urban development as the result of a negotiation between the local planning authority and two interest groups. They test two scenarios; one, where all actors have equal decision power, and another, where the planning authority has more decision power than the interest groups. In a later publication Ligtenberg, Wachowicz et al. (2004) have illustrated a third scenario, where both interest groups have no decision power, but are merely consulted by the planning authority.

Regarding these previous works, we propose a simulation model allowing us to test the hypothesis that differences in the form of urban developments result, at least partly, from national and local differences in institutions. To achieve this objective, the proposed simulation model takes an institutional approach and implements the actor interactions as described in part I. The model focusses on the interaction between the two types of prominant development actors in the housing development process, which are private housing developers and public planning authorities. Focus is on the relative effect of the negotiation position of the both types of actors on the morphological appearance of residential development. This allows answering questions such as: does urban sprawl emerge only if the public authority has a weaker negotiation position than the private developer?

The simulation model, entitled PARDISIM (Planning Authority and Residential Developer Interaction Simulation Model), simulates the housing development process through the negotiation between a local planning authority agent and a private housing developer agent according to the logic described on figure 5.1. In this figure, we can see that each agent aims to gain a bargaining position prior and during the housing development process. Housing development actors act on the social demand, but their personal objectives determine how they respond to the social demand. The interest of development actors in the housing development process, thereby the strength of their participation, depends on the gain they expect from it. This depends for an important part on the political and economical contexts of the residential development process. Nevertheless, the influence of the institutional and administrative contexts are also deemed important to the investigation, as they affect the negotiation position of the development actors.

An increase in bargaining power, gives an agent an increasing leverage to pursue the satisfaction of personal objectives. The promise of a certain gain might stimulate an agent to try to increase its bargaining position. In turn, when an agent increases its bargaining power, it will eventually have more influence on the morphological outcome of the urban development process.

More generally, the modelling of the interactions between development actors introduces the link between economic, political and other driving forces and urban land use change into urban growth simulation.

Figure 5.1 also suggests that the housing development process, viewed from the negotiation between development actors, has to be modelled dynamically in order to take into account existing interactions. Interactions occur between the agents but also involve the urban spatial configuration.

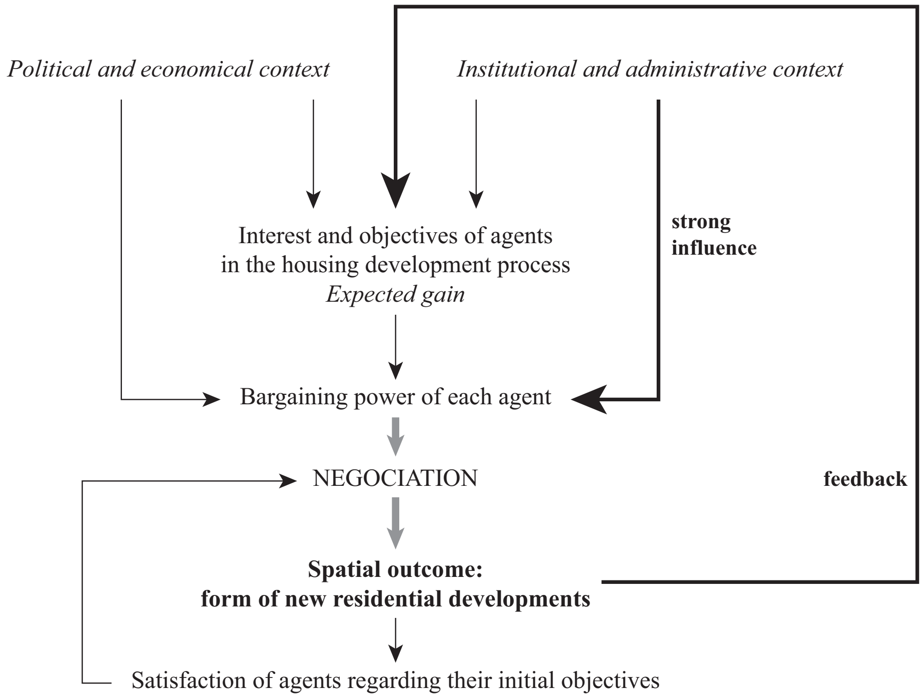


Figure 5.1 *– Interactions between the agent negotiation and the spatial outcome of the residential development process.*

PARDISIM is a two-agents simulation model, which simulates the housing development process through negotiation between a local planning authority agent and a private housing developer agent. Both agents have a strong, yet different, interest in the residential development process. They are prominent participants. The simulation of the interaction between these two social agents serves as a proxy for the public and private interests in the residential development process. The power balance between these two agents represents the local planning authority's ability to control and steer market forces.

The model should allow us to test the hypothesis that differences in the local form of residential developments result, at least partly, from national and local differences in the institutions. For this, the model simulates the emergence of different forms of residential development as a result of different behaviour of development actors.

PARDISIM is based on the agent-role model of the residential development proposed in chapter 4 to transcribe differences in the institutions between France, England, and the Netherlands. The possibility to adopt each role depends on the national and local institutional context. By adopting a role, an agent gains a more or less strong negotiation power. The interactions between the agents are modelled as a negotiation process. For this, we define and implement a negotiation mechanism that allows the integration of the power balance between the agents.

5.2 Modelling actor interactions using a negotiation model

Social agents, among whom the local planning authority and the private residential developer, interact at different instances and in different ways during the residential development process. The behaviour, decisions and interactions of social agents depend on several formal and informal institutions. The construction of a simulation model of the residential development process requires the formalisation of the social agents' behaviour, decisions and interactions. The first step is the identification of the simulation technique and the definition of how it best fits the purpose of the simulation.

Agent-based simulation has emerged over the last two decades as a technique to model distributed decision-making and behaviour. In the simulation of residential developments, the distributed decision-making often refers to residential location choices at micro-scale. The behaviour, that agents present in these models, is the (re-)location in a spatial environment. These models, which are sometimes referred to as agent-based modelling, are used to simulate the relationship between decisions of individuals or individual households and urban sprawl (Brown & Robinson, 2006; Li & Liu, 2007; Loibl & Toetzer, 2003). Another example is the simulation of rural-urban migration (Espindola, Silveira & Penna, 2006; Silveira, Espindola & Penna, 2006).

Agent-based modelling originates from artificial life simulation and individual-based modelling. Its initial use has been in ecological simulations, which has modelled and analysed the behaviour of large natural populations. However, a second type of agent-based is also finding increasing applications in spatial models, which is referred to as multi-agent simulation (Hare & Deadman, 2004). These simulation models originate from multi-agent systems, as they are also used in several distributed knowledge systems that aid spatial planning (Saarloos, Arentze, Borgers & Timmermans, 2005; Ligtenberg, Beulens, Kettenis, Bregt & Wachowicz, 2009; Zamenopoulos & K, 2003). Multi-agent simulation does not focus on the creation and simulation of large populations, but rather on the interactions between the few agents in the model (Ligtenberg, Wachowicz et al., 2004; Arentze & Timmermans, 2003a, 2003b).

The focus on agent decision-making and agent interaction in multi-agent simulation allows taking an institutional approach in the simulation of the residential development process. Individual agents can have complex decision rules based on behaviour and objectives of social agents in the residential development process. Also, multi-agent simulation models can contain protocols prescribing the different means in which agents can interact with the environment, and with each other. In fact, the multi-agent simulation approach and the institutional approach have very similar paradigms. Hence, the remainder of this chapter explains the definition of a multi-agent simulation model capable of simulating the residential development process in different planning systems.

In the institutional approach, as described by Ball (1986) and Healey (1992a), the social agents' behaviour, decisions and interactions depend on the institutions. In the context of a planning system, social agents play a set of economic roles, which represents the social agent's behaviour, strategies and decisions.

The network of social agents and the economic roles they play define how each social agent impacts the residential development process and resulting spatial configuration of residences.

Local authorities from different planning systems operate in different networks of social agents and economic roles. Each different network of social agents and their economic roles results in a different power balance between the social agents. The many decisions and agreements that follow agent interactions have a chronological order, which is stressed in the event-sequence approach, and also recognised in the agent-role approach in chapter 4. Social agents who play economic roles early on in the process, like land assembly, can set the conditions for the roles played later on in the process. Hence, agents who play those roles early on in the process can influence the behaviour and decisions of agents who play the roles that follow later on in the process.

This influence is, however, also related to the institutional context of the residential development process. As chapter 4 illustrates, the social agents who play the role of land assembly in the Netherlands, i.e. buy land with the intention of residential development, have a large impact on the further process, due to the constitutional position of land ownership. In France, which provides a similar constitutional position to landowners, the influence of land assembly on the development process is limited by powerful expropriation and pre-emption tools. Hence each network of social agents and economic roles represents a unique power balance between the social agents.

The simulation, and the ensuant analysis and comparison of the simulation results, of three urban areas from different planning systems using a single model requires a uniform model definition. Moreover the objective here is to find a model definition that captures the different behaviour of social agents under the influence of institutions. Yet, because the envisaged application is very general, the model definition should not be tangled up in complex interaction models related to the institutional context.

Chapter 4 compares the residential development process in France, England and the Netherlands. It illustrates how the pattern of behaviour, strategies and interactions differs between the three countries. Social agents interact with each other in different settings, and each setting has a different type of interaction. The local planning authority and the residential developer, two main social agents in the residential development process, interact in possibly several different ways. Residential developers request permission for the development and construction of residences from the local planning authority. However, aside from the permit to develop and construct residences, developers and authorities can also enter in a legal agreement regulating financial, organisational and spatial aspects of residential development not covered by planning permissions of construction permits. The negotiation leading up to such an legal agreement can sometimes be quite informal (Merlin & Choay, 2010).

Rather than direct interactions, local planning authorities and private residential developers can also interact indirectly through markets, especially land markets. They can exchange property, services or other goods through markets. But they also can compete with each other, if they both pose as either buyers or sellers. Finally, in the case of land markets in France, the local planning authority often has the function of regulator of the local property market

(Vilmin, 2008; Goodchild, Gorrichon & Bertrand, 1993). In the latter case, both social agents do not exchange goods, but the local authority aims to change the behaviour of actors with an interest in the property or land market. These interactions and the institutions that regulate both direct and indirect interactions are not uniform. They differ between different planning systems, moreover, they can even differ depending on the social agents involved in the interaction.

Since the residential development process almost always sees the involvement of multiple development actors, these interactions between social agents have a prominent place. The successful outcome of the interaction between social agents is often essential to the continuation and finally completion of residential development projects. A negative outcome of an interaction, e.g. refusal of a planning permission, could eventually lead to the abandonment of the project entirely.

Here the outcome of the residential development process is therefore viewed as the result of an aggregate of many agreements that follows the interactions between social agents. Each agreement covers part of the residential development process. In PARDISIM, the aggregate of agreements that follows the interactions of social agents is modelled as the outcome of negotiation between agents.

We limit ourselves to the simulation of the interaction between two development actors: the local planning authority and the commercial residential developer. Other types of interaction are also important to the residential development process and the resulting shape of residential development. Notable examples are the interactions between local planning authorities and the national authorities, competition and cooperation between municipalities. However, chapter 3 illustrates the importance of the interaction between the local authority and the development industry. At the local level this interaction has a significant impact on the spatial configuration and morphology of residential developments. Moreover, the spatial configuration and morphology are subject of the many interactions between both actors. Furthermore, as illustrated in chapter 4, the behaviour of commercial residential developers differ significantly between countries, as does the ability of the local planning authority to influence this behaviour. The interaction between the local planning authority and the commercial residential developer offers therefore most likely an explanation for geographical differences in the form of residential development.

In PARDISIM, the power balance between the local planning authority and the private residential developer is represented by the negotiation position of each agent. To simulate how the institutional context eventually affects the spatial configuration of residential developments, both agents will be given different negotiation positions. A better negotiation position corresponds to a more advantageous position in the network with other social agents and their economic roles, i.e. more influence on the outcome of the process due to the adoption of roles in the residential development process. A better negotiation position will have its effect on the outcome, the agent with the better position sees more of its objectives implemented in the residential developments.

5.3 Model layers

PARDISIM consists of three layers (figure 5.2): an agent layer, a land use layer and a service layer. The land use layer represents the current land use. The service layer gives the location of public and commercial services. The agent layer represents the residential development process. Herein two agents, representing the local planning authority, agent *PA*, and a residential developer, agent *RD*, negotiate on the location and type of new residences, at the level of individual buildings. An agreement between the agents leads to the construction of the new residences in the land use layer. The new residential development becomes part of the existing land use.

During the negotiation, the agents aim to maximise their private satisfaction function. They receive their satisfaction from the spatial configuration of the new residential developments: their form, their location relative to existing land use, access to public and commercial services. Hence, agents evaluate each proposal for new residential developments in relation to the land use in the land use layer and the services in the service layer. They use spatial indices to quantify the spatial configuration of new residential developments. The evaluation of the spatial configuration is perceived from the spatial analysis using fuzzy membership functions (Zadeh, 1965a; Zadeh, 1965b; Zimmermann & Zysno, 1983).

An important difference in the satisfaction of the agents is the perspective from which they evaluate residential developments. The planning authority agent aims to maximise social satisfaction, while the residential developer agent aims to maximise personal satisfaction. This is expressed in how the spatial configuration of residential developments is evaluated. The planning authority agent measures its satisfaction based on global characteristics of the spatial configuration, incorporating the impact of residential development on the existing land use. The residential developer, however, focuses much more on the new developments itself and aims for a spatial configuration that optimises the agent's evaluation of the form and location of new residences.

The extent to which agents are able to maximise their satisfaction function depends for an important part on the power balance between the agents. The agents need to cooperate, and thus reach an agreement on residential development, in order to have a positive satisfaction. However, their satisfaction functions may conflict. Hence the agents are forced to compromise, and agree with a lower satisfaction. If the power balance between the agents is level, both agents have to compromise equally. If, on the other hand, one agent has more power in the negotiation process than the other, the former will compromise less.

The land use layer consists of a high-resolution regular lattice of cells, in which each cell represents the land use at its location. The existing built structure clearly affects the location of new residential development. Moreover, existing low-rise residential buildings, high-rise residential buildings and other types of buildings each have a different effect on the location of new low-rise and high-rise residential developments (Rietveld & Wagtendonk, 2004; Haider & Miller, 2004; Adolphson, 2008).

In PARDISIM, eight different types of cells are identified. Four types represent buildings: low-rise residences (which refer to single family homes like

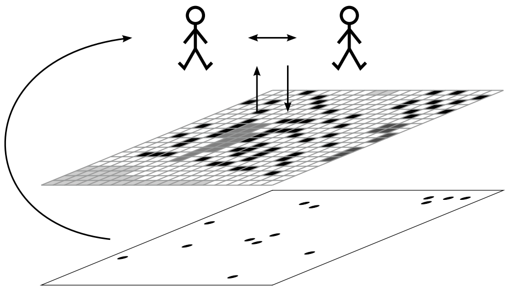


Figure 5.2 *– The simulation model exists of three layers.*

individual houses or terraced houses), high-rise residences (which includes everything higher than a individual houses, it mostly refers to multi-family buildings), industry and office buildings, other buildings (this includes churches, town halls, schools, libraries, shops and supermarkets). The other four cell types do represent unbuilt terrain: terrain that is available to residential development, terrain that is allocated to low-rise residential development, terrain that is allocated to high-rise residential development and terrain that is not available to residential development.

The objective is to have each individual residence represented by a cell. This would mean a cell size similar to the area occupied by an average house. Across the European Union, the average internal floor space ranges from 38.7m^2 in Romania to 133.5m^2 in Luxembourg (Dol & Haffner, 2010). The average internal floor space in France, England and the Netherlands is 91.0m^2, 86.9m^2 and 98.0m^2 respectively. Although the mentioned numbers do not concern the average area occupied by a residence, they can serve as an indication. This suggests a cell size between 9×9m and 10×10m. In order to include also private gardens and private parks surrounding collective buildings, the cell size in PARDISIM is 20×20m.

New residential developments are restricted to cells that are available for residential development. The other cell types play a role in the agents' evaluation of the spatial structure. Especially, the location of new developments relatively to existing residential, industrial office buildings is deemed important. Larger open areas, i.e. clusters of cells that do not contain any buildings, also affect the agents' evaluation of the spatial structure. As the agents reach an agreement on which cells in the land use layer are allocated to residential development, these cells are accordingly turned into cells that contain either low-rise buildings or high-rise buildings.

The service layer is a vector map with the location of the existing shops and public services. The location of new residential developments depends indeed on the access of public and commercial services (Tannier, Vuidel, Houot & Frankhauser, 2012; Rietveld & Wagtendonk, 2004; Haider & Miller, 2004; Adolphson, 2008).

Based on the frequency of visit, two distinct types of public and commercial services exist (Desse, 2001; Moati, Meublat, Pouquet & Ranvier, 2005). Daily-frequented services include schools, butchers, bakeries, news-agents and supermarkets. Weekly-frequented services include doctors, auto service centres, post offices, pharmacies, cafes and clothing stores. At this point, PARDISIM only includes daily-frequented services.

5.4 Model progression

The simulation of residential development progresses in multiple rounds. In each round the agents negotiate once towards the allocation of a predefined number of cells to low-rise and high-rise residential development. Figure 5.3 presents the progression of a single simulation round. The agents first define their optimal spatial configuration for the new residential developments. Next they negotiate. At each negotiation round an agent proposes the other agent an alternative spatial configuration of the residential developments. This process continues until an agreement is reached. The agreement is implemented, and the new situation serves as the initial situation in the next simulation round.

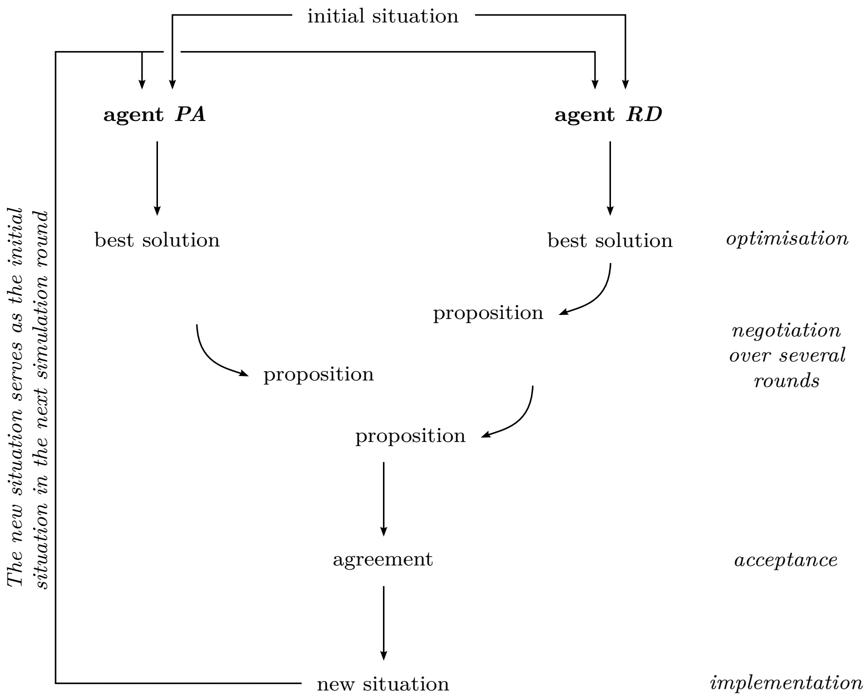


Figure 5.3 – *Progression of the simulation process in PARDISIM.*

Each simulation round represents a discrete time step of a period of 5 to 10 years. The total simulation covers a period of 20 to 30 years, which means that a simulation runs for several rounds. The outcome of the negotiation is an agreement on a set of residential developments, which are implemented in the cellular space at the end of each simulation round.

The aim of discrete time steps in PARDISIM is to approach the often project based residential development process, in which social agents decide on development projects, rather than individual residences. Residential development can be both project based (discrete development) and continuous. Project based residential development is dominant in both England and the Netherlands. In

France, both continuous and project based development play an important role. PARDISIM aims to approach this behaviour.

As a consequence of the objectives of agents, as they are described in chapter 6, the spatial configuration both agents agree on at the end of a simulation round will contain several clusters of cells allocated to residential development. Each cluster can be viewed as a residential development project. Variation in the length of each time step, and consequently the number of time steps in the simulation and the number of cells that the agents need to allocate to residential developments, affects the form of the developments. If the time steps are short, the number of cells the agents need to allocate is small, hence the clusters will be smaller. The spatial configuration that follows longer time step is more likely to be clustered. If more cells are allocated to residential development per simulation round, more clustered or aggregated residential developments can be the result.

Furthermore, multiple simulation rounds allow the possibility to change parameters or variables, e.g. the negotiation position, in between simulation rounds. It permits the simulation of scenarios, in which changes in the constitutional context cause the characteristics of the development process to change. Agents can also change their priorities in their objective function over time. An advantage of this approach is the smaller number of cells that agents need to allocate per simulation round. The latter makes the negotiation eventually computational less extensive. The simulation model will run quicker.

Chapter 6

The agents and their spatial objectives

The previous chapter shows that the subject of negotiation between the agents is the allocation of cells to new residential development in the cellular land use layer. The outcome of a negotiation results from the interplay between the agents' preferences for a certain allocation and how the agents trade-off these preferences to reach an agreement. The latter depends on the bargain power of each agent, and is discussed in the next chapter. In the current chapter, the focus is on the former.

An agent's preference for a certain allocation of new residential cells depends on the spatial relations between the built cells and the location of amenitiesS, but also between the built cells themselves. This raises two important questions. How do agents evaluate these spatial relations? And, how do they use this evaluation to identify their prefered spatial allocation of new residential cells? The answer to these questions is to be found in a quantitative description and evaluation of the spatial relations between built cells and their surrounding.

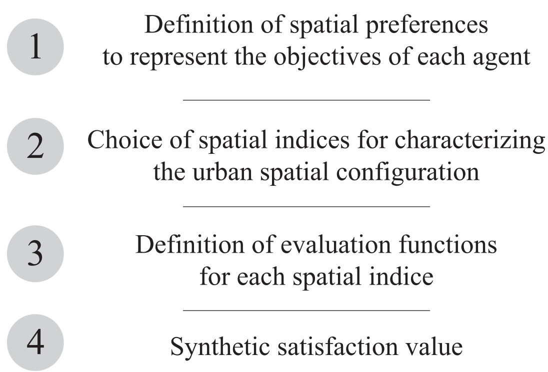


Figure 6.1 – *Process used to define and quantify the agents' spatial preferences*

In this chapter, we aim to define indices, evaluation functions and satisfaction functions that the agents in the simulation model use to evaluate, compare and select the allocation of cells to new residential development (see figure 6.1).

Section 6.1 formulates the presumed objectives of private residential developers and local planning authorities based on a literature study. These objectives are synthetized using eight spatial indices, four for each agent (section 6.2). Thereby each agent has a set of four spatial preferences for the location of new residential developments in the land use layer. PARDISIM does not implement other incentives than the spatial configuration that results from the negotiation. Finally section 6.3 describes how the four evaluation functions of each agent are aggregated into a single satisfaction function for each agent.

6.1 Agent objectives

Spatial preferences of local planning authorities

Local planning authorities pursue residential developments that are economically, environmentally and socially sustainable (see section 2.2). New residential developments need to contribute to the maintance or increase of the economic viability of the urban area. Local planning authorities must also ensure or even improve the environmental quality, including the protection of natural resources, and the quality of life. The planning concepts discussed in the sections 2.3 and 2.4 are a response to concerns of space consumption, fragmentation of open area and the quality of life and can serve as an indication of the planning authorities' spatial preferences.

The provision of housing through residential development contributes to the economic sustainability of the urban area. The availability of housing to local residents helps with the prevention of them moving away. In addition, residential development can also help to attract people from outside and contribute to the attraction of economic development to the urban region. It provides a clear incentive to local planning authorities to promote residential development.

The extent of the residential development needed for economic sustainability differs for each urban area. It is often subject to spatial and urban policies of regional and national governments. Hence, the economic sustainability of the growth in the number of residences can not be related to the spatial configuration of the urban area. The number of new residences is therefore an exogenous parameter, set prior to the start of the simulation.

Increasing space consumption and fragmentation of open area are a threat to environmental sustainability. The quality of life relates to the same issues as social sustainability. This is attested by the current dominance of the compact city planning concept as the basis for many spatial policy documents. Also, many of the other planning concepts in sections 2.3 and 2.4 advocate spatial restrictions to residential developments. Two spatial preferences for residential developments are derived from this. First, increased density of residential developments leads to less use of open area. Second, the construction in large clusters, preferably connected to the existing built area, prevents the fragmentation of the open area.

Bramley and Power (2009) have identified two key dimensions of social sustainability or quality of live. These are social equity and sustainability of community. The former concerns the equal distribution of resources and opportunities (Burton, 2000). In the context of the spatial configuration of residential developments equal distribution of access to public and commercial services, and other amenities contributes to social equity (Talen, 1998). Access, especially non-motorised access, to services and amenities is an integral part of spatial policies, since it is not only expected to contribute to social equity, but also to environmental sustainability by promoting cycling and walking.

Sustainability of community relates to the social cohesion of the community. Residential stability, interaction and participation, sense of place, and security are aspects of a community that significantly help its sustainability (Bramley & Power, 2009). Among planners and policy makers, mixing socially different residents is generally believed to have a positive effect on these aspects. And thus, despite extensive academic debate concerning its effectiveness, social mixity has a prominent place in urban and spatial policies (Lees, 2008; Uitermark, Duyvendak & Kleinhans, 2007; Cameron, 2003). As a consequence, social mixity for residential developments is the preference of a heterogenous distribution of different types of residences. The mixity of different types of residences is therefore a clear objective of local planning authorities.

Spatial preferences of private residential developers

Private residential developers are far from homogeneous (Coiacetto, 2001). They often operate in a local or regional environment, where their behaviour depends on the local political and cultural context (Coiacetto, 2000). However, in general, residential developers are profit seeking entities, who generate their gain through land speculation and housing construction (Golland, 1996). The behaviour of a developer depends on the expected development value, which can be expressed as the expected rents and income, and the costs, which are determined by land values, construction costs and finance charges (Henneberry & Rowley, 2002; Somerville, 1996). The planning authority's plans and spatial policies, which restrict development options, also affect the behaviour of residential developers (Levine & Inam, 2004; Ryan, 2006).

It is well known that the residential developers' spatial preferences are driven by the incurred costs and the expected development valua, or marketability, of the residential developments (Mohamed, 2009). However, very few studies exist that investigate the spatial preferences of private residential developers. A notable exception is a study by Pacione (1990). He has surveyed residential developers in Scotland, and finds that developers consider, among other characteristics, the environmental quality, access to the city centre, the size of the development site and the social class of adjacent residential areas. Developers find access to employment, the proximity of local shops and schools and topographic conditions less important. Similarly, a survey by Robinson and Robinson (1987) shows that the proximity of open area and access to the central business district are spatial characteristics of potential development sites important from the point of view of private residential developers. Alternatively, some authors have used regression analysis to identify the residential developers' spatial preferences. A study by Haider and Miller (2004) shows that the location choices of developers in the Greater Toronto Area depends on the housing type; for each housing type the developers prefer a different location. The preferred location for high rise buildings is close to the central business district and close to infrastructure nodes and employment, whereas low rise houses are likely to be constructed in less densely populated suburbs away from subway stations, employment and shopping malls. An important find in the research of Haider and Miller (2004) is that new housing developments are often located near existing houses of the same type. This could indicate a preference of residential developers for homogeneous residential developments. Similar results have been presented for the Netherlands by Rietveld and Wagtendonk (2004). The strongest correlation exists between the location of existing homes and the location of new residential developments of the same type. Homes are likely to be developed close to a train station, but no correlation has been found between the location of residential developments and the proximity of an access to highways or nature areas. Highways and railways appear to be push factors and proximity to employment is only important in the less densely populated areas of the Netherlands, where potential employment could be further away. Adolphson (2008) has performed a similar study for the municipality of Strängnäs, Sweden. The location choice for new multifamily houses is strongly correlated to the proximity of urban centres and industry, while new single-family homes are most likely located close to existing single-family homes.

Comments

Based on the ideas exposed previously, a set of four spatial preferences are defined for each agent. The planning authority agent (agent *PA*) prefers spatial configurations of residential developments that minimise fragmentation of the built-up area. Both existing residences as well as new residences should have good access to both open area and daily-frequented services. Furthermore, agent *PA* likes to promote a mixity of high-rise and low-rise residential buildings. Finally, agent *PA* has an optimal density for residential developments.

The residential developer agent (agent *RD*) favours residential development at a different density. Also, agent *RD* prefers homogenous developments and finds only access to open area important. Lastly, residential developments in clusters have a preference over solitary residential developments.

The definition of the agent's spatial preferences is such that the two agents have a different preference for the spatial configuration of residential developments. The preferences of agent *PA* for high density residential development with a mix of different types of homes conflicts with the preferences of agent *RD* to develop homogenously and with a lower density. In some occasions, even the agent *PA*'s preference for access to daily-frequented services can collide with the agent *RD*'s preference for access to open area.

Agent *PA*, which represents the local planning authority, has a preference for sustainable residential developments. It aims at ensuring the welfare of the entire community. Hence, agent *PA* adopts spatial preferences that pertain to the *global* effects of the spatial configuration. Conversely, the main interest of agent RD (private residential developer) is the implementation of residential developments that are commercially viable. The residential developer is interested in a spatial configuration that causes the property value to increase for new residential developments. The effect of new residential developments on the existing spatial configuration is of minor importance. Therefore, agent *RD*'s spatial preferences relate mostly to the *local* effects of the spatial configuration, especially the configuration of new residential developments.

6.2 Quantification of agents' spatial preferences

The agents' spatial preferences, as they are derived from the housing development actors' interests, are qualitative indications of a spatial structure that the agents desire will emerge from the housing development process. For an agent to be able to compare different spatial structures and to decide which spatial structure best meets the agent's objectives it is necessary to devise quantitative rules. These rules need to deal with two issues. Firstly, they must enable an agent to compare two different spatial structures and decide, which spatial structure best meets a single objective. Secondly, the rules must let an agent compare two spatial structures, analyse how both spatial structures meet each of its objectives and decide which structure leads to the highest satisfaction.

Quantifying the urban spatial configuration

Spatial indices, also refered to as spatial metrics, landscape metrics or landscape indices (Jacquin, Misakova & Gay, 2008; Antrop & Van Eetvelde, 2000), originate from research in ecology, but have become being commonly used in the analysis of the urban spatial structure.

Herold, Couclelis and Clarke (2005) define spatial indices as 'measurements derived from the digital analysis of thematic-categorical maps exhibiting spatial heterogeneity at a specific scale and resolution' (p. 374). Spatial indices aid the analysis of the spatial structure as they can quantify a categorical representation of the spatial structure with a limited number of classes. Hence they can be used to analyse thematic maps (Herold, Liu & Clarke, 2003; Gustafson, 1998). This requires, however, the definition of a model of the spatial structure that fits the subject of analysis.

Indices quantify usually either the composition or the spatial configuration of a spatial structure (Gustafson, 1998). Composition refers to the quantity at which classes or land uses are present in the study area, indices that quantify the composition of a spatial structure include richness and evenness indices. The spatial configuration refers to the quantification of spatial properties of patches and cells in the study area. Examples of spatial configuration indices are indices expressing the shape and size of land use patches. Alberti and Waddell (2000) have also introduced a third category of indices, spatial neighbourhoods, which quantify the spatial relationships between classes or land uses of a different type. The contagion index is an example of a spatial neighbourhood index.

Form of the agents' evaluation functions

The evaluation function expresses how the outcome of an index is interpreted by the agent; it defines for all possible outcomes a corresponding evaluation value. Many different functions can be used as evaluation functions: linear, logistic, gaussian, exponential, etc. Here only three types of evaluation functions are considered: linear, logistic, and gaussian.

The advantage of the linear function is its simplicity. It is easy to understand and easy to define the parameters that define the function: they simply are the index values where the evaluation starts or ends (being equal to either one or zero in our case, see below). Here the linear functions are defined such that there exists a plateau where the evaluation equals to one and there exist index values for which the evaluation is equal to zero. Between these two extremes there is a transition where the index value and its evaluation are linearly related (see figure 6.2 and equation 6.1, equation 6.2 and equation 6.3). Three different relations exist: positive, negative and trapezium.

$$\mu(X) = \begin{cases} 0, & \text{if index} \leqslant \lambda_1 \\ \frac{1}{\lambda_2 - \lambda_1} \times (\text{index} - \lambda_1), & \text{if } \lambda_1 < \text{index} \leqslant \lambda_2 \\ 1, & \text{if index} > \lambda_2 \end{cases} \tag{6.1}$$

$$\mu(X) = \begin{cases} 1, & \text{if index} \leqslant \lambda_1 \\ 1 - \frac{1}{\lambda_2 - \lambda_1} \times (\text{index} - \lambda_1), & \text{if } \lambda_1 < \text{index} \leqslant \lambda_2 \\ 0, & \text{if index} > \lambda_2 \end{cases} \tag{6.2}$$

$$\mu(X) = \begin{cases} 0, & \text{if index} \leqslant \lambda_1 \\ \frac{1}{\lambda_2 - \lambda_1} \times (\text{index} - \lambda_1), & \text{if } \lambda_1 < \text{index} \leqslant \lambda_2 \\ 1, & \text{if } \lambda_2 < \text{index} < \lambda_3 \\ 1 - \frac{1}{\lambda_4 - \lambda_3} \times (\text{index} - \lambda_3), & \text{if } \lambda_3 \leqslant \text{index} < \lambda_4 \\ 0, & \text{if index} \geqslant \lambda_4 \end{cases} \tag{6.3}$$

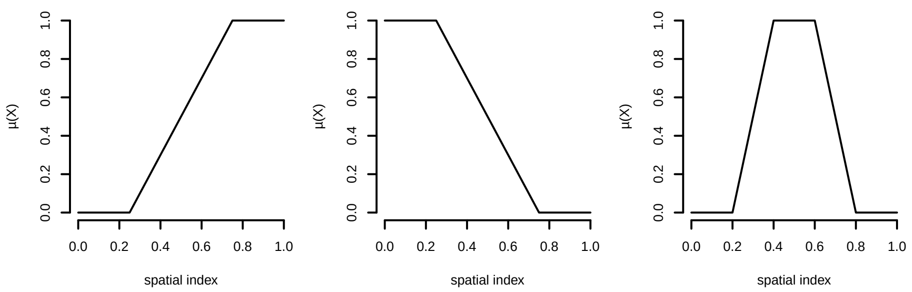


Figure 6.2 *– Different types of linear evaluation functions for the evaluation of the spatial index value*

The disadvantage of the linear function is that, at the extremes, the evaluation value is either one or zero, which means that in these areas a slight 'improvement' of the index value does not result in an increase of the evaluation of the index value. There is a discrete moment when the evaluation changes as the index value changes. Furthermore, the evaluation function is separated into three to five curve portions.

Opposed to the linear evaluation function, are the logistic evaluation function and the gaussian evaluation function. The first defines the either positive or negative correlation between the index value and the evaluation. The latter defines the case where there is a clear optimal evaluation for a certain value of the index; if the index value gets either larger or smaller, the evaluation approaches zero.

In comparison to the linear evaluation function, the definition of the parameter for the logistic and gaussian functions are less straight forward. On the other hand the evaluation functions consist of one equation and are smooth over the entire extent of the index. In other words, the derivative of the function is a continuous function (see figure 6.3 and equations 6.4, 6.5 and 6.6).

$$\mu(X) = \frac{1}{1 + \alpha \cdot e^{-\beta \cdot \mathrm{index}}} \tag{6.4}$$

$$\mu(X) = 1 - \frac{1}{1 + \alpha \cdot e^{-\beta \cdot \mathrm{index}}} \tag{6.5}$$

$$\mu(X) = e^{-\frac{(\mathrm{index} - \alpha)^2}{2\beta^2}} \tag{6.6}$$

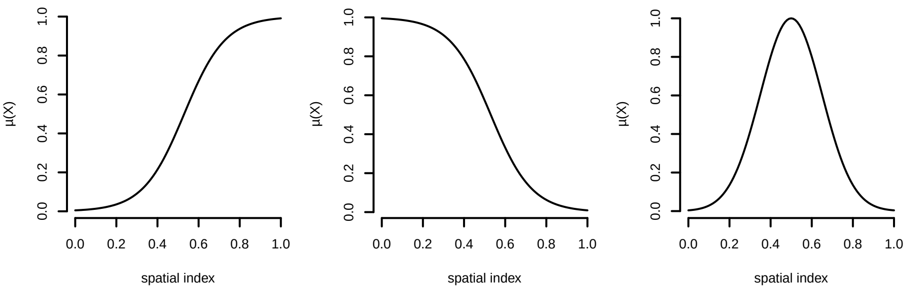


Figure 6.3 *– Different types of logistic and gaussian evaluation functions for the evaluation of the spatial index value*

More importantly, both the logistic and gaussian functions have two other advantages over the linear function. Firstly, in case of the logistic function each value of the index corresponds to a unique evaluation value. The same is true for the part of the Gaussian function that lies beneath the optimal evaluation and also for the part that lies above the optimal evuation value. This means that every change in the index value leads to a change in the evaluation value. Any improvement in the spatial configuration that leads to a change in at least one index value is translated into a higher evaluation of the spatial configuration. This means that for every change in the spatial configuration it is possible to evaluate whether that change has led to a spatial configuration that is closer to satisfying the agents objectives. Since the search for the optimal spatial configuration consists of a long series of small steps (see chapter 7), it is hugely important that every little changes can be evaluated as either an improvement or not.

Secondly, in both the logistic evaluation function and the gaussian evaluation function, the progress is not constant. The evaluation function has the largest inclination at 0.5. Hence, if the evaluation of an index value is equal to 0.5, changes in the index value lead to bigger changes in the evaluation compared to equal changes in the index value when the evaluation is close to either one or zero. Moreover, in the search for a spatial configuration that meets the agent's objectives, the preference lies at spatial configurations that cause an improvement in the index values for which the evaluation is close to 0.5. This has the most impact on the overall evaluation. This effect is missing in linear evaluation functions. Also, this is behaviour seen in real-world actors. The latter often aim to improve (in either a negotiation or an optimisation) those aspects that are below optimal, in stead of improving aspects that are already close to optimal.

In the chosen formalization of agents' spatial preferences, evaluation functions are interpreted as fuzzy membership functions (Yager, 1978; Zadeh, 1965a). Fuzzy set theory allows working with imprecise knowledge (an element may belong more or less to a fuzzy set). Because fuzzy set theory offers a range of mathematical tools for manipulating such imprecise knowledge, we chose to use it to quantify spatial preferences (i.e. spatial objectives) that are intrinsically imprecise (Oh & Jeong, 2002; Tannier, Vuidel, Houot & Frankhauser, 2012)

For D the set of all possible alternatives and s all the possible situations (states), it is possible to define a fuzzy set H :

$$H \subseteq D \tag{6.7}$$

$\mu_H(s)$ is the fuzzy measure of H

$$\mu_H(s) \in [0, 1] \tag{6.8}$$

Quantification of spatial preferences of the local planning authority

Limiting the fragmentation of open areas (evaluation index A)

In a very general sense, fragmentation is related to shape complexity. Commonly used metrics to quantify shape complexity and fragmentation are edge density, contagion index, fractal dimension, and any other metrics based on the perimeter-area ratio. The problem with this is that in case of small patches the geometry of the raster (in particular, its spatial resolution) influences the fragmentation measures (Milne, 1991). This can be partly solved by creating a global metric that is an area weighted mean (e.g. area weighted mean patch fractal dimension (McGarigal, Cushman, Neel & Ene, 2002)). However, in the case of the model that is developed here, this would mean that the existing built area, which is not changing, gets a dominant weight. If the initial built pattern is already well developed, the ratio between the number of cells allocated to residential development and the number of cells with existing buildings can be very low. The result of which would be that the changes in the spatial configuration would lead to very small changes in the measured fragmentation index. Consequently, defining an evaluation function that works with the small changes brings us back to the problem with the raster geometry.

Patch count and patch density are also related to fragmentation and shape complexity. It is however important to note that the patch count is related to the urban growth as well. Depending on the existing spatial configuration, the patch count can either increase or decrease with urban growth. If the original patch count is low, new patches are likely to emerge as the result of urban growth. The increase in the number of patches is an indication of the increase of fragmentation. If, however, the number of patches is already high, urban growth often leads to patches growing and merging with adjacent patches. In such a case the number of patches decreases if urban growth takes place within the 'peri-urban' zone with many small patches. If however, the urban growth takes place beyond the zone with a high patch density, thus in the rural zone, the number of patches is likely to increase. Thus in general, a decrease in the number of patches in case of urban development is an indication of a more compact development, whereas an increase in the number of patches indicates fragmentation which can be the result of urban sprawl.

Recognising that urban growth eventually leads to some increase in the number patches of built areas, the objective of the planning authority is to minimize the relative growth of the number of built patches. Hence the index A that measures the fragmentation is defined as the increase in the number of patches of residential cells divided by the number of patches in the old (i.e. initial) situation. A relative index is defined.

$$A = \frac{\text{\# patches in the new situation} - \text{\# patches in the old situation}}{\text{\# patches in the old situation}} \tag{6.9}$$

The number of patches is defined by first creating a buffer of 20m (the length of one cell) around all cells allocated to built area, which will connect cells together. Next, the number of disconnected patches that emerge from this operation is determined. Patches are defined by dilating the all built cells with one cell length in all eight directions. A patch of cells is connected to another patch of cells if at least of one cell of the one patch is found in the cell's 8-cell neighbourhood of the other patch.

The evaluation function ($\mu_A(X)$) for urban configuration X based on the criteria A is negatively correlated to A: if A increases then $\mu_A(X)$ decreases. Furthermore, as finding an optimal spatial configuration of new residential development starts with a large number of small patches (see chapter 7), even a large number of patches needs to get an evaluation which is higher, albeit just slightly, than zero. This in order to ensure that during the algorithmic process of finding the optimal solution for the allocation of new residential area a decrease in the number of patches is positively evaluated. The evaluation function of the relative increase in the number of patches is defined in such a manner that even if the number of patches is initially very high a slight decrease in the number of patches leads to an increase in the evaluation of the relative increase in the number of patches. Therefore $\mu_A(X)$ is defined as:

$$\mu_A(X) = 1 - \frac{1}{1 + \alpha_A \cdot e^{-\beta_A \cdot A}} \tag{6.10}$$

Increasing the accessibility to daily frequented amenities (evaluation index B)

Over the years many indices to measure accessibility have been developed, which include different factors that influence accessibility. Accessibility indices can be classified as one of three types (Miller, 1999; Handy & Clifton, 2001).

First, constraint oriented accessibility indices define accessibility of an amenity by the factors that limit the access to it. An obvious constraint that limits the access to an amenity is the length or the duration of the trip needed to get to the amenity. Hence, accessibility can be measured by the shortest distance or quickest way to the amenity closest by (Joseph & Phillips, 1984). Alternatively, accessibility of an amenity can be defined by the availability of amenities within a fixed distance from a location from where people aim to access them (Cervero, 1996). Witten, Exeter and Field (2003) distinguish between availability of an amenity within a fixed distance, where an amenity is either accessible or not, and choice, which increases if more amenities come available within the fixed distance. Finally, another common constraint oriented accessibility measure is spatio-temporal accessibility (Kwan, 1999; Huisman & Forer, 2005), where accessibility is limited by the time people or households have available.

Second, attraction-accessibility indices define accessibility as a combination of the length of the trip needed to get to an amenity and the atractiveness of the amenity. The latter depends on its qualitative and quantitative characteristics like number of jobs (Geurs & Van Wee, 2004; Song, 1996), number of commercial services (Páez, Gertes Mercado, Farber, Morency & Roorda, 2010; Iacono, Krizek & El-Geneidy, 2010; Tannier, Vuidel, Frankhauser & Houot, 2010) or size and quality of green space (Wendel-Vos et al., 2004; Hillsdon, Panter, Foster & Jones, 2006; Maas, Verheij, Groenewegen, De Vries & Spreeuwenberg, 2006). These indices are often revered to as gravity-based indices, because of the anology with the law of gravity: gravitational pull of an object is positively related to the size of the object, but negatively related to the distance to the object. Song (1996) has related accessibility to urban density and found that an attraction-accessibility index with accessbility decaying exponentially with increasing distance best predicts urban density. This suggests that an attraction-accessibility index best approaches how accessibility is perceived in an urban environment.

Last, utility-based accessibility indices have a more personal approach, since they can differ for each individu. These indices consider next to the journey length or duration, which is related to the travel cost, the gain made with a journey (Miller, 1999). An individu will aim to maximise the difference between costs and benefits, in other words, an individu aims to maximise the utility gained from a trip.

In our model, in order to keep it as straightforward as possible, the agents measure accessibility using a constraint oriented accessibility index. An attraction-accessibility approach would have added complexity requiring an investigation of the attraction of individual public and commercial services, aggregated public and commercial services in service centres like malls and shopping districts, urban parks, and rural area and natural preservation areas in the urban fringe. Especially since the attraction of public and commercial services and other amenities is expected to change as a direct or indirect result of housing development. Modelling the attraction of amenities and services is therefore deemed to be beyond the scope of this research. Considering this, index B combines the evaluation of the proximity of public green and open area, the accessibility of schools, and the accessibility of daily frequented commercial services. The latter concerns shops for daily shopping.

In the model, six different types of shops, services and amenities are considered: supermarket, bakery, butcher, news agent, school and open area. Schools and shops are points in the service layer. Whereas open areas are non built surfaces in the land use layer. They can be either lacunes internal to the built areas or areas outside the built areas, i.e. beyond the urban fringe. The accessibility is measured by averaging the distance from a residential cell to the three closest amenities of a different type. Distances measured are Euclidean distances. This choice is supported by two arguments. First, the indices are calculated in an evolving spatial configuration: each time the indices are calculated, the cells for which they are calculated can be in a different location. Consequently, all accessibility measures have to be recalculated each time, which requires lots of computation resources. Second, the model does not generate a road network that goes along with the residential development. Indeed, since changes to the local road network and housing development are very interdependent, the implementation of the evolution of the infrastructural network in the simulation would cause a huge increase in the complexity of the model. Because the infrastructural network does not evolve with the housing developments, it is not appropriate to use network distances to measure the accessibility.

To map the open areas, we have chosen to draw an urban envelope through a generalisation from buildings to built area. Remember that during the negotiation process, the agents evaluate many different possible spatial configurations, each representing a different urban development project. Each spatial configuration adds a set of built cells to the existing sets of built cells, which results in a need to redefine the urban envelope at each iteration of the optimisation process. This requires a dynamic definition of the urban envelope and hence excludes the possibility of defining the urban envelope prior to the negotiation process. The urban envelope must be easy and quick to define for each spatial configuration. Furthermore, the method must mark intra-urban non-built areas, like public parks.

Commonly used methods to extract the urban envelope are either the dilation of individual building blocks (Chaudhry & Mackaness, 2005; Frankhauser, 2004; Lagarias, 2007), or the dilation of individual building blocks and the erosion of the resulting shape (Bailly, 1996; Guérois, 2003). It depends on the principle that the dilation of buildings blocks close to each other results in these buildings blocks to merge.

Dilation means that each building block is increased in all directions (De Keersmaecker, Frankhauser & Thomas, 2003). If two or more building blocks intersect after the dilation operation, these building blocks are merged into one object. During the erosion operation the dilated and possibly merged building blocks are decreased in all directions with the same distance the original building blocks have been dilated. The effect of these two operations is that, if multiple building blocks merge during the dilation, the erosion, which takes place from the outside inwards, will not completely undo the increase of the dilation (see figure 6.4). The original individual building blocks remain connected.

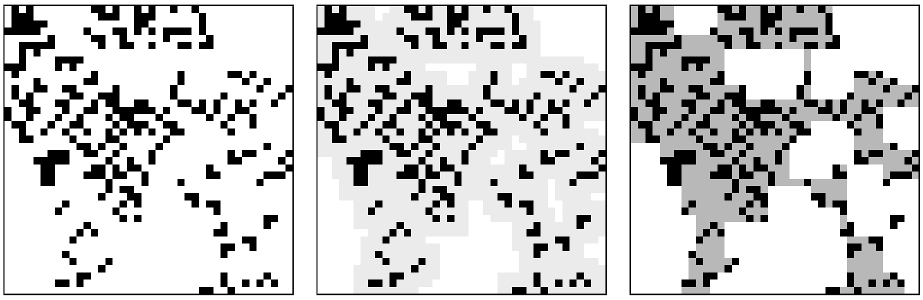
The dilation and erosion distance determines how many individual building blocks remain connected to one or more other building blocks. An increasing dilation distance causes more and more building blocks to merge and remain connected after the erosion operation. On the other hand, decreasing the dilation and erosion distance can create pockets in the urban envelope, which possibly represent intra-urban open areas (see figure 6.4). This trade-off illustrates the dilemma of setting the dilation and erosion distance for the case studies that are introduced in part III of the thesis.

The French National Institute of Statistics and Economic Studies (INSEE, 2011) has defined an urban unity as a continuous, built zone with at least 2000 inhabitants, and a single building is part of this urban unity if it is less than 200m apart from any building within the urban unity. Similarly, the British Office for National Statistics (Office for National Statistics, 2004) has defined an urban area as a built zone of at least 20ha with at least 1500 residents where, like the French definition, built structures are part of the urban area if they are less than 200m away from it. The requirement that built structures are less than 200m away corresponds with a dilation distance of 100m. Chaudhry and Mackaness (2005) have found that a 100m dilation distance gives the best results for definition of the urban envelope for Edinburgh. Tannier, Thomas, Vuidel and Frankhauser (2011) have suggested that the dilation distance that needs to be used to aggregate individual buildings to urban unities depends on the spatial morphology. They have found that the relationship between dilation distance and the number of patches to be found is not linear. In fact, they have shown that in case of a linear increasing dilation distance, the decreasing number of patches shows clear changes in the speed at which it decreases. These changes, they have argued, point to dilation distance that identify patches of urban unities. In their ungoing research using the same method they have found that the dilation distance in Belgium cities is around a 120m. Guérois (2003) has used a dilation distance of 400m and a erosion distance of 300m to define the urban envelope. On the other hand, however, a small dilation distance can already cause small streets and courtyards to be filled in and large clusters to emerge (Thomas, Frankhauser & Biernacki, 2008).

The dilation distance used depends, however, on the objectives and the scale at which it needs to be defined (Frankhauser, 2004). How far does an urban building block need to be apart from a cluster of building blocks to not be considered part of that cluster? How large does an open area need to be to create a pocket or indent in the urban envelope? More specifically, the choice of a dilation distance depends on what is considered inside and outside the urban envelope in both the purpose the urban envelope serves and the urban area studied.

The empirical cases on which the model will be applied later on (in part III of the thesis) are small urban areas with a quite high building density. After having tested different dilation and erosion distances, it has appeared that a dilation and erosion distance of 40m (two cells length) provides the best results. It results in the merging of built cells into a few large clusters of built area and yet preserving some of the open areas within the urban area as pockets in the urban envelope.

During the simulation, the location of schools and shops does not change, neither are new service points added during the simulation. Thus the average shortest distance to commercial and public services increases during the simulation as more residential cells are added to the spatial configuration. It becomes more difficult to find locations that are close to existing service points. On the



(a) Built cells **(b)** Dilation of the built cells with two cells **(c)** Built area remains after contractions by two cells

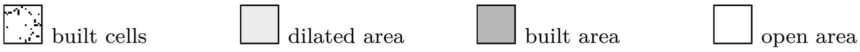


Figure 6.4 *– The dynamic definition of the urban boundary through dilation and contraction.*

other hand adding new residential cells to the spatial configuration influences the accessibility to open areas of existing residential cells. So the accessibility index B measures the increase in the average distance to the closest three different amenities compared to the initial situation.

For each cell $j \in J$ allocated to existing residential buildings, b_j is the average distance from cell j to three closest amenities of a different type. J is the set of cells allocated to existing residential buildings. Similarly, K is the set of cells allocated to residential development, hence b_k, where $k \in K$, is the average distance form cell k to three closest amenities of a different type. The average distance to the closest three different amenities before residential developments (B^{ini}) and the average distance to the closest three different amenities in the situation after residential development is implemented (B^{cur}) is defined as:

$$B^{\text{ini}} = \frac{1}{J} \cdot \sum_{j=1}^{J} b_j \tag{6.11}$$

$$B^{\text{cur}} = \frac{1}{J+K} \cdot (\sum_{j=1}^{J} b_j + \sum_{k=1}^{K} b_k) \tag{6.12}$$

B is defined as:

$$B = \frac{B^{\text{cur}} - B^{\text{ini}}}{B^{\text{ini}}} \tag{6.13}$$

The evaluation function of index B for the public authority agent is defined as follows:

$$\mu_B(X) = 1 - \frac{1}{1 + \alpha_B \cdot e^{-\beta_B \cdot B}} \tag{6.14}$$

ν	description
0	Area without built construction, unavailable to urban development
1	Newly built low-rise residential buildings
2	Existing low-rise residential buildings
3	Newly built high-rise residential buildings
4	Existing high-rise residential buildings
5	Industrial buildings
6	Special purpose buildings
7	Open area available to urban development

Table 6.1 *– Overview of the different cell types in the raster layer*

Favoring the mixity of housing types (evaluation index C)

The morphological diversity (more specifically, the mix of low-rise and high-rise buildings) is used by the agent *PA* as a proxy for social diversity. The morphological mix is measured by the ratio between the number of cells of a different residential type and the number of all residential cells in the 24-cell Moore's neighbourhood (5×5 cell neighbourhood) of every newly developed residential cell. Thus, for each low-rise residential cell the index counts all the cells with high-rise residential cells in the 24-cell Moore's neighbourhood and divides this number by the number of all residential cells in the same neighbourhood. Similarly, for each high-rise residential cell the index counts all the cells with low-rise residential cells in the 24-cell Moore's neighbourhood and divides this by the total number of residential cells in the 24-cell neighbourhood.

Let ν_i be the type of cell $i \in$ all cells. And let $N = \{0, \ldots, t\}$ (here t equals to 7) be the set of all different cell types (the values of n have the same meaning as the values of ν in table 6.1), then let v_k^n be the number of cells of type n in the neighbourhood of cell $k \in K$, where K equals all the cells allocated to residential development.

$$c_k = \begin{cases} \frac{v_k^3 + v_k^4}{v_k^1 + v_k^2 + v_k^3 + v_k^4} & \text{if } \nu_k \in \{1, 2\} \\ \frac{v_k^1 + v_k^2}{v_k^1 + v_k^2 + v_k^3 + v_k^4} & \text{if } \nu_k \in \{3, 4\} \end{cases} \tag{6.15}$$

where, v_k^1, v_k^2, v_k^3, v_k^4 are the number of cells of type newly built low-rise residential buildings, existing low-rise residential buildings, newly built high-rise residential buildings, existing high-rise residential buildings, respectively, in the 24-cell Moore's neighbourhood of cell k;

As the location of existing residential cells does not change during the simulation, and adding new residential cells only has a small influence on the morphological mixity of existing residential cells, the index C is only calculated for the newly added residential cells and not for all residential cells. The index C is defined as the average of c_k for all newly added residential cells:

$$C = \frac{\sum_{k=1}^{K} c_k}{K} \tag{6.16}$$

The evaluation of the morphological mix C is defined by:

$$\mu_C(X) = \frac{1}{1 + \alpha_C \cdot e^{-\beta_C \cdot C}} \tag{6.17}$$

In case of complete mixity, the ratio of low rise houses in the direct vicinity of high rise residential buildings is equal to the share of low rise houses in the development proposal. Similarly, the ratio of high rise residential buildings in the direct vicinity of low rise houses is equal to the share of high rise residential buildings in the development plans. As the global index is defined as the average of the mixity values for all newly developed cells, the maximum value depends in the ratio between cells allocated to low-rise residential development and cells allocated to high-rise residential development. The maximum value for C is thus defined as share high rise $\times$ share low rise + share low rise $\times$ share high rise. In theory, this value could be a little higher because the mix of existing low-rise residences with high-rise residential development and vice versa contribute to increasing mixity. In practice however, the above definition of the maximum achievable value for C provides a guide in the definition of the values of α_C and β_C. For each case study $\mu_C(X)$ differs.

Increasing housing density (evaluation index D)

Index D functions as a proxy for the density. For each cell allocated to residential development $k \in K$, d_k is expressed as the number of empty cells in the 8-cells neighbourhood (3×3 cells neighbourhood) of that newly developed cell. Therefore $d_k \in \{0, 1, 2, 3, 4, 5, 6, 7, 8\}$. The number of empty cells in the 8-cells neighbourhood gives an indication if the cell is part of a dense residential development or not. The average of the number of empty neighbours per cell gives an indication of the density of residential developments.

As the density of existing residential cells hardly changes as the result of adding new residential cells, the density is calculated for the newly added cells only. For each newly developed cell the density is evaluated separately. Here the gaussian evaluation function is used, because it is assumed that both actors have specific preference for an optimal density. The average of all evaluations of the density of newly developed cells expresses the overall evaluation of the density of the proposed development. We have chosen for the presented method of calculating density because the number of empty cells has a single optimum. Below and above this optimum the evaluation is lower. In case the average number of empty cells for all cells is evaluated, cells with a fewer than desired number of empty neighbouring cells will be compensated by cells with a more than desired number of empty neighbouring cells. However, when the evaluation of each individual cell is calculated before the individual evaluations are averaged, this is not the case. If the number of empty neighbouring cells does not match the optimum, the evaluation is smaller than one and can not be compensated.

The evaluation function for d_k is defined as:

$$\mu_{d_k}(X) = e^{-\frac{(d_k - \alpha_{d_k})^2}{2\beta_{d_k}{}^2}} \tag{6.18}$$

The evaluation function for D is defined as:

$$D = \frac{\sum_{k=1}^{K} \mu_{d_k}(X)}{K} \tag{6.19}$$

Quantification of spatial preferences of the private housing developer

Preference for spacious development (evaluation index E)

Like the planning authority, the housing developer has a preference for the density of new housing developments. Therefore the exact same index for density is included as for the agent *PA*. However the optimal density is likely to be different for both agents. The preferences of agent *PA* and agent *RD* are based on different motivations. Agent *PA* aims to limit the physical urban growth by increasing density and at the same time is concerned with the quality of new neighbourhoods. These preferences have their effect on the density of residential developments. On the other hand, agent *RD* has economic motives. Lower density means the value of an individual residence will increase, however a higher density allows selling more units. Depending which argument is the most important the density of residential developments prefered by agent *RD* is higher or lower than the density prefered by agent *PA*. Here is assumed that agent *RD* prefers a lower density. The membership function $\mu_E(X)$ is defined similarly to $\mu_D(X)$:

Here also applies that each individual cell is evaluated and the global evaluation is the average of the evaluations of the individual cells.

$$\mu_{e_k}(X) = e^{-\frac{(e_k - \alpha_{e_k})^2}{2\beta_{e_k}{}^2}} \tag{6.20}$$

The evaluation function for E is defined as:

$$E = \frac{\sum_{k=1}^{K} \mu_{e_k}(X)}{K} \tag{6.21}$$

Preference for homogeneous development (evaluation index F)

The marketability of newly developed housing depends on the location, in particular the proximity of buildings that decrease the market values of newly developed houses. Notably, the proximity of residences of different types decreases the value of the developers' investments. Thus housing are preferably developed away from these structures and concentrated in homogeneous developments.

This objective is in direct conflict with the objective of morphological mixity of the planning authority. The same index is used (F is equal to C), however the evaluation function is opposite to that of the planning authority.

The evaluation of the homogeneousness of housing development F is defined as:

$$\mu_F(X) = 1 - \frac{1}{1 + \alpha_F \cdot e^{-\beta_F \cdot F}} \tag{6.22}$$

Proximity of open spaces (evaluation index G)

Residential developments close to public green, parcs, and open areas usually benefit from a good aesthetic quality of the environment (pleasant landscape). Therefore the agent *RD* aims to build housing close to urban green or open areas. Index G measures the accessibility of a residential cell to the closest open area.

To map the open areas, we chose to draw an urban envelope just as in the case of the calculation of index B (accessibility to amenities) for the agent PA. Using the same dilation and erosion method as used for the index B, the urban envelope is defined. A cell is considered an open area cell if this cell is non-built and outside the urban envelope (Longley, Batty & Shepherd, 1991; Frankhauser & Tannier, 2005). The dilation distance used for defining the urban envelope of index G is, however, higher than for defining the urban envelope of index B: 60m. instead of 40m. Consequently, only big internal lacunes are considered and open areas are mainly located outside the urban fringe.

The accessibility to open area is expressed as the straigth line distance between the considered built cell and the 'open area' cell clostest to the built cell. The index G calculates the shortest mean distance of newly built residentials cells to the urban envelope:

$$G = \frac{\sum_{k=1}^{K} g_k}{K} \tag{6.23}$$

Where g_k is the shortest distance from cell $k \in K$ (a cell allocated to residential development) to open area. The evaluation function $\mu_G(X)$ is defined as:

$$\mu_G(X) = 1 - \frac{1}{1 + \alpha_G \cdot e^{-\beta_G \cdot G}} \tag{6.24}$$

Limiting the number of new development sites (evaluation index H)

Development of housing spreads over multiple development sites causes overhead costs. Therefore the private housing developer prefers to develop the least possible number of sites.

For identifying the number of development sites, patches of newly developed residential cells are defined in a similar way as done for the index A. The difference is that only the newly built residential cells are here considered. H is the number of patches of newly developed cells.

The evaluation function of index H for the RD agent is defines as:

$$\mu_H(X) = 1 - \frac{1}{1 + \alpha_H \cdot e^{-\beta_H \cdot H}} \tag{6.25}$$

6.3 Satisfaction from the spatial structure

The satisfaction function of both agents is determined by the weighted average of all eight evaluation indices. In this way the outcome of both functions can be located in the same 8-dimensional space. In case of the planning authority agent, most weight is given to the first four indices, while the private developer agent gives more weight to the latter four indices. Thus the evaluation functions of the spatial configuration (X) are given as follows:

$$\begin{aligned} \mu_{PA}(X) = {} & \rho_A\mu_A(X) + \rho_B\mu_B(X) + \rho_C\mu_C(X) + \rho_D\mu_D(X) \\ & + \rho_E\mu_E(X) + \rho_F\mu_F(X) + \rho_G\mu_G(X) + \rho_H\mu_H(X) \end{aligned} \tag{6.26}$$

$$\begin{aligned}\mu_{RD}(X) = \sigma_A\mu_A(X) + \sigma_B\mu_B(X) + \sigma_C\mu_C(X) + \sigma_D\mu_D(X) \\ + \sigma_E\mu_E(X) + \sigma_F\mu_F(X) + \sigma_G\mu_G(X) + \sigma_H\mu_H(X)\end{aligned} \tag{6.27}$$

where,

$$\sum_{u=A}^{H} \rho_u = 1, \quad \text{and} \quad \sum_{u=A}^{H} \sigma_u = 1 \tag{6.28}$$

Chapter 7

Agent decision rules

The objective functions, as defined in the previous chapter, allow agents to quantify, order and compare different spatial configurations of residential developments. Hence, they permit agents to search and find the spatial configuration that best fits their personal objectives. However, the objective functions alone do not allow agents to choose between different compromises, that trade-off agent satisfaction for the susceptibility of an agreement.

The core of PARDISIM is the negotiation between agent *PA* and agent *RD*, which simulates the interaction between social agents. The objective of this chapter is to implement the negotiation such that the negotiation outcomes represent the spatial configurations that emerge from the interactions between social agents in the residential development process in France, England and the Netherlands. The negotiation in PARDISIM is modelled using the Orthogonal Strategy negotiation (Somefun, Gerding, Bohte & Poutré, 2004). The assumption behind it is that

1. agents behave according to a limited rationality, and
2. compromises that emerge from the residential development process are close to pareto optimal solutions.

The issue of the implementation focuses on the characteristic of the interactions, more specifically the complexity of the subject of negotiation, the necessity of cooperation between agents despite sometimes conflicting objectives, and differences in the power balance between agents. The importance of the topology in agents' evaluations of spatial configurations causes that the possible solutions for the implementation to be limited. On the other hand, it causes the formalisation and the implementation to be complex. This chapter discusses the choice for as well as the formalisation and the implementation of the Orthogonal Strategy negotiation.

Through the negotiation process the agents need to allocate cells to residential development in the land use layer that best fit both agents' satisfaction functions.

The formalisation and the implementation of the negotiation process in the simulation model depends on four factors: the subject of negotiation, the negotiation mechanism, the availability of information, and negotiation strategies.

Whereby the subject of negotiation and the negotiation mechanism are interdependent and determine also how the agents' satisfaction functions are to be formalised. Similarly, the availability of information and the negotiation strategies are interdependent. They determine the agents' behaviour in the negotiation process and how the negotiation progresses. Section 10.1 defines the first two of these factors, while the latter two are discussed in section 10.2.

7.1 Agent negotiation

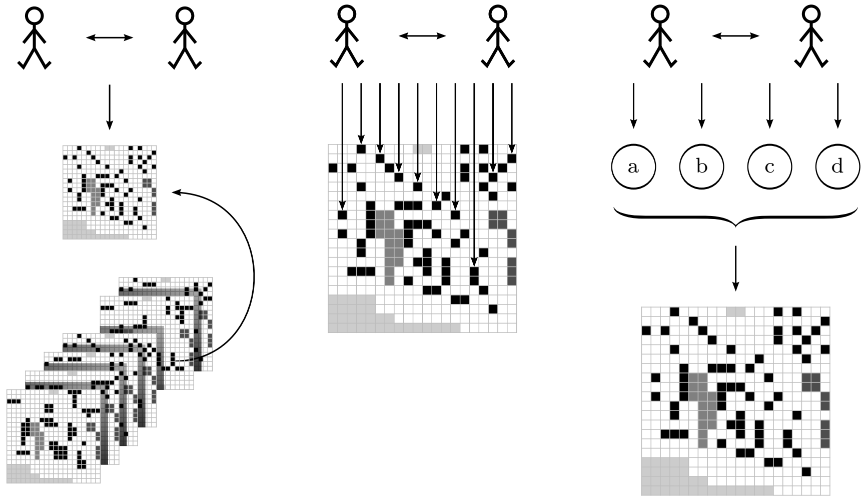
Subject of negotiation

The spatial configuration of the land use, which encompasses both existing and new residential development, determines the agents' satisfaction. In the negotiation both agents aim to optimise the spatial configuration such that it maximises their personal satisfaction. Since the agents have different optimal spatial configurations, they need to find a compromise. The spatial configuration of the compromise and the related satisfaction level is determined by how the subject of negotiation is defined. Figure 7.1 shows three ways to define the subject in a simulation model.

The obvious distinction between the three definitions is between single issue and multi issue. In the single issue approach (figure 7.1a) the entire spatial configuration is considered as a single issue. The solution space consists of all possible spatial configurations of new residential developments. For each solution the agents determine their personal satisfaction. The agents have to agree on a single solution.

Alternatively, the solution space can be defined as the set of possible locations for residential developments (figure: 7.1b). Each location could consist of either a single cell or a cluster of cells and a possible agreement contains multiple locations. Evaluation rules define the optimal location for each individual development. Agents negotiate on each location independently, until they reach a given number of residential developments. However, the independent negotiation on multiple locations for residential developments, does not allow the consideration of topological relationships between the individual locations.

The final way of modelling the subject of negotiation (figure: 7.1c) focuses on the set of characteristics (a,b,c,d) of the spatial configuration of the residential developments, rather than on the spatial configuration itself. The multi-dimensional solution space contains all possible configuration of characteristics. A possible configuration of characteristics is one that corresponds with one or more spatial configurations of residential developments. The agents aim to optimise the configuration of characteristics such that the agent's satisfaction is maximised. This means that an agent aims to maximise the evaluation of the criteria that it deems most important. The outcome of the negotiation is the spatial configuration that matches the characteristics the agents agreed on. This definition of the subject of negotiation assumes that the characteristics are independent. However, the spatial characteristics of the spatial configuration of residential developments are interdependent.



(a) single issue negotiation **(b)** multi issue negotiation: allocation of cells individually **(c)** multi issue negotiation: negotiation on individual characteristics

Figure 7.1 *– Three ways of modelling the negotiation between two agents on the allocation of cells to residential development.*

Negotiation mechanism

Sandholm (1999) has distinguished six different mechanisms of negotiation between multiple agents. Agents can negotiate with each other through voting, auctioning or bargaining. More complex mechanisms are the general equilibrium market mechanism, contract net and coalition formation. The latter three focus on negotiation between many agents. They provide both a mechanism for agents to find each other and when found to come to an agreement. Some authors (Jennings, Sycara & Wooldridge, 1998) have argued that these mechanisms are cooperation mechanisms rather then negotiation mechanisms. This is certainly true if the agents are not self-interested.

The general equilibrium market mechanism is based on a competitive mechanism between agents (Wellman, 1993; Cheng & Wellman, 1998). Agents are either consumers, who buy and sell goods or tasks, and producers, who use private technology to transform goods and tasks into other goods and tasks. Agents exchange goods and tasks through auctions led by a mediator. Each good or task has its own auction. The price of each good or task is adapted until an equilibrium between supply and demand is reached. The process results in an optimal global distribution of goods and tasks among the agents.

The contract net shows strong resemblance with the general equilibrium market mechanism. Profit seeking agents exchange goods, tasks or information. However, rather than through auctions, the exchange is regulated by locally established contracts, i.e. without a mediator (Smith, 1980).

Coalition formation is applied in domains where agents possibly can increase their satisfaction by forming coalitions with other agents (Sandholm, 1999). Tasks are executed at a lower cost, or the gain from the executed tasks is higher. The mechanism consists of three optimisation or negotiation problems: coalition structure generation, optimisation within a coalition and payoff division. The coalition structure generation seeks the optimal division of agents among coalition, such that an individual agent cannot increase its satisfaction by forming a different coalition. Optimisation within a coalition deals with the complex issue of finding the optimal distribution of tasks among the agents in the coalition. Finaly, the payoff division strives to divide the gains made by the coalition among the same agents so that the agents are motivated to stay within the coalition.

Complex negotiation mechanisms start to find their way in the simulation of urban systems' dynamics. Ettema et al. (2007) have described a conceptual multi-agent simulation model of an urban system in which agents represent residents and firms. The model also include agents that represent development actors like developers and planners. The negotiation between the agents is implemented according the general equilibrium market mechanism. Broker agents will bring agents together and set the price. Parker and Filatova (2008) have proposed a framework for the simulation of land use development using a contract net approach. Agents represent households, developers and rural land owners, and buy and sell land or augment the value of the land through development. These complex mechanisms do however not fit the objectives of PARDISIM, as presented above.

Voting, auctioning and bargaining are truly negotiation mechanism. With voting, agents vote on spatial configurations, and the solution with the most votes get accepted. Arentze and Timmermans (2003a) have implemented voting in a simulation model of the development of a shopping centre. In multiple rounds, a developer agent produces alternative propositions for the allocation of cells to a set of retailers. The retailers than can vote in favour or against parts of each proposal. In a model that has been created by Ligtenberg, Bregt and Van Lammeren (2001) and Ligtenberg, Wachowicz et al. (2004), agents need to allocate cells to urban land use. Based on their personal and private preferences the agents vote on the cells they prefer to see allocated to urban land use. Cells that have received the most votes are allocated to urban land use.

In case of an auction, agents bid on cells or locations with the intention to obtain or occupy them. The agent who places the highest bid on a location wins and obtains the cell or location. The outcome of the negotiation process is a spatial configuration in which cells or locations are occupied by different types of agents. The spatial configuration depends on the spatial preferences and objectives of the agents and the budget they have for bidding. A few examples of the use of auction as a negotiation mechanism are Arentze and Timmermans (2003b), in which retailer agents bid on potential shop locations in a development area, and Liu et al. (2006), who have described residential agents bidding on residences that are available to them.

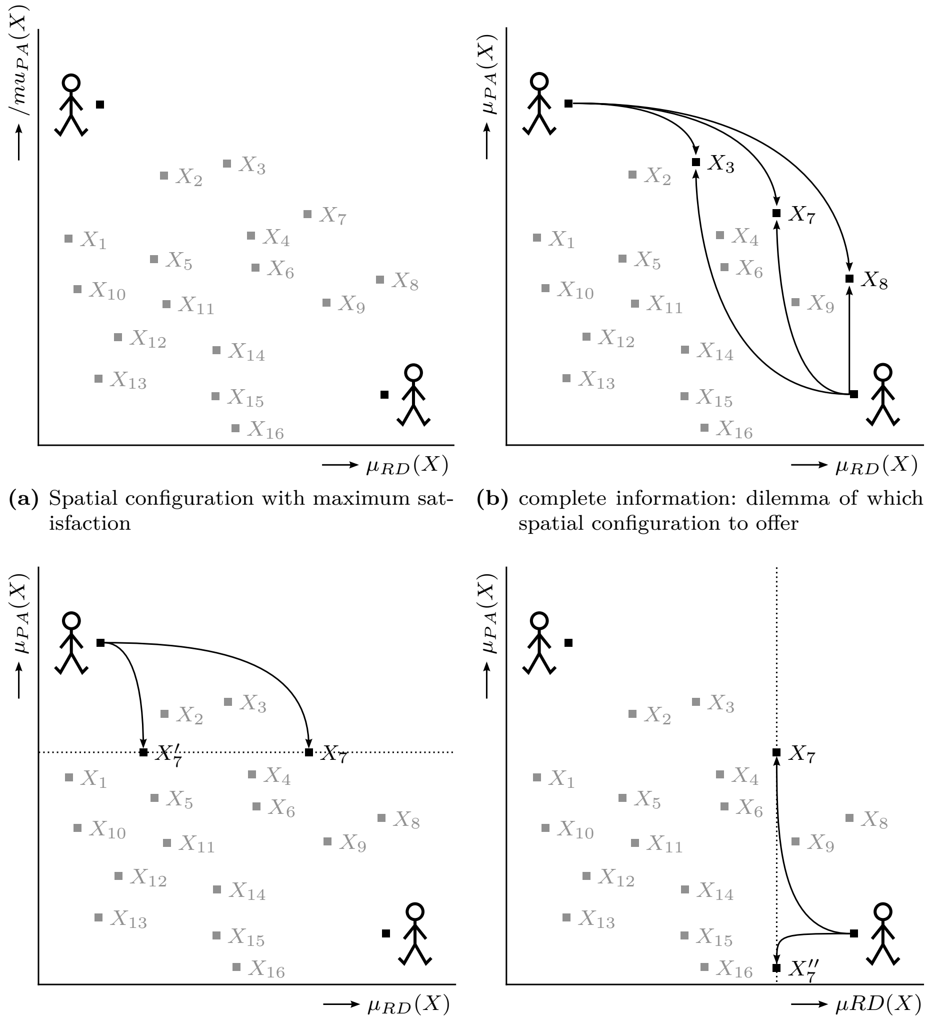
With bargaining, agents interact directly with each other. Agents generate a single proposition, that include all aspects of the subject of negotiation. Game Theory proposes several different bargaining games. The Nash demand game and the Ultimate game are probably the most well known bargaining games (Binmore, Osborne & Rubinstein, 1992). In the Nash demand game two agents simultaneously demand a share of a divisible good. If the demands are compatible, the good is distributed accordingly, if however the demands are incompatible, neither agent receives any satisfaction. In the Ultimate game, one agent proses a distribution of a divisible good. The other agent can either accept or reject. In the latter case both agents again receive nothing. Both games consist of only one round. Alternatively, the alternating-offers game is a game with multiple rounds (Rubinstein, 1982). Each round one agent makes a proposition to the other agent who in return can make a counter proposition in the next round. The game ends if one agent accepts the other agent's proposition. The game is sometimes also refered to as repeated Ultimate game. In the monotonic concession game two agents propose a deal at the same time at each round (Rosenschein & Zlotkin, 1994). At least one agent needs to concede at each round. The game ends when an agents accepts the propositon by the other agent, or if at a round neither agent concedes.

In a few studies, agents negotiate between each other using variations to the alternating-offers game. Ferrand (1996) has proposed a model framework in which agents bargain by offering partial solutions to a spatial problem. This study still lacks elaboration and a practical implementation. However, bargaining is also found in planning support systems. Ligtenberg, Beulens et al. (2009) have illustrated a distributed spatial planning system. Agents bargain through a mediator or facilitator. Agents create propositions for the allocation of cells to a land use type, which is proposed to the facilitator. The latter collects all propositions and creates a new proposition, which is then returned to negotiating agents. In the next round the agents define new propositions based on the last proposition of the facilitator. Saarloos et al. (2005) have defined a similar system. Agents bargain with each other on which cells they claim in a cellular space for their specialist area or land use. Bargaining is structured through an initiator, where agents do not communicate directly with each other. The function of the initiator is the same as the facilitator in the model of Ligtenberg, Beulens et al. (2009). PARDISIM also uses the alternating-offers game to implement the negotiation between agent *PA* and agent *RD*.

Focus on the alternating-offers game

An important element in the alternating-offers game is the strategy of agents. Based on the satisfaction functions introduced in chapter 6, the agents can determine the optimal spatial configuration in a set of viable spatial configurations (see figure 7.2a). However, to reach an agreement agents will need to concede to inferior spatial configurations until the agents meet each other somewhere in the middle. This poses a dilemma to the agents as illustrated in figure 7.2b. Conceding too much results in an agreement that does not provide the maximum possible satisfaction, however, if conceding too little the agent risks not reaching an agreement at all and incurring zero satisfaction. The issue gets even more complicated in case of incomplete information, as shown in figures 7.2c and 7.2d. In case of incomplete information an agent will have trouble determining if a proposition for a spatial configuration of cells allocated to residential development is indeed a concession. It could well be possible that the new proposition is less well received by the opposing agent than the previous proposition.

The implementation of a strategy requires an incentive for agents to concede. A time limit or deadline is an incentive, because if agents do not come to an agreement before the deadline the agents will receive less or zero satisfaction. Other incentives that cause agents to trade-off personal satisfaction for the opportunity to reach an agreement exist. PARDISIM implements a very simple strategy. Agents will do each negotiation round a concession, which is based on the negotiation position of the agents. The next section sets how the Orthogonal Strategy allows to find propositions in a solution space with incomplete information.



(a) Spatial configuration with maximum satisfaction

(b) complete information: dilemma of which spatial configuration to offer

(c) incomplete information: possible locations of X_7 according to agent PA

(d) incomplete information: possible locations of X_7 according to agent RD

Figure 7.2 *– Strategies in bargaining with complete information and bargaining with incomplete information. Which solution makes the best proposition, if its location in the solution space is unknown?*

7.2 Orthogonal Strategy

The Orthogonal Strategy allows agents to determine the best offer in an alternating-offers game. It comprises a concession strategy, which defines how much an agent concedes with a single offer it intends to make, and a Pareto search, which allows the agent to find the offer that is most likely accepted by the opposing agent (Somefun, Gerding, Bohte & Poutré, 2004; Somefun, Gerding & La Poutré, 2006; Wu, Weerdt & Poutré, 2009). These two elements allow agents to choose the spatial configuration from the many possible spatial configurations that results in the most efficient progress of the negotiation. Both elements make the negotiation result in an agreement that yields the most possible satisfaction for both agents.

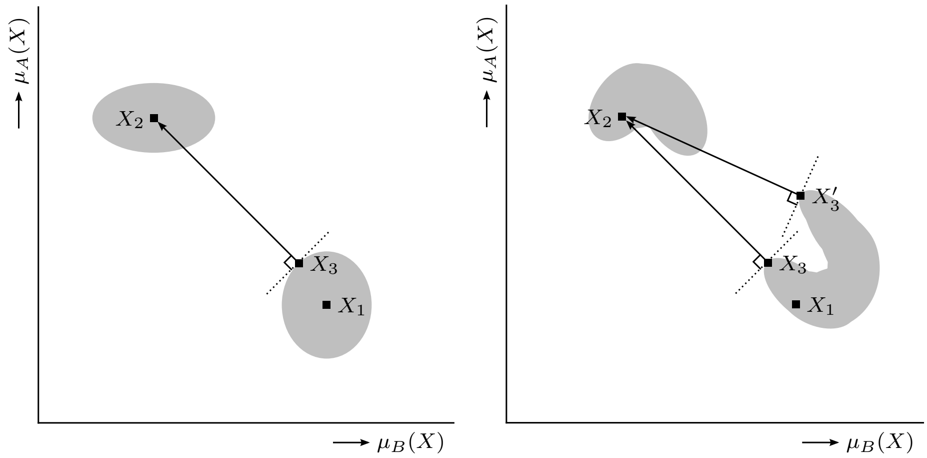
The concession strategy determines how much an agent will concede towards the opposing agent.The negotiation protocol in PARDISIM does not include an incentive that allows the definition of agent strategies. The negotiation protocol is designed such that agents always come to an agreement. The objective of PARDISIM is to evaluate the effect of the negotiation position of agents on the spatial configuration of residential developments, rather than the effect of different negotiation strategies. Hence, in PARDISIM, the size of concession is predefined and fixed, based on the bargaining position of the agents.

The Pareto search allows agents to determine the directions in which they need to concede to come closer to the opposing agent. An agent is willing to concede from a previous offer or, in case of the first offer, the spatial configuration that provides maximum satisfaction. This concession to accept less satisfaction increases the number of spatial configurations an agent will agree to. The Pareto search determines which of these agreeable spatial configurations is likely to provide the most satisfaction to the opposing agent. In light of the cooperation between the agents, the offering agent wants to propose the solution that gives it the same satisfaction, but optimises the satisfaction of the opposing agent.

The Orthogonal Strategy is a negotiation strategy for multi-issue or multivariable satisfaction functions. It finds the Pareto optimal offer in a multidimensional solution space. Based on the concession from an agent's current position in the solution space, the agent can define a set of possible propositions that fall within the concession. In a linear solution space, the possible propositions that an agent is willing to concede to, fall within an area around the proposition that the agent is conceding from (see figure 7.3a). An agent does not necessarily need to know the satisfaction function of the opponent. Moreover, the proposition that is the closest to the opponent's last offer is set as the optimal offer.

Agent *PA* and agent *RD* evaluate the spatial configuration of residential developments in different manners. However, in order to be able to use a multi-issue negotiation protocol, the satisfaction function should be of the same dimension. The satisfaction function therefore contains both the same eigth evaluation functions. If an agent is indifferent to characteristics quantified by one or more evaluation functions, the outcome of these evaluation functions is given a weight of zero. Let us here remind the satisfaction functions for both agents as they have been defined in the equation 6.26 and equation 6.27.

$$\begin{aligned}\mu_{PA}(X) = {} & \rho_A\mu_A(X) + \rho_B\mu_B(X) + \rho_C\mu_C(X) + \rho_D\mu_D(X) \\ & + \rho_E\mu_E(X) + \rho_F\mu_F(X) + \rho_G\mu_G(X) + \rho_H\mu_H(X)\end{aligned} \tag{7.1}$$



(a) Pareto search in a linear solution space

(b) Pareto search in a non-linear solution space

Figure 7.3 *– Pareto search in a two-dimensional solution space. In a linear solution space the possible propositions, that conform the concession strategy, lie all within an area around the last proposition. The most efficient proposition is the one closest to the opponent's last proposition. In a non-linear space these characteristics are not necessarily true.*

$$\begin{aligned}\mu_{RD}(X) = {} & \sigma_A\mu_A(X) + \sigma_B\mu_B(X) + \sigma_C\mu_C(X) + \sigma_D\mu_D(X) \\ & + \sigma_E\mu_E(X) + \sigma_F\mu_F(X) + \sigma_G\mu_G(X) + \sigma_H\mu_H(X)\end{aligned} \tag{7.2}$$

However, one problem remains, as the evaluation functions are interdependent. It is not possible to change the spatial configuration of cells allocated to residential development such that the outcome of only one evaluation function changes. As a consequence, the solution space in PARDISIM is non-linear. The area that contains the spatial configurations that fall witin the agent's concession strategy is not necessarily convex. The spatial configuration that is closest to the opponent's last offer might not be on the straight line between both agents' last offers, and might not be the most efficient next offer (see figure 7.3b). The Pareto search becomes a greedy search that can get stuck at a local optimum. Despite this shortcoming, it is expected that the use of the Orthogonal Strategy here will generate realistic results. Moreover, the behaviour and decision-making of both the local planning authority and the private residential developer are also not always Pareto optimal due to limited rationality.

To formalise the Pareto Strategy, and especially the Pareto search, in PARDISIM, the satisfaction functions are redefined as points in a 8-dimensional space. Let U be a 8-dimensional space where each dimension represents a different evaluation space of possible spatial configurations of the cellular space. Then $u(X)$ is a vector that gives the outcome of the eight evaluations of a spatial configuration X.

$$u(X) = (\mu_A(X), \mu_B(X), \mu_C(X), \mu_D(X), \\ \mu_E(X), \mu_F(X), \mu_G(X), \mu_H(X)) \tag{7.3}$$

Let ρ and σ be the following vectors.

$$\rho = (\rho_A, \rho_B, \rho_C, \rho_D, \rho_E, \rho_F, \rho_G, \rho_H) \tag{7.4}$$

$$\sigma = (\sigma_A, \sigma_B, \sigma_C, \sigma_D, \sigma_E, \sigma_F, \sigma_G, \sigma_H) \tag{7.5}$$

Then the objective functions $\mu_{PA}(X)$ and $\mu_{RD}(X)$ can be written as the inner product of two vectors ($u^{\mathrm{t}}(X)$ is the transposed vector of $u(X)$).

$$\mu_{PA}(X) = \rho \cdot u^{\mathrm{t}}(X) \tag{7.6}$$

$$\mu_{RD}(X) = \sigma \cdot u^{\mathrm{t}}(X) \tag{7.7}$$

Let $M = \{1, \ldots, y\}$ be the set of all negotiation rounds, which defines y as the maximum number of negotiation rounds. And let X_m be the spatial configuration proposed by one agent to the other agent at negotiation round m. Then the spatial configurations X_1 and X_2 that the agents initialy propose to each other at the start of the negotiation are defined by:

$$X_1 = \arg\max_X \mu_{PA}(X) \tag{7.8}$$

$$X_2 = \arg\max_X \mu_{RD}(X) \tag{7.9}$$

Where,

$$\mu_{PA}(X_1) = \rho \cdot u^{\mathrm{t}}(X_1) \tag{7.10}$$

$$\mu_{RD}(X_2) = \sigma \cdot u^{\mathrm{t}}(X_2) \tag{7.11}$$

In the next stage of the negotiation process, after the initial first proposition by each agent, one agent starts with a counter proposition that aims at decreasing the distance between the two propositions in the solution space. Therefore, let ω_m be the distance between the propositions made in negotiation rounds $m-1$ and m. The distance between the last two propositions is expressed as follows.

$$\omega_m = \|u(X_{m-1}) - u(X_m)\| \tag{7.12}$$

The objective is to find the proposition that minimises the distance ω_m, but also conforms the agent's concession strategy. If (ψ_m) is how much of its satisfaction an agent is willing to concede from its current proposition, then the most efficient proposition of an agent at negotiation round m is found by the following equation.

$$X_m = \{\arg\min_X \omega_m \mid \mu(X_m) \geqslant \mu(X_{m-z} - \psi_m\} \tag{7.13}$$

Here, z is the number of agents in the negotiation. In case of a local planning authority agent *PA* and a private residential developer agent *RD*, the most efficient counter propositions are given by:

$$X_m = \{\arg\min_X \omega_m \mid \mu_{PA}(X) \geqslant \max(0, \mu_{PA}(X_{m-2}) - \psi_{PA})\} \tag{7.14}$$

and

$$X_m = \{\arg\min_X \omega_m \mid \mu_{RD}(X) \geqslant \max(0, \mu_{RD}(X_{m-2}) - \psi_{RD})\} \tag{7.15}$$

The concession strategy of the agents is defined based on the negotiation power in the residential development process. ψ_m is therefore fixed at a different value for each agent, which remains constant over the course of the negotiation.

$$\psi_{PA} = \epsilon^{\eta_{PA}} \quad \text{and} \quad \psi_{RD} = \epsilon^{\eta_{RD}} \tag{7.16}$$

The value of $\epsilon \in [0,1]$ defines the concession rate. A higher concession rate causes the agents to do larger concessions and the negotiation ends in less negotiation rounds. The agent who concedes first generates on average a lower satisfaction in case of a higher concession rate. η_{PA} and $\eta_{RD} \in \{\frac{1}{2}, \frac{2}{3}, 1, \frac{3}{2}, 2\}$ define the negotiation positions of the agents, which here is one of the previously mentioned five values over the course of the negotiation.

7.3 Implementation of the negotiation

The decision rules presented in the previous section pose us with two optimisation problems. At the start of each negotiation, both agents define the spatial configuration of cells allocated to residential development that maximises their personal objective function. Next, during the negotiation each proposition is the result of a conditional optimisation. In the latter, the agents aim to find the point in the solution space closest to the opponent at which the size of the concession is restricted to a maximum.

Both optimisation problems require the allocation of cells in a two-dimensional raster. Due to the small cell size selected for the cellular space, the number of cells available to be allocated to residential development is large. This results in an astronomical number of possible different spatial configurations. Additionally, the solution space is non-linear, because the eight different indices are interrelated. Changing the spatial configuration to improve the evaluation of a specific index may result in other evaluations of indices decreasing in value. Moreover, the optimisation problem at hand is *np*-complete. The only way of finding the solution is through evaluating all possibilities. Solving both optimisation problems requires a randomised heuristic search algorithm.

Several search algorithms exist that allow to find the optimal solution or near optimal solution in a *np*-complete problem, without evaluating all possible solutions. For PARDISIM we looked at two possible algorithms: *Simulated Annealing algorithm* and *genetic algorithm*. As discussed next, finding a solution quick enough requires an additional heuristic. This appeared to be difficult in a genetic algorithm. Furthermore, the initial situation plays an important role in a genetic algorithm. In PARDISIM, the cells allocated to residential development change very little during the optimisation process, which complicates the selection of the initial situation. Contrarily, in the simulation annealing algorithm the initial situation is chosen randomly.

Simulated Annealing is an algorithm that helps to find a global optimum. The algorithm starts with a random spatial configuration of the allocation of cells to residential development and calculates the evaluation value of that spatial configuration. The outcome is set as the optimal solution. Next another spatial configuration is defined by changing a random number of cells in the original solution and calculating the evaluation value of the new spatial configuration. If the new spatial configuration has a higher evaluation value, it replaces the optimal solution. If however, the evaluation of the new spatial configuration is worse, it replaces the optimal solution with probability $Prob$.

The algorithm takes a greedy approach by always accepting a new spatial configuration as the optimal solution if it is better than the current optimal solution. By randomly accepting a new spatial configuration if it is worse than the current optimal solution prevents the algorithm from getting stuck at a local optimum. To ensure that the algorithm reaches a stable solution, the probability $Prob$ needs to be reduced over the course of the optimisation process. Many strategies exist for the definitions of $Prob$. Here, we use a function that has been proposed by Aerts and Heuvelink (2002):

$$Prob = e^{\frac{\mu(X_{opt})-\mu(X_{new})}{s_{stage}}} \tag{7.17}$$

Where $\mu(X_{opt})$ is the evaluation of the current optimal spatial configuration of cells allocated to residential development, $\mu(X_{new})$ is the randomly changed derivative of the optimal spatial configuration. The algorithm runs over multiple stages and within each stage many iterations. At each stage the value of s_{stage} is lowered by:

$$s_{stage+1} = r \cdot s_{stage} \tag{7.18}$$

At the start s_0 is chosen such that 80% of the inferiour solutions are still accepted as the new optimum, and r is somewhere between 0.80 and 0.98. The Simulated Annealing algorithm does not necessarily find the optimal solution; it, however, does approach the optimal solution. The algorithm stops after a predefined number of stages, after which little increase of $\mu(X)$ is expected.

Although Simulated Annealing is a means to find a solution more quickly, the calculations necessary to reach an optimal solution are vast for large datasets. Santé-Riveira, Boullón-Magán, Crecente-Maseda and Miranda-Barrós (2008) have applied the algorithm to a dataset with 180,000 cells, and the calculations needed about 5 hours. This is to much considering that during one simulation round, the initialisation requires the calculation of two optimal solutions, one for each agent, and each proposition in the negotiation process also requires the optimisation of the spatial configuration. As a result, even with the use of a heuristic algorithm, simulations will run for too long. Hence, the size of the optimisation problem, or more specifically the number of interations, needs to be reduced.

The number of iterations can be reduced by limiting the number of alternative spatial configurations. One option is to reduce the number of possible spatial configurations by the introduction of a (dynamic) development zone in which allocation of cells to residential development is allowed. The development zone resembles spatial development plans of local planning authorities, which identify locations available for residential development. In the case studies presented in chapter 8 large areas are defined as not available for residential development. Another option is an increase of the cell size, which drastically reduces the number of possible spatial configurations of cells allocated to residential development. The cell size in PARDISIM (20×20m.) is already a compromise between cartographic detail and computational complexity.

Alternatively, Duh and Brown (2005) have proposed the introduction of a second heuristic. In PARDISIM, both agents have a preference for clustered residential developments. This information could be incorperated in the algorithm. At the initialisation, a fixed number of cells ($devSize$) of the cells available to residential development (X_{con}) are allocated to residential development. At each iteration a random number of cells allocated to residential are re-allocated to available for residential development and other cells are allocated to residential development. The probability of cells to be allocated to residential development depends on whether or not they are located within the neighbourhood of a cell already allocated to residential development. In PARDISIM, the neighbourhood size ($bufsize$) is 4, creating a 80-cell neighbourhood with increased probability of being allocated to residential development.

PARDISIM has been programmed in JAVA (with the use of GeoTools, Java Advanged Imaging, Xstream and Java Topology Suite). Algorithm 1 gives the entire optimisation algorithm in pseudo code. Where $P = \{p_1, \ldots, p_n\}$ indicates for each cell the probability coefficient with which it is allocated to new residential development. And, $coef$ is the coefficient with which $p[i]$ is augmented, to indicate that the probability of $x[i]$ to be part of the optimal solution gets higher. Also, $reLoc$ is the probability a cell in X_{opt} is relocated to create the new set of residential developments X_{new}. Finally, n is the total number of cells in the cellular space of the case study.

Algorithm 1 Knowledge informed Simulated Annealing

$X_{\text{opt}} \leftarrow X_{\text{con}}$.randomSelectMultipleCells($devSize$)
for $stage \in Stages$ **do**
  for $iteration \in Iterations$ **do**
    $B \leftarrow X_{\text{opt}}$.bufferCells($bufSize$)
    for $i \in [1, n]$ **do**
      if $x[i] \in B \cap X_{\text{con}}$ **then**
        $p[i] \leftarrow coef$
      else
        if $x[i] \in X_{\text{con}}$ **then**
          $p[i] \leftarrow 1$
        end if
      else
        $p[i] \leftarrow 0$
      end if
    end for
    $X_{\text{new}} \leftarrow \varnothing$
    for $x \in X_{\text{opt}}$ **do**
      if random$[0, 1] < reLoc$ **then**
        $x_{\text{temp}} \leftarrow X_{\text{con}}$.randomSelectCellWithProbability(P)
        X_{con}.removeCell(X_{temp})
        X_{con}.add(x)
        X_{new}.add(x_{temp})
      else
        X_{new}.add(x)
      end if
    end for
    if $\mu(X_{\text{new}}) \geqslant \mu(X_{\text{opt}})$ **then**
      $X_{\text{opt}} \leftarrow X_{\text{new}}$
    else
      if random$[0, 1] < s_{stage}$ **then**
        $X_{\text{opt}} \leftarrow X_{\text{new}}$
      end if
    end if
  end for
end for

Part III

Application of PARDISIM: Three case studies in the French, English and Dutch context

Chapter 8

Definition of the case studies

The heart of PARDISIM is the negotiation between agent *PA* and agent *RD*. Both agents have a multi-issue satisfaction function and negotiate towards a Pareto optimal solution, using the Orthogonal Strategy. The simulation consists of several simulation rounds, each of which involves multiple negotiation rounds. The latter involves many iterations. At each iteration the model calculates, the satisfaction of the agent regarding the solution proposed by himself and the other agent and the distance between the two solutions. The outcome of the calculation and more generally the functioning of the model depends on a large number of parameters, which are supposed to have an effect on the outcome of the simulation.

Both substantive and technical criteria play a role in the selection of the case studies. This chapter will address both issues. First the discussion focusses on the selection of three localities as case studies: Lingolsheim-Ostwald, Chorley and Malden-Groesbeek. We will argue that these case studies meet both the technical and substantive criteria. Next we give a description of the preparation of the data. The chapter ends with a discussion of the parameters of the model. Special attention is given to the selection of evaluation functions and how the changes in parameters affect the form of the evaluation functions and hence the outcome of the simulations.

8.1 Selection of the case studies

In line with the comparison between the planning systems in France, England and the Netherlands (see chapter 4) PARDISIM is tested on a case study from each of these three countries (see figure 8.1). The residential development has to be representative for the residential development that results from the interplay between development actors in French, English or Dutch planning systems. Furthermore, to exclude the influence of services outside the study area on the location of residential developments, isolated urban areas are prefered. Selected urban areas must also have had sufficient residential development and similar size of residential development.

Due to the complexity of PARDISIM, there are also some technical restrictions. The indices describing the agents' analysis of the spatial configuration of the land use layer, and some of the evaluation of indices, are calculated at the level of individual cells. Increasing the size of the study area will dramatically increase the number of calculations needed in the simulation. This applies both to an increase in the number of cells to be allocated to residential development, as well as to an increase in the number of cells that can be allocated to residential development. The number of iterations will increase, as well as the number of calculations per iteration. Depending on the parameters, an individual simulation of one of the case studies can easily take several hours or even a lot more. Consequently, the size of the urban region that can be simulated is limited.

Another restriction has been also the availability of data. Especially historical data is very often not digitised and only available in paper form or not available at all. The latter has caused some issues. The case studies have been selected based on a visual comparison of maps and an estimation of the size of residential development. Besides the mentioned criteria, the case studies have also been selected because of the familiarity with the urban region of one of the people directly involved with the research project. Therefore, despite the aim to find case studies that are similar, some morphological differences and differences in size exist.

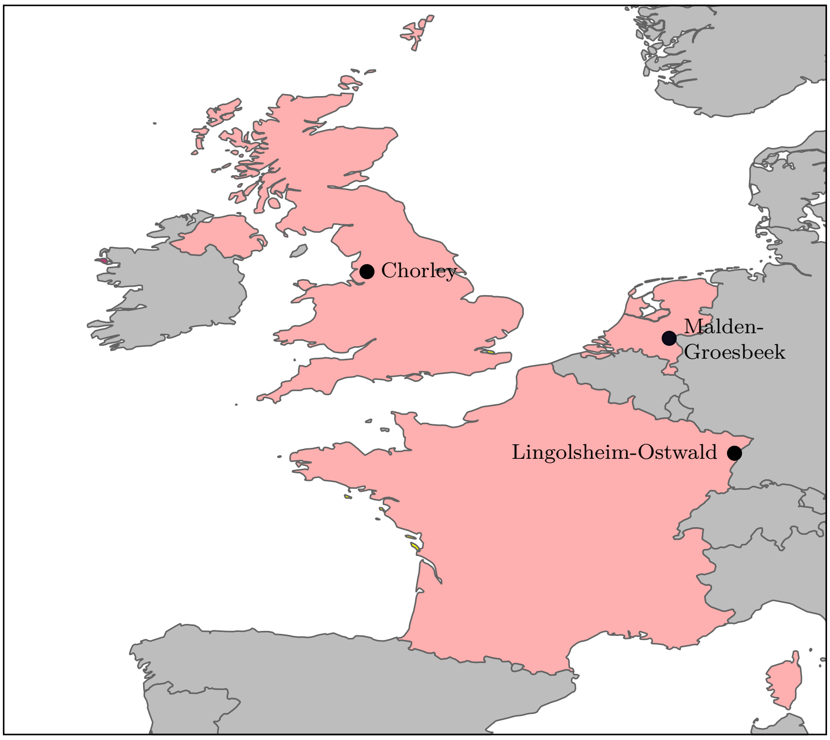


Figure 8.1 – *The location of the case studies Lingolsheim-Ostwald, Chorley and Malden-Groesbeek in France, Great-Britain and the Netherlands, respectively.*

Lingolsheim (about 17 000 inhabitants) and Ostwald (about 11 000 inhabitants) form the French case study (INSEE, 2009). Both towns are close to Strasbourg (about 272 000 inhabitants). A small part of the area in the case study falls directly under the local authority of Strasbourg. The studied area belongs to the *Communauté urbaine de Strasbourg*. A *Communauté urbaine* is a formal cooperation between local authorities in major urban regions in France. It is the most integrated form of intercommunual collaboration between local authorities. A *Communauté urbaine* is usually defined by the state and local authorities are not free to leave it.

Since the 1980s the residential development policy in the study area has had a focus on increasing density. An increase in the building density is achieved by reducing the size of parcels for the development of individual houses. Actually many semi-detached houses were built. At the same time, there has also been a preference for the development of small multi-family buildings. In the 1980s these have been apartment buildings with four to six floors. Later on smaller buildings (three to four floors) have become more popular. The density of the built pattern of Lingolsheim-Ostwald makes it comparable with the English and Dutch case studies.

The English case study consists of Chorley (about 33 000 inhabitants) and Euxton (about 7700 inhabitants) (Office for National Statistics, 2004). Chorley is in a strongly urbanised part of England. Both towns are part of the Borough of Chorley located in Lancashire. Just north of Chorley is Leyland (about 37 000 inhabitants) and Preston (about 185 000 inhabitants). These three cities are the heart of Central Lancashire (also referred to as 'Greater Preston' or 'Preston Urban Area'), a cooperation between the Preston City Council, the South Ribble Borough Council (the local authority in which Leyland is) and the Chorley Borough council. These three local authorities are also part of the Central Lancashire City Region, which covers most of Lancashire and also includes Blackpool, Blackburn and Burnley. Finally, Chorley is at 40 km from Manchester and 50 km from Liverpool.

Development pressure on Chorley (and on Leyland and Preston) has been large. The last few decades Chorley has grown extensively. The Central Lancashire New Town played an important role in the residential development in Chorley. This Development Corporation, which is a cooperation between Preston, Leyland and Chorley, designed expansion plans for the urban region. The Development Corporation ceased to exist, however the cooperation between the Preston City Council, the South Ribble Borough Council and the Chorley Borough Council still exists. The collaboration between the three local authorities has emerged from the belief that the three council areas function as a single integrated local economy (Central Lancashire, 2012).

Chorley is both economically and administratively integrated with Leyland and Preston, within the Central Lancashire City Region (Central Lancashire or Greater Preston). However, morphologically, Chorley remains isolated, i.e. Chorley is not part of a larger continuous built-up area. Especially the latter makes Chorley a suitable case study for the purpose of simulating residential development with PARDISIM.

The Dutch case study is situated in the east of the Netherlands and consists of the towns Malden (about 12 000 inhabitants), Molenhoek (about 3700 inhabitants), Heumen (about 1600 inhabitants), Mook (about 3000 inhabitants), Bredeweg (about 2600 inhabitants) and Groesbeek (about 12 000 inhabitants) (Gemeente Heumen, 2012; Gemeente Mook en Middelaar, 2012; Cillessen, 2012). Just north of the study area is Nijmegen, which is a major city with about 165 000 inhabitants. The study area is part of the functional area of Nijmegen. Especially Malden is a town which houses many commuters who work in Nijmegen, and is considered a sleeper town.

About 30km north of Nijmegen is Arnhem, a city of a similar size. These two cities, together with their surrounding area (including the study area) form an urban region (*Knooppunt Arnhem Nijmegen*). The urban region is strictly speaking a cooperation between the local authorities in the region. It does not have an elected government, rather all local authorities in the urban region are represented in the board.

Dukenburg, a neighbourhood at the west of Nijmegen, was a first large development site. Later, under influence of the *Tweede Nota Ruimtelijke Ordening* (Ministerie van VRO, 1966) development has moved to growth centres, of which Malden was one. The town has doubled in size during the period studies. Other growth centres where Wijchen and Beuningen, who attracted most developments. In this period, the development of Nijmegen was oriented in south-western direction. Later, with the introduction of the *Vierde Nota Ruimtelijke Ordening Extra* (Ministerie van VROM, 1991) development has also moved in Northern direction. Currently, the focus is on strengthening individual towns in the urban network (College van Bestuur Stadsregio Arnhem Nijmegen & Gedeputeerde Staten van Gelderland, 2006), including most notably Malden and Groesbeek. The focus is not on strengthening the functional hierarchy between towns and cities.

Malden, Molenhoek and Mook are situated at a historic transport axis. As a result of the growth of these individual towns, an almost continuous urban zone has emerged along the transport axis. Groesbeek on the other hand is somewhat isolated. Development in western direction is blocked by the presence of a forest area between Groesbeek and Malden. East of the study area is the border between the Netherlands and Germany. Only recently the border became more permeable, with mostly Dutch moving to towns east of the border.

The three study areas are located in urbanised areas, and a lot of the development pressure has been caused by nearby cities. Moreover, the study areas are economically and politically integrated in a wider urban context. Residential development policies concerning the size of residential developments are made at the local or even regional level. Chorley and Malden-Groesbeek are morphologically separated, i.e. they are not part of a continuous built area, whereas the Lingolsheim-Ostwald study-area is attached to the built area of Strasbourg. However, in this latter case, the allocation of areas to residential development still is determined by local factors.

The objective of the three case studies is to test PARDISIM and to see if a difference in power balance between development actors could be responsible for differences in the shape of urban development. Although a single case study is not fully representative for the residential development process in a country, it allows to test the hypothesis that geographical differences in the spatial configuration of urban development can be explained by differences in the power balance between development actors, which might be the consequence of differences in the regional or national context.

8.2 Datasets

Each case study requires the creation of a cellular land use layer and a service layer. The objective is to simulate residential development in the three case studies over a period of 30 years. We have chosen to simulate historic residential development, i.e. residential development of the last 30 years, in the case studies. This allows us to avoid predicting the evolution of objectives of development actors, and it enables the comparison of the simulation results with real residential developments.

With the choice of simulating historic residential development an important issue emerges. PARDISIM simulates only residential development; other urban developments, like industrial development and the creation of public and commercial services are not simulated by the model. Hence, urban land uses other than residences either remain in the historic situation during the simulation, or are set to the current situation. Here we have chosen for the latter solution. Except for the residences, the land use layer represents the current situation. Also, the service layer represents the services in the current situation. The evolution of urban land use is assumed to be anticipated by residential development actors.

The initial situation of the land use layer is created in four steps. The first step entails the creation of a vector dataset of all buildings in the case study area. The second step subtracts from the vector dataset, the residential development that has taken place during the studies period. Next, the dataset is rasterised. The last step identifies areas that are unavailable for residential development. This includes main roads, industrial areas and existing urban areas. Also this information is rasterised. Finally the two rasters are combined to form the initial situation of the land use layer.

The vector data of all buildings has been derived from topographic maps. For all three case studies digital topographic maps are available. For Lingolsheim-Ostwald BD Topo of the *Institut national de l'information géographique et forestière* (IGN) provides the information. BD Topo contains the vector representation of the land use as well as thematic information concerning the type of use of buildings and the height of buildings. The topographic information represented in the spatial dataset dates from 2008.

For Chorley land use data has been derived from OS Street View (available from www.ordnancesurvey.co.uk), which is a raster map. The map was last updated in 2011. The buildings have been selected from the raster map in GIMP and successively, traced and converted into a vector map of the buildings using QGIS. This provided a vector map with the location and ground areas of buildings. To obtain thematic information, most notably the distinction between residential buildings, industrial or commercial buildings, and other buildings (e.g. supermarkets, pubs, churches and public buildings) aerial photos have been used, which are available online. From these photos also the height of buildings is estimated, moreover a distinction has been made between single family homes (e.g. individual houses and terraced houses) and multi-family buildings (e.g. apartment buildings). However, no multi-family buildings have been found in the Chorley study area.

The spatial data for Malden-Groesbeek has been retrieved from Open-streetmaps (www.openstreetmap.org). This spatial data source provides the locations and ground areas of buildings. The accuracy of the data has been verified with a paper copy of the topographic map, because Openstreetmaps is a community driven data source, and is continuously updated. The spatial information in the topographic map is from 2006. Only minor changes have been made. On the other hand, Openstreetmaps lack accurate thematic information. Hence, similar to the case of Chorley, the thematic information, the use of buildings and the height of buildings, has been retrieved from aerial photos.

Paper copies of historic topographic maps of the study areas have been used to identify the residential development in the study areas. The used maps date from 1980 in the case of Lingolsheim-Ostwald, 1974 in case of Chorley and 1975 and 1982 in case of Malden-Groesbeek. All residential buildings, that appear in the current situation, but do not appear in the historic map, have been identified as residential development and thus deleted from the dataset. We have chosen not to add buildings present on the historic map, but which do not exist anymore. Often new residential developments replace them. Also, PARDISIM does not allow for the removal of buildings. Table 8.1 presents the number of features representing residential buildings that have been removed, and illustrates the size of residential development in each case study.

		Lingolsheim-Ostwald	Chorley	Malden-Groesbeek
Historic situation	low rise residential buildings	4184	5288	5358
	high rise residential buildings	290	0	6
	non-residential buildings	575	598	1007
Residential developments between historic and current situations	low rise residential development	1723	4646	1526
	high rise residential development	66	0	26
Current situation	non-residential buildings	575	598	1007

Table 8.1 *– The number of features representing buildings in the historical and current situations in each case study.*

The vector map of all buildings has been rasterised using a 20×20m cell size. Because most individual houses are a lot smaller than 400 m^2 and would not appear in the final cellular land use layer, cells are allocated to built land use if at least 25% of its area consist of a built structure. The vector map of all buildings is first converted to a raster with a 1×1m cell size using QGIS. Next, using GRASS GIS, the small cells are aggregated to larger cells with the criteria that, if 25% of the surface is covered by 1×1m cells that represent built area, the entire 20×20m cell is converted to built area.

In the final step the area that is not occupied by built area has been divided into cells that are available to residential development and cells that are not available to residential development. Areas not available for residential developments consist of natural areas and forest, water (e.g. lakes, canals and rivers), zones within 60m from industry or within 40m from major roads and railways, and urban area. The latter refers to small open areas between buildings that appear as unconstructed area in the land use raster as described above. These areas are occupied by local roads, parking space, private gardens and urban parks.

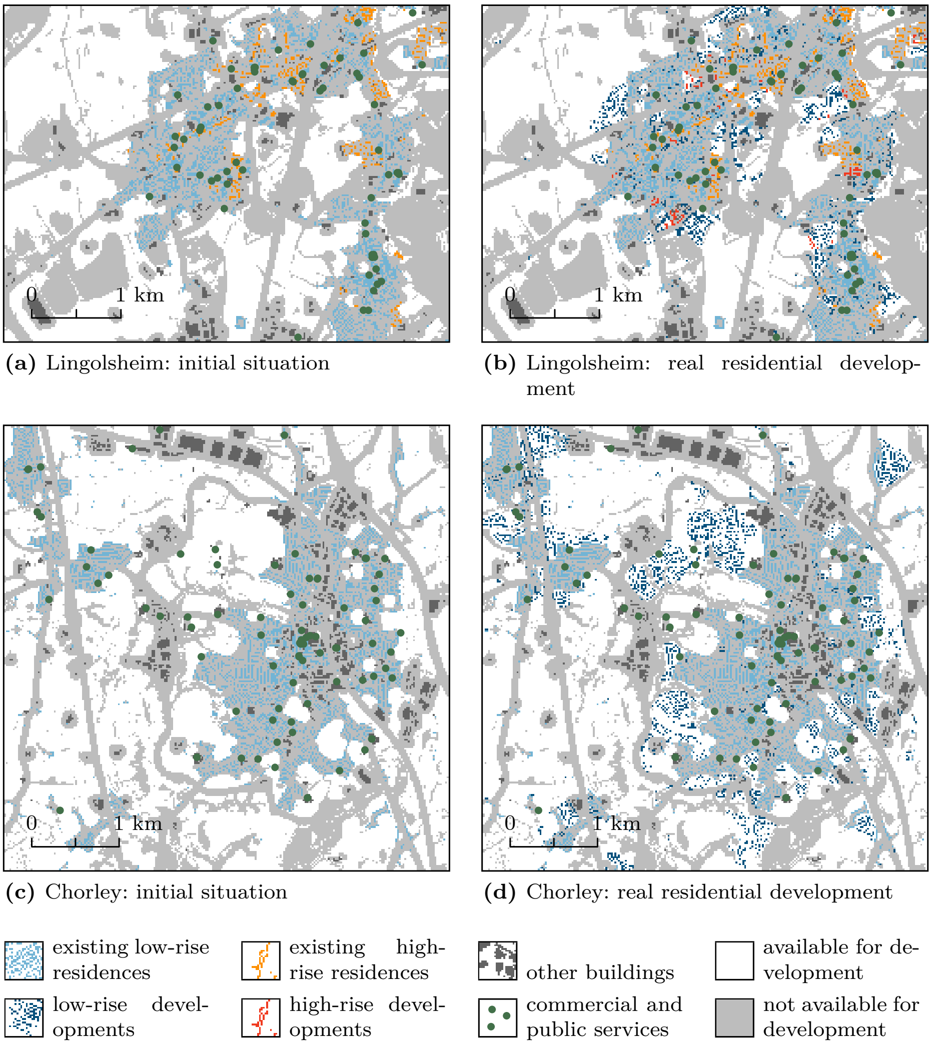
A dilation and erosion technique around buildings defines the urban areas. This technique creates an outwards buffer of 60m around all buildings, dissolving all overlapping buffers into a single polygon. Next the area is reduced by creating an inwards buffer of 60m. The area that remains is considered as urban area that is not available for residential development.

The areas not available for residential development has been rasterised and combined with the raster representation of all buildings. Figure 8.2 gives the initial land use layer for each case study. The figure also presents the real residential development, which will function as a comparison for the simulation results. Hereby should be noted that some of the residential developments are however located in areas that are defined as not available to residential development. Table 8.2 gives the number cells allocated to the different land uses in the land use layer.

	Lingolsheim-Ostwald	Chorley	Malden-Groesbeek
cells available for residential development	17 828	31 406	60 950
cells not available for residential development	23 167	25 213	80 207
low rise cells in the initial situation	2708	3721	3870
high rise cells in the initial situation	570	0	47
non-residential cells	1052	2160	2931
low rise developments since the initial situation	1169	2027	1091
high rise developments since the initial situation	137	0	95

Table 8.2 *– The number of different cells in each case study: land use layers*

The service layer has been created by digitising the daily frequented services as they are available in online databases (www.yell.com, www.pagesjaunes.fr, www.detelefoongids.nl). The websites, that are the front-ends of these databases,



(a) Lingolsheim: initial situation

(b) Lingolsheim: real residential development

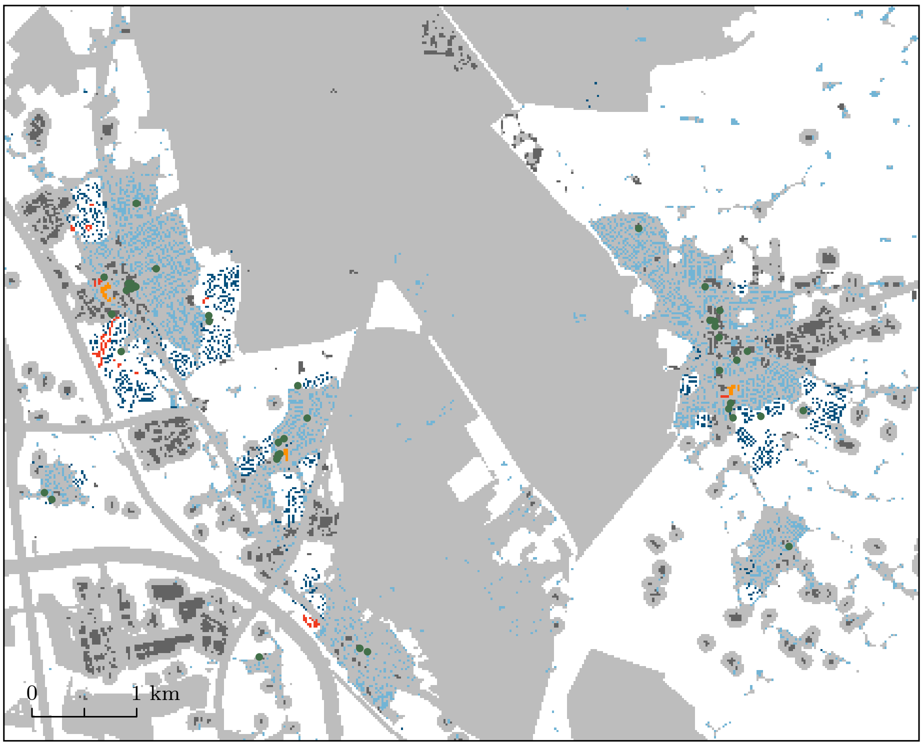
(c) Chorley: initial situation

(d) Chorley: real residential development

Figure 8.2 – *Rasterised land use layer based on the historical situation and the rasterised representation of the current situation, highlighting the residential development that has taken place.*

present locations of services in maps, making it easy to digitise that information for the use in PARDISIM. Using this feature, the locations of supermarkets, bakeries, butchers, schools and news-agents has been retreived. Concerning news-agents, there remains an issue. In France, news-agents exist in the shape of *bureau de tabac*, which combine the activities of news-agents with the sale of tabaco. In the Netherlands, news-agents are a rare concept and are rarely found outside major train stations and airports. Instead, in the case of Malden-Groesbeek, newsagents have been replaced with bookstores, which often also sell newspapers and magazines. Table 8.3 gives an overview of the number of instances per type of service; figure 8.2 shows the location of the commercial and public services in the study areas.

(e) Malden-Groesbeek: initial situation



(f) Malden-Groesbeek: real residential development

	Lingolsheim-Ostwald	Chorley	Malden-Groesbeek
bakeries	16	7	6
butchers	3	5	2
newsagents	9	7	2
schools	23	39	17
supermarkets	10	22	15
total	61	80	42

Table 8.3 *– The number of services per type in the three case studies.*

8.3 Definition of the parameters

PARDISIM requires four different types of parameters to be set in order to define the agents' evaluation of the spatial structure and their satisfaction function. A first parameter is the development objective, which defines the number of cells that need to be allocated to residential development. For each case study this number is the same as the size of the real residential development (see table 8.2). Other parameters define the progression of the negotiation and the Simulated Annealing algorithm. Appendix A gives an overview of all parameters.

The parameters have been defined using intuitive reasoning and brief testing. Especially the parameters of the Simulated Annealing algorithm have been set such that they give a reasonable result. Optimisation of these parameters is deemed to be beyond the scope of this research and will therefore not be further discussed. This section focusses on the definition of the parameters concerning the evaluation functions and the satisfaction functions. It also briefly addresses the parameters that concern the negotiation process.

Parameters for the evaluation functions (see chapter 6 for their definition)

The evaluation funtions used are either logistic functions or gaussian functions. Both functions have two variables α and β that determine the shape of the function. The logistic functions result in a S-shape or reversed S-shape, whereas the gaussian functions result in a bell shape. The evaluation functions are the same for all three case studies, except for the indices C and F which depend on the ratio between high-rise and low-rise residential buildings.

In the logistic function α and β define respectively the horizontal shift and the inclination of the function. Changing α corresponds with moving the demarcation between the index value of the spatial configuration that leads to complete satisfaction, and the index values that lead to complete dissatisdaction of the agent's objectives and index value of spatial configurations that do not meet agent's objectives. Changing β causes the transition zone between meeting the objectives and not meeting the objectives to increase or decrease. Hence β defines how strict the agent is. Decreasing β means that an agent becomes more flexible, and thus more willing to concede the spatial configuration on that specific aspect.

In the gaussian function, α corresponds with the optimum value and β defines the width of the bell shape.

A gaussian function is used for representing the evaluation of indices D and E (density of residential development) by agent PA and agent RD respectively. The determination of α and β in the two gaussian functions is relatively easy. Here α is set to 5.75 in case of agent PA and 6.75 in case of agent RD. The value of β is set to the same value for both agents: $\beta = 0.8493$. This value is such that in case of $d_k = e_k = 6.25$ both agents' evaluation functions return a value of $\mu_{d_k}(X) = \frac{1}{2}$ or $\mu_{e_k}(X) = \frac{1}{2}$. This results in a rather steep inclination of the chosen functions, see figure 8.3.

In case of the logistic functions used for representing the evaluation of the other indices, the definition is slightly more complicated. A logistic function will never return the value 1 but only approaches that value. It is therefore not possible to link α and β to an optimal value. Instead the definition of these two parameters can be guided by the values $\mu_{\text{index}} = \frac{1}{2}$ and $\mu_{\text{index}} = \frac{3}{4}$. The first value lies in the middle between the optimal and the worst solution. The latter serves as a proxy for the optimal value, where it is assumed that a value $\mu_{\text{index}} = \frac{3}{4}$ or higher is considered satisfactory.

Table 8.4 gives an overview of the values that are used to calculate the parameters α and β for all logistic evaluation functions. These values have been chosen empirically assuming that they are reasonable with respect to our a priori knowledge of the preferences of both agents. The inclination of the evaluation function $\mu_H(X)$ is kept low for a technical reason: at the start of the optimisation process the cells allocated to residential development are selected randomly. This results in many patches of residential development scattered over the study area. During the optimisation process the patches of residential development gradually group together if this results into a higher satisfaction. Tests with PARDISIM have revealed that if the inclination of the evaluaiton function is too steep the patches of residential development will not group together. Figure 8.3 and figure 8.4 display the evaluation functions. Note that in the case of Chorley all residential developments consist of low-rise developments and therefore indices C and F are irrelevant.

Parameters for the negotiation

The most important parameters that concern the negotiation are ϵ, η_{PA} and η_{RD}, as discussed in section 7.2. ϵ is defined to control the duration of the negotiation. Its value defines the balance between the duration of the negotiation and the possible advantage of agents during the negotiation. If ϵ is too small, the negotiation will take too long. However, if ϵ is too high, the agents will agree to a solution too quickly, giving the agent who starts the negotiation a disadvantage. A series of tests have been executed, and it appears that the value $\epsilon = 0.025$ gives good results.

Hereby should be noted that the duration of a negotiation also depends on the value of η_{PA} and η_{RD}, which define the bargaining power of each agent. High values for these parameters result in a long negotiation process with possibly more than 20 rounds, whereas low values can reduce the number of negotiation rounds to only a few rounds.

index	$\mu_{\text{index}} = \frac{1}{2}$	$\mu_{\text{index}} = \frac{3}{4}$	α	β
A	0.25	0.1	6.240	7.324
B	0.25	0.01	3.141	4.578
C: Lingolsheim-Ostwald	0.09609	0.1202	79.27	48.51
C: Malden-Groesbeek	0.07639	0.1042	21.52	40.18
F: Lingolsheim-Ostwald	0.09609	0.07195	79.27	48.51
F: Malden-Groesbeek	0.07639	0.04861	21.52	40.18
G	60	40	27	0.05493
H	50	35	38.94	0.07324

Table 8.4 *– The index values of real residential developments used to calibrate the logistic evaluation functions and associated α and β values*

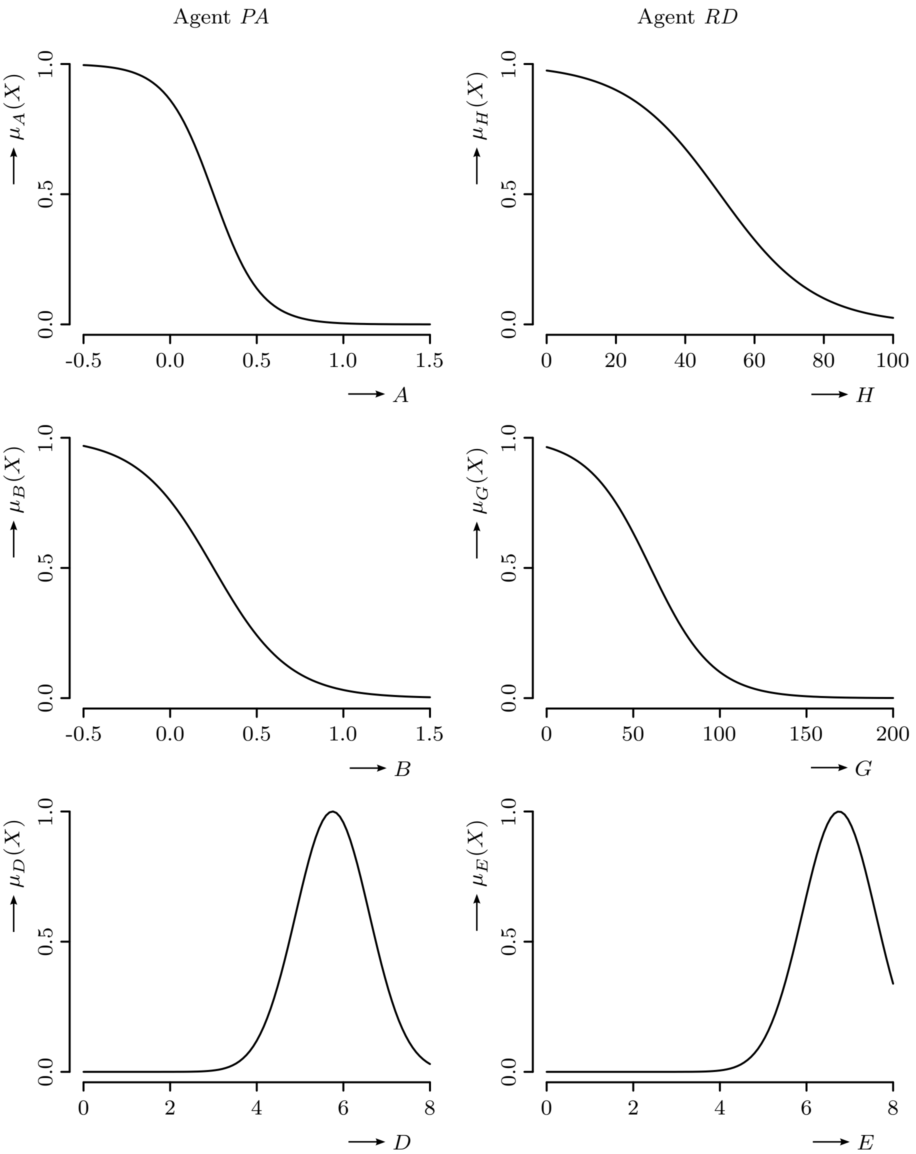
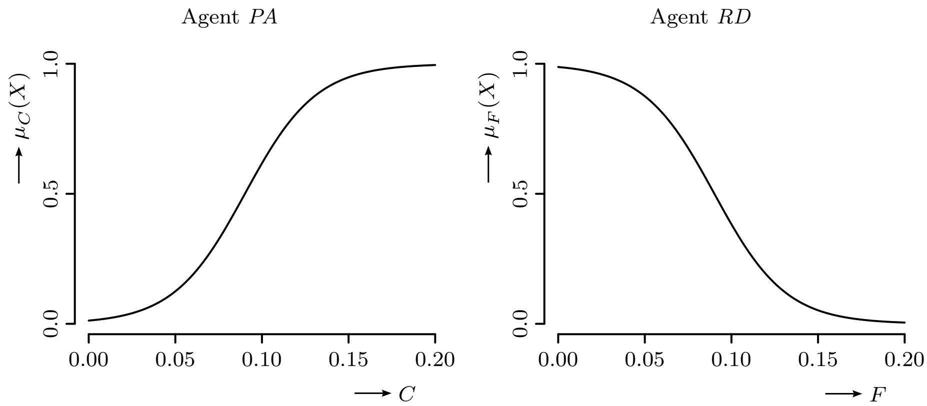
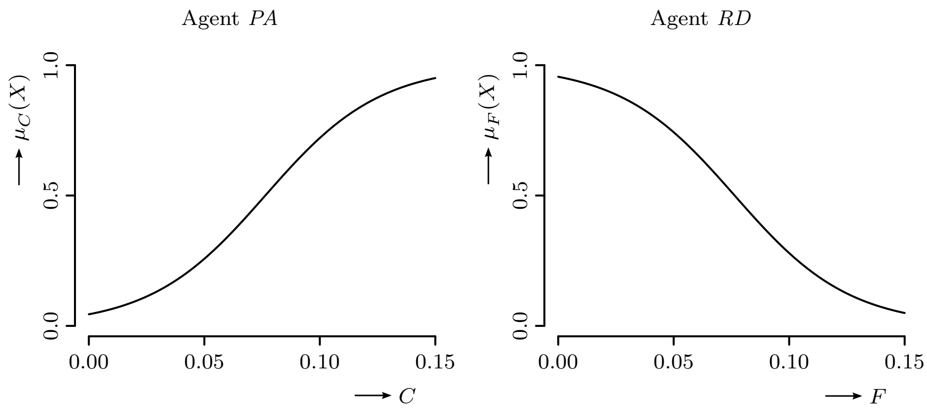


Figure 8.3 *– The agents evaluation functions for the indices A (change in the number of patches of built land) and H (absolute number of patches), B (change in accessibility of public services and open area) and G (absolute distance to open area), and D and E (both a proxy for the density of residential development), which are used in the simulation of all three case studies.*



(a) Lingolsheim-Ostwald



(b) Malden-Groesbeek

Figure 8.4 *– Evaluation functions for the indices C and F, measuring mixity between low-rise and high rise residential development, in the cases of Lingolsheim-Ostwald and Malden-Groesbeek.*

Chapter 9

First simulation results

The negotiation process has a central role in PARDISIM. The two most important elements in the negotiation process are the evaluation of the spatial structure by the individual agents and the proposition of alternative locations of residential developments. With each proposition an agent concedes a fix amount of its satisfaction and moves into the direction of the opposing agent. An agent accepts a proposition if it provides more satisfaction than a new counter proposition.

The objective of PARDISIM is to investigate how a difference in the power balance between the local planning authority and the private residential developer results into a different spatial configuration of residential developments. A development actor with a better negotiation position will see more of his spatial objectives implemented in the final spatial configuration of the residential development. Hence in PARDISIM, an agent's concession depends on its negotiation position. More specifically, an agent with a weak negotiation position will concede in bigger steps than an agent with a strong negotiation position.

This chapter shows the initial testing of PARDISIM, using the parameters discussed in the previous chapter. For each case study three scenarios have been tested, all three with a different negotiation position of agent *PA*. Section 9.1 begins with the evaluation of the optimal spatial configuration for each agent. This optimal configuration serves as the start of the negotiation process. The remainder of the chapter discusses the negotiation process and the simulation results.

9.1 Search for the optimal spatial configuration

Chapter 6 defines rules for the analysis and evaluation of the spatial structure. Based on the spatial objectives of local planning authorities and private residential developers, the agents have been given a set of rules for the evaluation of the spatial structure. Each agent evaluates four criteria of the spatial configuration: compactness of the residential development (index A for agent *PA* and H for agent *RD*), accessibility from the residential developments (index B for agent *PA* and G for agent *RD*), mixity of low-rise and high-rise developments (index C for agent *PA* and F for agent *RD*), and density of the residential developments (index D for agent *PA* and E for agent *RD*). In the case of mixity and density, the agents are in direct conflict with each other. On the other two criteria the agents do not necessarily exclude each other, but they evaluate the spatial structure at a different scale. Agent *PA* takes a global approach and evaluates the compactness and accessibility of all residences, whereas agent *RD* only considers the residences to be developed.

In PARDISIM, the negotiation in each simulation round starts with each agent determining its optimal spatial configuration based on the agents' evaluation functions. Here we illustrate the consequences for the spatial structure of the differences in the spatial objectives of the agents. The allocation of cells to residential development is optimised using either the decision rules of agent *PA* or those of agent *RD*. The number of cells allocated to residential development in the optimisation process corresponds with the real residential development that has taken place in the study area (see table 8.2).

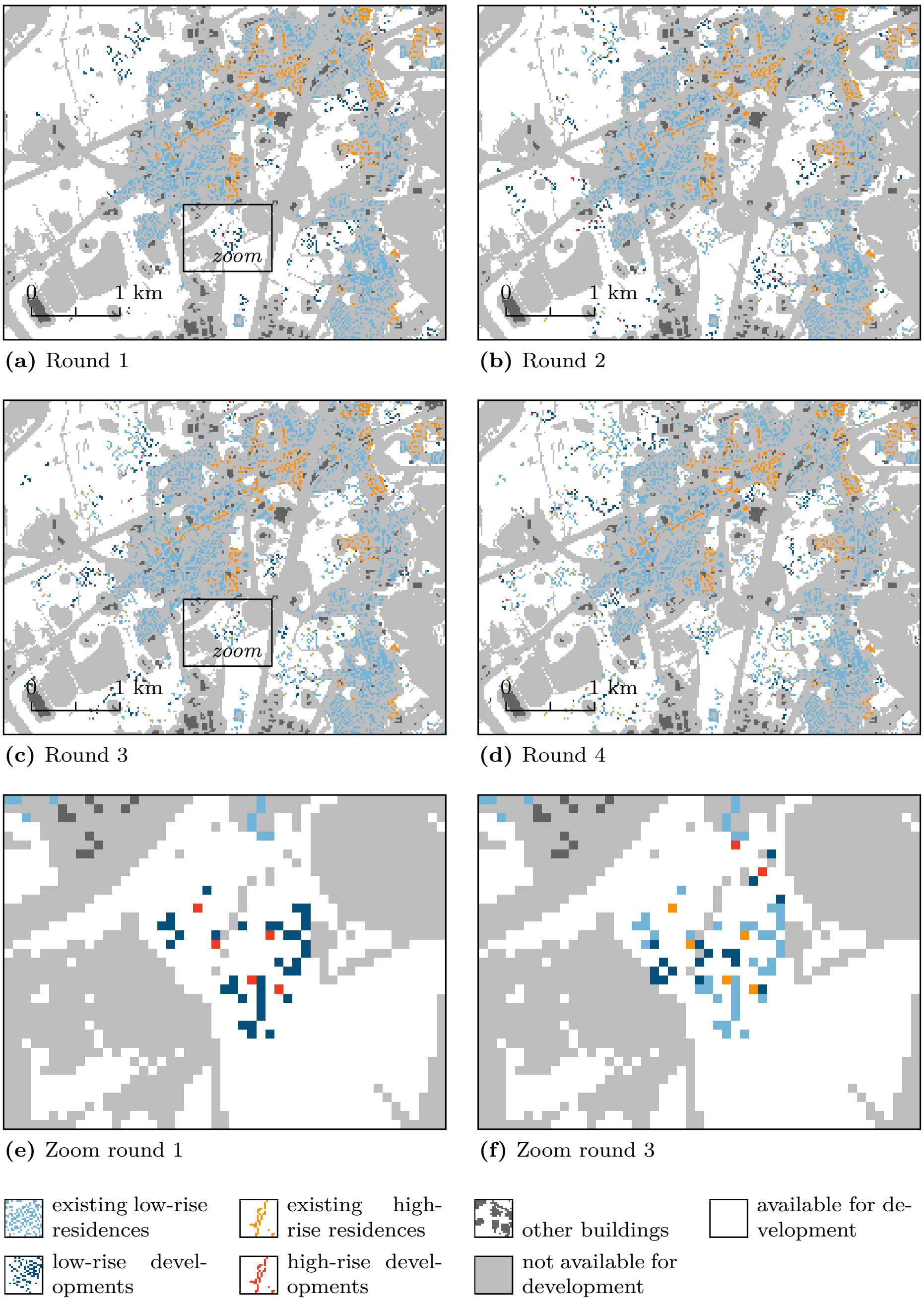
The parameters defined in the previous chapter (see table 8.4) are adapted to the simulation in four rounds, where in each round a quarter of the total residential development is realised. In order to be able to compare the optimal solution with the outcome of the simulation process, the optimisation process has also been excuted in four stages. At each stage the location of a quarter of the total residential development has been optimised according the evaluation rules of either agent *PA* or agent *RD*. The outcome of this stage serves as the initial situation for the optimisation of the next optimisation round. Figure 9.1 shows the outcome of each stage in the optimisation for agent *PA* in the case of Lingolsheim-Ostwald. Notice that the optimisation process and the simulation process within PARDISIM are executed on a multi-processor server using 8 processors. The optimisation process takes only a few minutes on this machine.

The outcome of the optimisation process is presented in figure 9.2. Table 9.1 gives the evaluation of the spatial configuration considering each stage of the optimisation process.

A visual comparison of the optimal spatial configurations for agent *PA* and agent *RD* immediately shows a difference in the spatial distribution of the residential development. In all three case studies, the outcome of the optimisation according the evaluation rules of agent *RD* is more spread out than the optimisation according to the evaluation rules of agent *PA*. In the case of Chorley, and to a lesser extend in Lingolsheim-Ostwald, the residential developments fill up the available space.

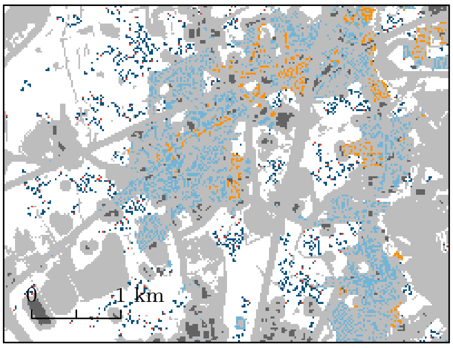
Comparing the outcome with the spatial distribution of the real residential development (see figure 8.2) shows that in all three case studies the real residential development is more compact than the development found in the optimisation process. Although, in the cases of Lingolsheim-Ostwald and Chorley the optimal spatial configuration according the evaluation rules of agent *PA* shows some resemblance with the real residential development. In both cases the optimal solutions places the residential development in approximately the same location.

The evaluation results (see table 9.1) clearly illustrate the effect of conflicting objectives. Obvious is the conflict on mixity (indices C and F), where the optimal mixity of both agents is mutually exclusive. Density (indices D and E) is also a direct conflict between the agents. However, the optimal solution of an

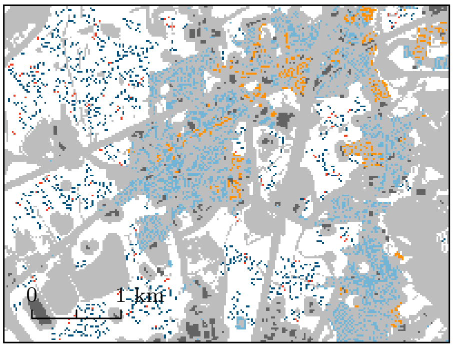


(a) Round 1 **(b)** Round 2 **(c)** Round 3 **(d)** Round 4 **(e)** Zoom round 1 **(f)** Zoom round 3

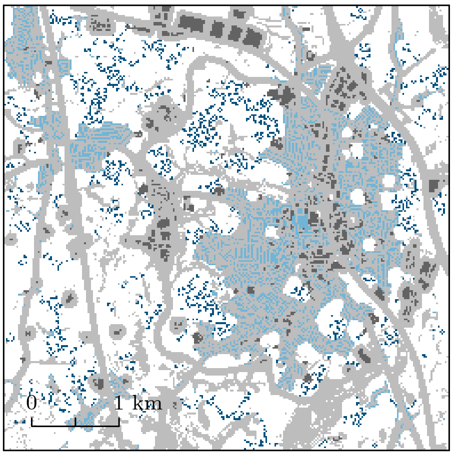
Figure 9.1 *– The optimisation process in four rounds. The outcome of each round serves as the initial situation for the optimisation in the next round, until at the end of the last round the optimal solution for the entire period on interest has been found.*



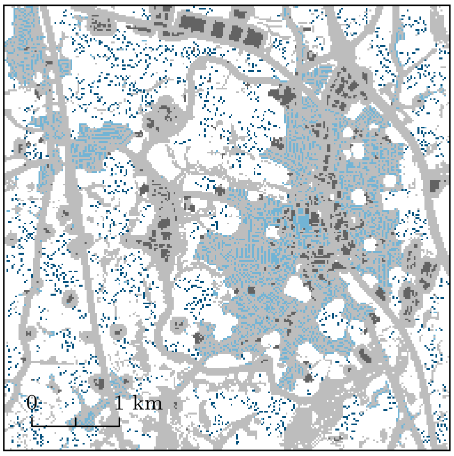
(a) Lingolsheim-Ostwald: optimal spatial configuration agent *PA*



(b) Lingolsheim-Ostwald: optimal spatial configuration agent *RD*



(c) Chorley: optimal spatial configuration agent *PA*



(d) Chorley: optimal spatial configuration agent *RD*

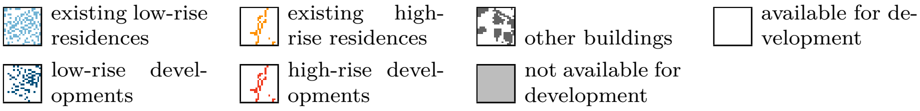
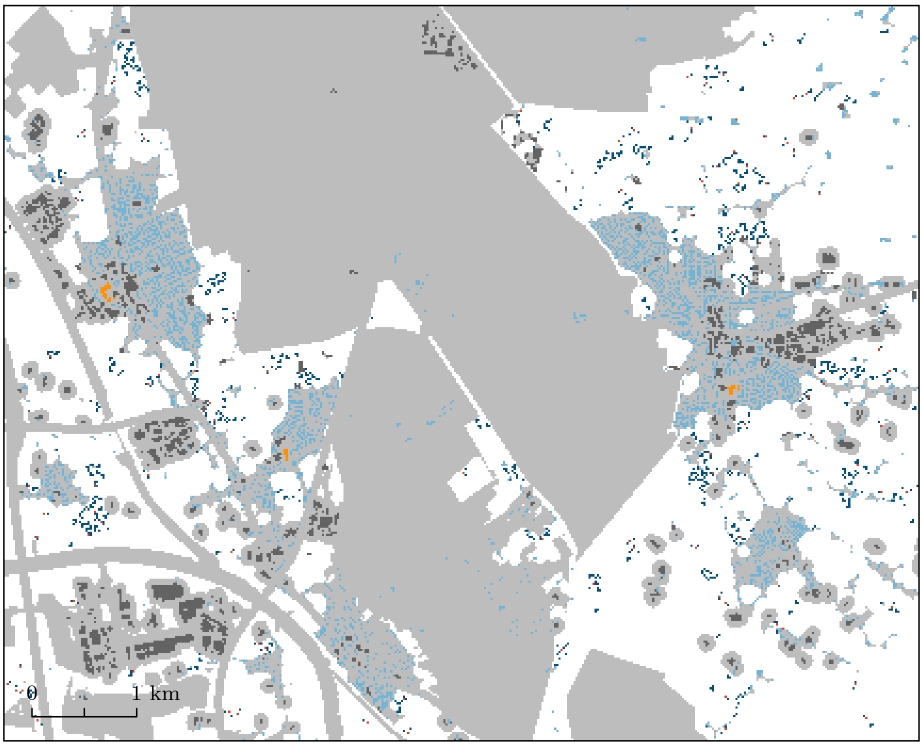
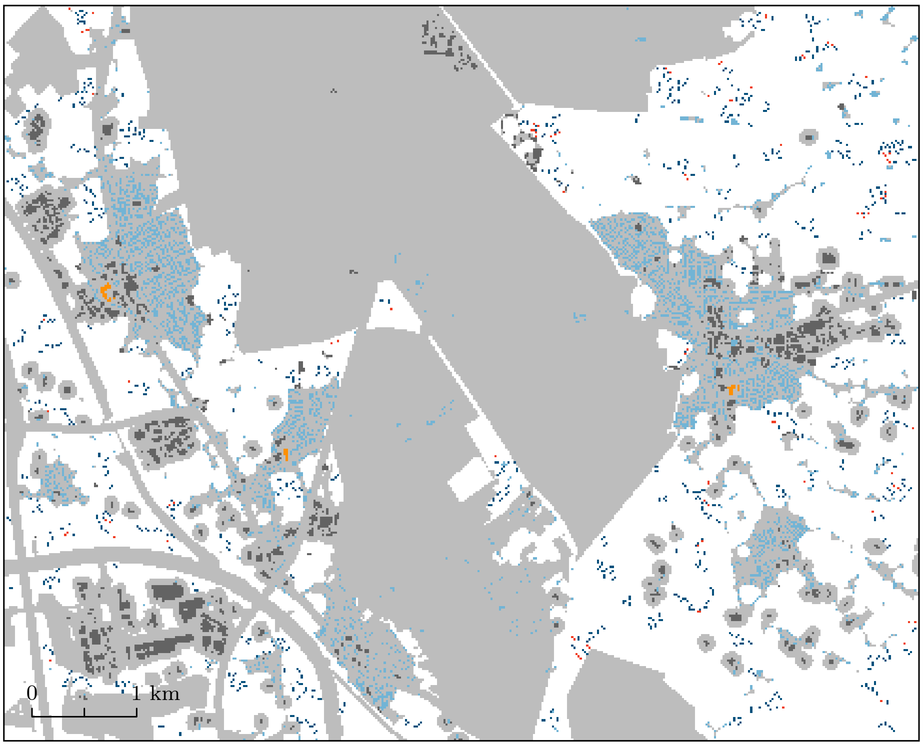


Figure 9.2 *– Optimal spatial configurations for agent PA and agent RD in all three case studies. As in figure 9.1, the simulated spatial configuration of residential development in Malden-Groesbeek exhibits few cells of high-rise development lost in the high number of cells allocated to low-rise development. See the red cells that appear between patches of dark blue cells.*



(e) Malden-Groesbeek: optimal spatial configuration agent *PA*



(f) Malden-Groesbeek: optimal spatial configuration agent *RD*

round	satisfaction	A (patches)	B(accessibilty)	C(mixity)	D(density)	E(density)	F(mixity)	G(accessibity)	H(patches)
Lingolsheim - agent PA									
1	0.7863	0.8263	0.6656	0.9813	0.6719	0.6556	0.01872	0.8522	0.8336
2	0.8091	0.8767	0.6421	0.9860	0.7316	0.6166	0.01397	0.8445	0.7889
3	0.8474	0.9643	0.6703	0.9860	0.7691	0.6123	0.01397	0.8441	0.3576
4	0.8457	0.9524	0.6963	0.9813	0.7528	0.5769	0.01872	0.7985	0.3576
Lingolsheim - agent RD									
1	0.8983	0.4160	0.5267	0.02236	0.3862	0.8804	0.9776	0.8918	0.8435
2	0.8981	0.8350	0.6254	0.01933	0.4136	0.8747	0.9807	0.8841	0.8529
3	0.8882	0.7896	0.6397	0.02236	0.4053	0.8711	0.9776	0.8704	0.8336
4	0.8953	0.9239	0.6720	0.02586	0.4423	0.8529	0.9741	0.8681	0.8860
Chorley - agent PA									
1	0.8023	0.9277	0.7159	-	0.7635	0.6088	-	0.8186	0.6254
2	0.8002	0.9467	0.6859	-	0.7680	0.6132	-	0.8409	0.2934
3	0.8095	0.9517	0.6887	-	0.7882	0.6187	-	0.8177	0.4634
4	0.8236	0.9536	0.7204	-	0.7970	0.6272	-	0.8385	0.1565

Chorley - agent RD									
1	0.7770	0.7416	0.6160	-	0.3786	0.8544	-	0.8857	0.5905
2	0.7400	0.8069	0.6679	-	0.3922	0.8507	-	0.8873	0.4817
3	0.6724	0.8780	0.6926	-	0.3805	0.8081	-	0.8676	0.3409
4	0.6553	0.9401	0.7117	-	0.3883	0.8196	-	0.8675	0.2785
Malden - agent PA									
1	0.8239	0.8694	0.7200	0.9768	0.7292	0.6511	0.02319	0.8674	0.6254
2	0.8283	0.8837	0.7300	0.9768	0.7227	0.6244	0.02319	0.8719	0.5000
3	0.8294	0.8747	0.7306	0.9797	0.7326	0.6323	0.02030	0.8617	0.5183
4	0.8295	0.8774	0.7341	0.9768	0.7298	0.6335	0.02319	0.8666	0.4453
Malden - agent RD									
1	0.8624	0.8399	0.6946	0.04440	0.3816	0.8841	0.9556	0.8885	0.7215
2	0.8621	0.8227	0.7068	0.04440	0.3608	0.8835	0.9556	0.8878	0.7215
3	0.8467	0.8214	0.7210	0.04440	0.3817	0.8789	0.9556	0.8932	0.6591
4	0.8460	0.8232	0.7119	0.05055	0.3707	0.8397	0.9495	0.8881	0.7066

Table 9.1 *– Agents' satisfaction of the optimal solutions; total value and splitt between the evaluation of the eight indices.*

agent still brings some satisfaction to the other agent. On the other hand accessibility (indices B and G) is not a conflict between the agents. However since agent PA evaluates access to public and commercial services part of accessibility whereas agent RD only considers access to open area, the optimal spatial configurations of agent RD may be strongly fragmented and accessibility evaluations of both agents could conflict.

Similarly, indices A and H seem not to be in conflict. However, in the case of Chorley, agent RD's evaluation of the number of patches drops in value with every stage of the optimisation process. The value of $\mu_H(X)$ gets eventually very low at stage 4 of the optimisation process. As a result, agent RD's satisfaction of the optimal spatial configuration is significantly lower than agent RD's satisfaction in the other optimisation results. A possible reason for this is the fragmentation of the area available to residential development combined to the high number of residential developments that need to be allocated: with each successive optimisation round it becomes harder to create clusters of cells allocated to residential development.

In all three case studies agent PA's evaluation of B is lower than agent RD's evaluation of G. In the case of Lingolsheim-Ostwald the difference between the two values is the biggest of all three case studies. It eventually leads to a low total satisfaction value. Also agent PA's evaluation of D is lower than agent RD's evaluation of E, which applies to all three case studies. This also has an impact on the global satisfaction of the agents.

The optimisation of the evaluation rules of both agents leads to different spatial configurations of the residential development. The evaluation of the optimisation results illustrates a clear conflict between the agents. This conflict is evident in the spatial configuration as shown in figure 9.2. The optimal spatial configurations for both agents also differ from the real residential development in the study areas (the real residential development is more compact). This needs to be taken into account in the evaluation of the simulation results.

The optimal spatial configurations for both agent PA and agent RD serve as a starting point of the negotiation process. Based on these optimal solutions the agents alternate in offering each other an alternative spatial configuration. Which agent starts the negotiation is a model parameter. The alternative solution has to meet two criteria. The evaluation value of the alternative solution must fall within the concession strategy of the agent. Also, the new spatial configuration needs to be closer to the spatial configuration proposed by the opposing agent (see section 7.2).

9.2 Influence of the agents' negotiation position on the concession size

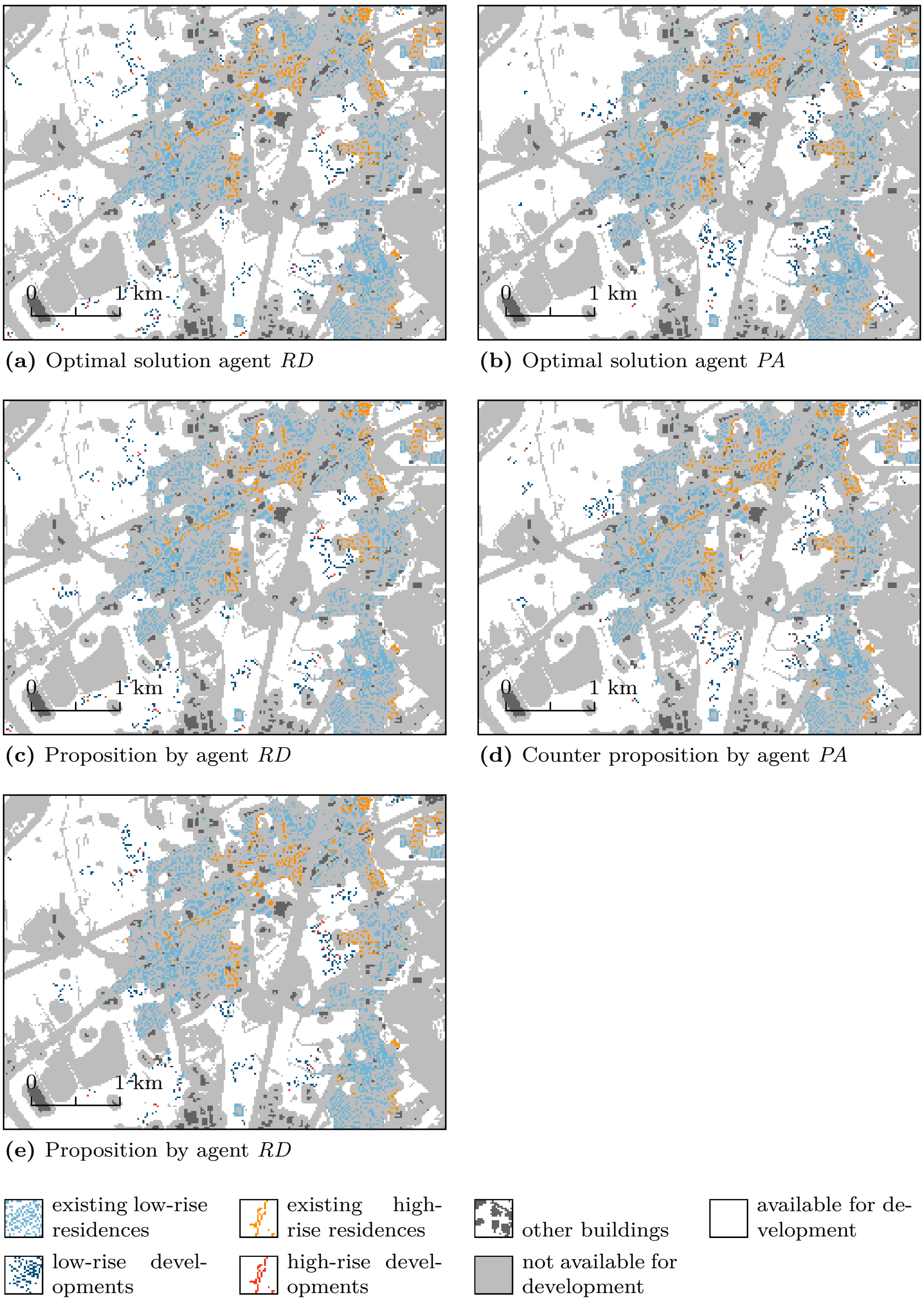
The concession an agent makes at each iteration depends on the parameters ϵ, η_{PA} and η_{RD}. These parameters are defined at the start of the simulation and determine how much the agents concede at each negotiation round (see equations 7.14, 7.15 and 7.16). Here, ϵ defines the basic concession size, and η_{PA} and η_{RD} define how the agents' concession sizes deviate from the basic size in correspondance with the agents' negotiation position. In correspondance to the constraint of a maximum concession each agent changes its last proposition in order to find the solution that is closest to the last proposition received from the opposing agent. Hereby should be noted that the maximum concession is programmed as a strict constraint. If the Simulated Annealing algorithm finds a solution that exceeds this constraint, the solution will be discarded. We have found that this can become an issue if ϵ, η_{PA} and η_{RD} are set too strict.

As a result, every negotiation round an agent proposes an alternative spatial configuration, which is derived from the agent's last proposition. The new proposition provides the agent with less satisfaction, but it provides the opposing agent with more satisfaction than the agent's last proposition. Hence, at each negotiation round the agents move closer to each other, until one of the agents finds that the counter proposition by the opposing agent falls within the constraint of the maximum concession. At that point the agent will accept the counter proposition and the negotiation ends.

Figure 9.3 illustrates this process for Lingolsheim-Ostwald. It gives the propositions of each negotiation round in the first simulation round. In this situation η_{PA} and η_{RD} are set to 0.5 and 1 respectively. These values represent a weak negotiation position for agent *PA* and a normal negotiation position for agent *RD*. Figures 9.3a and 9.3b give the spatial configurations that are results of the optimisation process. Based on these two spatial configurations, agent *RD* proposes the solution in figure 9.3c. The solutions in figure 9.3d and 9.3e are subsequently proposed by agent *PA* and agent *RD* respectively. Agent *PA* eventually accepts the last proposition by agent *RD* and the negotiation ends. The maps show the evolution of the agents propositions. Especially in the transition from figure 9.3b to figure 9.3d the residential development seems to become less dense as the result of the concession made by agent *PA* to agent *RD*.

Figure 9.4 illustrates for the same case the evolution of the evaluation values. Each line gives the trajectory of the evaluation of a spatial index as a result of the evolution of the agent's propositions in the negotiation process. The graphs in the left column show how agent *RD* evaluates the spatial configuration of the different propositions and the graphs in the right column show how agent *PA* evaluates the spatial configurations of the same propositions. The figure clearly illustrates that both agents concede personal satisfaction in order propose a spatial configuration that is more likely to be accepted by the opposing agent. As the negotiation progresses, the agents' evaluation values of the spatial configurations evolve towards each other.

The figure also shows where apparent conflicts between the agents exist. The evaluation functions for C and F, which both represent mixity, are mutually exclusive. If in a spatial configuration, the evaluation of C ($\mu_C(X)$) is high, then consequently, the evaluation of F ($\mu_F(X)$) is low and vice versa. Therefore, at the start of the negotiation a big gap exists between the agents. The agents have to bridge this gap. Another conflict exists between the agents on the density of residential development (indices D and E). Both agents prefer a different density of residential developments. The gap between the curves for the evaluation of indices D and E is however a lot smaller than in the case of the evaluation of C and F. An agent still perceives some satisfaction if the density is optimal for



(a) Optimal solution agent *RD*

(b) Optimal solution agent *PA*

(c) Proposition by agent *RD*

(d) Counter proposition by agent *PA*

(e) Proposition by agent *RD*

Figure 9.3 – *Lingolsheim-Ostwald - Negotiation between agent PA and agent RD, where agent PA has a weak negotiation position and agent RD has a normal negotiation position. Both agents start with the proposition of their optimal solution, next the agents alternate propositions of spatial configurations until one agent accepts. In this case agent PA accepts the last proposition by agent RD.*

the other agent.

In contrast, the agents are not expected to be in conflict with each other on accessibility (indices B and G) and compactness. The indices and the corresponding evaluation functions are considered compatible. This is evident for the evaluation of the accessibility. In case of both B and G the evaluation values $\mu_B(X)$ and $\mu_G(X)$ are already close to each other with the initial spatial configurations proposed by either agent at the start of the negotiation process. However, in the case the indices A and H, a significant gap exist between the initial propositions by both agents at the start of the negotiation process. This illustrates that although the spatial objectives concerning compactness do not seem to be in conflict, some spatial configurations exist which the evaluates very differently. Note that the conflict on compactness and accessibility could also emerge in the course of a simulation.

Finally, figure 9.4 shows the effect of a difference in negotiation power. At the first negotiation round agent *RD* makes an alternative proposition. This is illustrated by a decline in of the black line in the graphs in the left column and a similar incline in the graphs in the right column between negotiation round 0 and 1 (at the exception of the evaluation curves for compactness). Next, agent *PA* makes an alternative proposition, which leads to an incline of the grey line in the graphs on the left and a decline in the graphs on the right between negotiation rounds 1 and 2. The incline and decline in the evaluation curves in case of a proposition by agent *PA* in the second negotiation round are much bigger than the incline and decline of the evaluation values in case of a proposition by agent *RD* in the first negotiation round. The significant difference in the changes in the incline and decline of the grey and black curves shows that agent *PA* makes the biggest concession, as a result of its weaker negotiation position.

Choosing a strong negotiation position for agent *PA* (i.e. $\eta_{PA} = 2$) reduces the size of its concession at each negotiation round. As a result the agents will negotiate over more negotiation rounds in order to come to an agreement. Figure 9.5 shows the evolution of the evaluation of the index values in case of a strong negotiation position for agent *PA* ($\eta_{PA} = 2$).

The conflicts that exist are the same as discussed above. However, the negotiation process takes longer, 22 negotiation rounds against 3 negotiation rounds in the previous example. Similar behaviour has also been observed in the case study of Malden-Groesbeek. In a simulation where agent *PA* is given a weak negotiation position, the negotiation ends after a few negotiation rounds. If however, agent *PA* has a strong negotiation position, the agents need about 20 negotiation rounds in order to come to an agreement. In the case of Chorley, the number of required negotiation rounds is significant lower. Because the residential developments only contain low-rise buildings, the agents do not have a conflict over the mixity of residential developments. This could be a possible reason for the fewer negotiation rounds required in the case of Chorley.

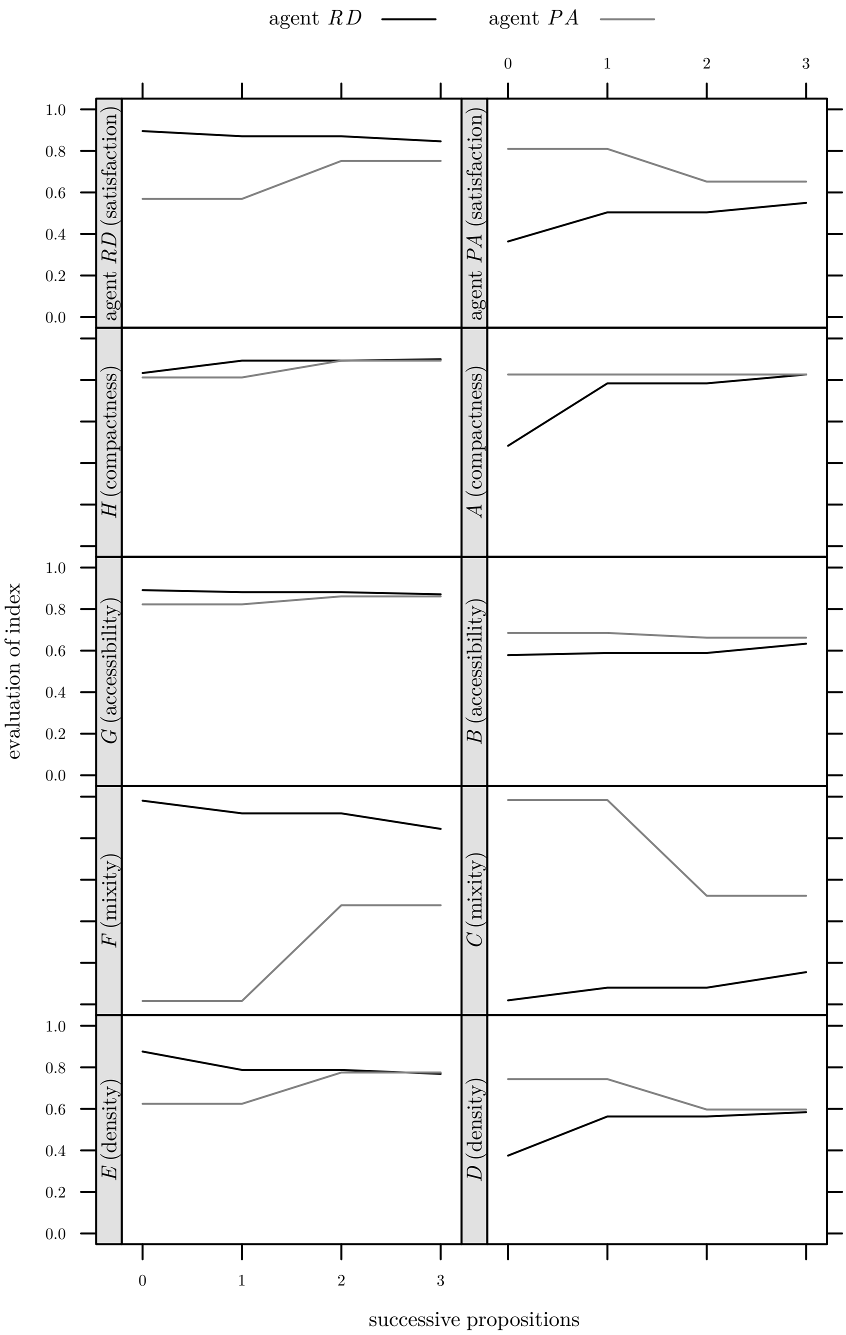


Figure 9.4 *– Evolution of the evaluation values during the negotiation process in the case of Lingolsheim-Ostwald; agent PA has a weak negotiation position and agent RD has a normal negotiation position.*

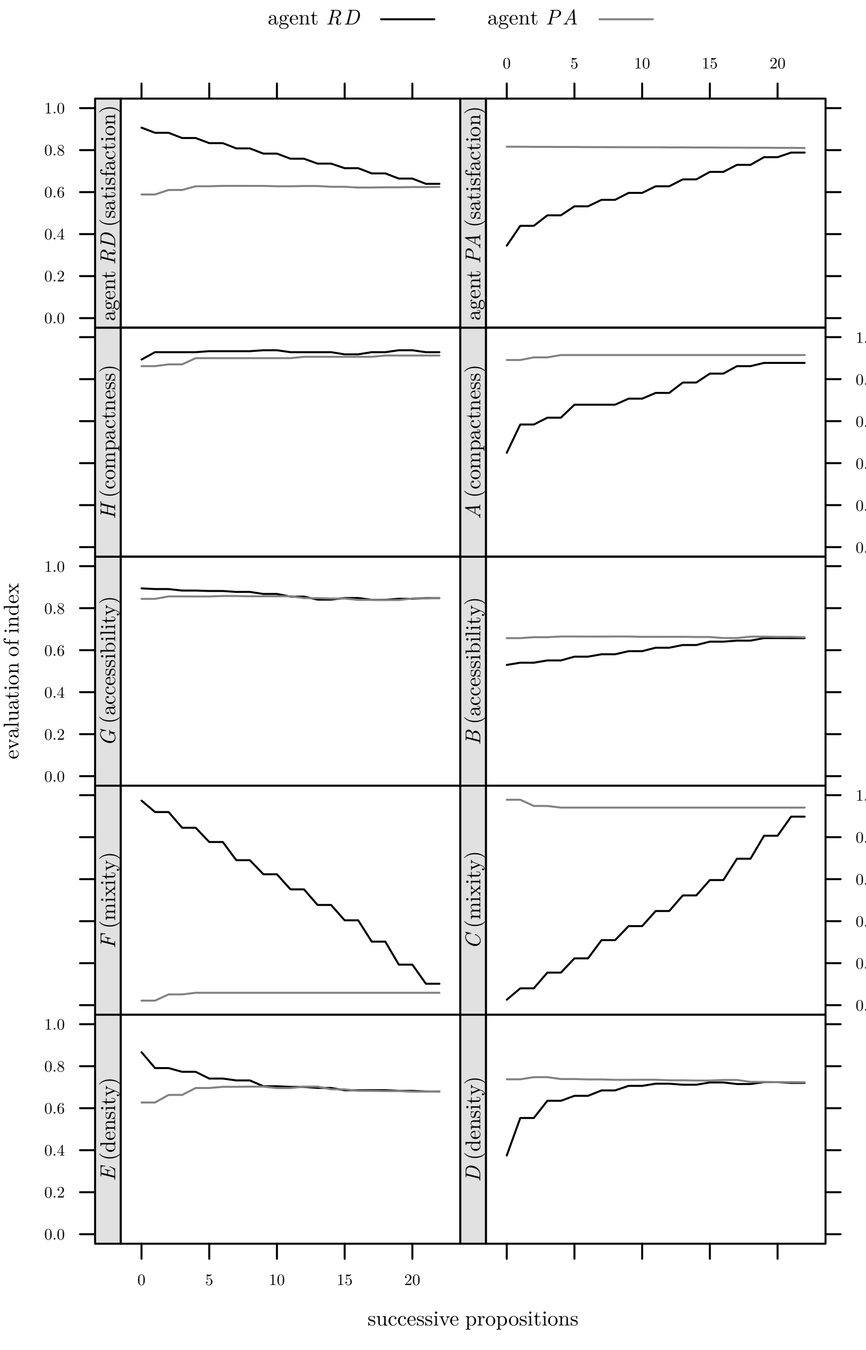


Figure 9.5 *– Evolution of the evaluation values during the negotiation process in the case of Lingolsheim-Ostwald; agent PA has a strong negotiation position and agent RD has a normal negotiation position.*

9.3 Influence of the agents' negotiation position on the form of the spatial configuration

For all three case studies residential development has been simulated in three scenarios in which the power balance between the agents differs. To create a different power balance the negotiation position of at least one of the agents, defined by η_{PA} and η_{RD}, must change. In all three scenarios agent *PA* is given a weak negotiation position ($\eta_{PA} = \frac{1}{2}$), a normal negotiation position ($\eta_{PA} = 1$) and a strong negotiation position ($\eta_{PA} = 2$). The negotiation position of agent *RD* remains unchanged ($\eta_{RD} = 1$). All other parameters have been set as discussed in section 8.3 and given in appendix A.

Each simulation runs over four rounds, and in each simulation round the agents allocate a fixed number of cells to residential development. The total number of cells allocated to residential development at the end of the simulation corresponds to the residential development in the study areas over the studied period (see table 8.2). Figure 9.6 presents the simulation results for Lingolsheim-Ostwald and Chorley. The simulation results for Malden-Groesbeek are presented in appendix B.

This section discusses and visually compares the simulation results with each other and with the existing residential development. The values of spatial indices are also given to support the discussion.

The real residential development (see figures 9.6c, 9.6i and B.1c), in all three case studies, is compact. The majority of the residential development has been constructed in a few large clusters, which are often situated near by or even attached to existing built area. Large areas remain open. In contrast, the simulation results show a different pattern. Residential development is very dispersed and spread out over all the area that is available for residential development. This pattern is however to be expected based on the definition of the agents' optimal spatial configurations (see figure 9.6a, 9.6b, 9.6g, 9.6h, B.1a and B.1b).

The comparison of the spatial pattern shows however some differences between the different cases. In the cases of Lingolsheim-Ostwald and Chorley the spatial pattern of residential development changes under the influence of an increasing negotiation position of agent *PA*. The cells allocated to residential development seem to be situated closer to each other, creating denser residential development. Moreover, the patches of residential development, which are completely dispersed in the case where agent *PA* has a weak negotiation position, move closer to the existing built area as the negotiation position of agent *PA* improves. The difference in density between the three scenarios is clearly visible in the cases of Lingolsheim-Ostwald and in Chorley. In both cases the spatial configuration that results from the scenario with a weak negotiation position for agent *PA* looks very similar to the optimal spatial configuration of agent *RD*. However, if agent *PA* has a strong negotiation position, the resulting spatial pattern resembles the optimal spatial configuration of agent *PA*. This would suggest that the negotiation position of the agents has an influence on the spatial pattern that results from the simulation.

The effect of the increasing negotiation position of agent *(*PA) is less visible in the case of Malden-Groesbeek. Moreover, in the scenario where agent *PA* has a normal negotiation position (see figure B.1e), residential development is clustered around Groesbeek and Bredeweg (at the east side of the study area).

However, in the scenario where agent *PA* has a strong negotiation position residential development seems to be more dispersed (see figure B.1f). Based on these results it is hard to say what the effect is of the stronger negotiation position of agent *PA*.

In all three case studies, the three scenarios produce a pattern of residential development with a similar form. Many clusters of residential development appear in the shape of ribbon development. This effect is the strongest in the cases of Lingolsheim-Ostwald and Chorley. In Malden-Groesbeek residential development remains more dispersed, and has fewer clusters. Yet, many of those clusters also appear as ribbon development. The scenario shown in figure B.1e seems to be an exception.

This suggests that ribbon development maximises the evaluation of the spatial structure for both agent *PA* and agent *RD*. Characteristic of ribbon development is that residences are connected to each other and form a single patch. This satisfies the objective to limit the number of patches. Both agent *PA* and agent *RD* aim to limit the number of patches (evaluation functions $\mu_A(X)$ and $\mu_H(X)$). Ribbon development also yield high values of evaluation functions $\mu_D(X)$ and $\mu_E(X)$. The parameters have been set such that agent *RD* prefers the development of cells that have either one or two cells in the 8-cell neighbourhood allocated to either residential use or residential development. Agent *PA* prefers the development of cells with two or three neighbouring cells allocated to residential use or residential development. At the same time ribbon development provides access to open area from the cells allocated to residential development (evaluation functions $\mu_B(X)$ and $\mu_G(X)$).

In the current definition of PARDISIM, the only incentive to locate residential development in large dense clusters, like in the case of real residential development, comes from evaluation function $\mu_B(X)$. The outcome of this evaluation function depends, next to the accessibility of open area, on the accessibility of public and commercial services. Section 9.1 already illustrates that an increase in the dispersion of residential developments has only a small effect on the outcome of the evaluation of accessibility. This explains the dispersion of the cells allocated to residential development in the optimal spatial configuration for agent *PA*. This dispersion progresses down the simulation.

In addition to the visual analysis of the simulation results, table 9.2, table 9.3 and table 9.4 give the values of the six indices for the final spatial configuration that results from the three tested scenarios. Also, the tables present the same index values for the real residential development and the results of the optimisation process. Analysis of these indices provide additional information on the spatial configuration and helps to better understand the reasons behind the simulation results.

The comparison of the index values for the real residential development in the three case studies reveals that the residential development in Lingolsheim-Ostwald is the most compact of the three. Assuming that, the local planning authorities in all three case studies equally strive for compact residential development, and, commercial residential developers in the three case studies also have the same spatial objectives, then the planning authorities of Lingolsheim-Ostwald have been most successful in the implementation of their spatial objectives. Hence, the local planning authorities of Lingolsheim-Ostwald have had the best negotiation position.

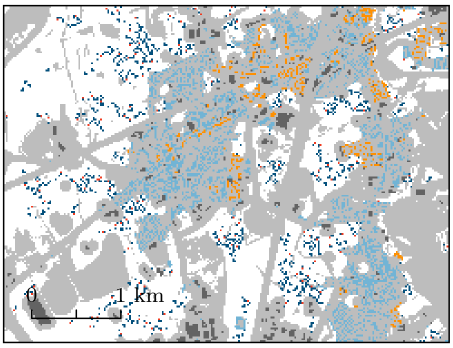
The objective of the analysis of the index values is to see if the simulation results become more compact with an improved negotiation position for agent *PA*. Also, we aim to see which simulation results best resembles the spatial configuration of the real residential development.

The comparison of the index values of the spatial configuration of the real residential development in Lingolsheim-Ostwald with the index values of the spatial configuration that resulted from the optimisation process shows that the change in the total number of patches (A) is in fact the only index where the value in case of the real residential development falls between index values for the spatial configuration that resulted from the optimisation process for both agents. On the basis of this index it is possible to compare the real residential development with the results of the simulation. Moreover, the evolution of the total number of patches is the same in the real residential development and the simulation scenarios where the negotiation position of agent *PA* is either weak or normal. For the other indices no similar values have been found. The index values for B, C/F and D/E are lower in case of the real residential development. The are also lower for the final spatial configuration compared to the optimisation results. On the other hand, the average distance to open area from new residential developments (G) and the number of patches of new residential development (H) are much bigger than in both spatial configurations that result from the optimisation process.

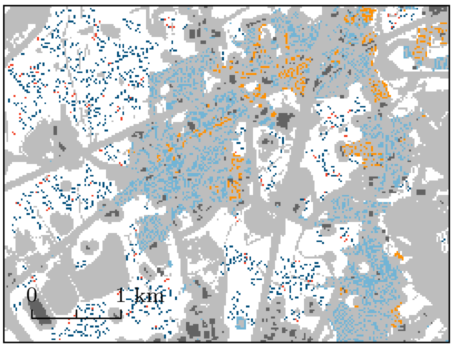
Agent *PA* aims to minimise the increase in the average distance to public services and open area. However, the optimal spatial configuration of agent *PA* does not optimise the index value for accessibility. This could be due to a conflict between agent *PA*'s objectives; the optimisation of a different index results in the rapid decrease of accessibility. Another explanation is that the definition of the evaluation function, or more specifically, the definition of the parameters α_B and β_B, are too forgiving. A similar argument can be made for the average number of empty cells neighbouring a cell allocated to residential development. The real residential development in Lingolsheim-Ostwald has in fact been constructed at a higher density than the density agent *PA* considers optimal.

On the other hand agent *PA*'s evaluation of the mixity between high-rise and low-rise residential development seems too strict. The value for agent *PA*'s optimal value is close to the maximum possible value for the index. Indeed, in case of the real reasidential development, high-rise development is clustered together in a few clusters (see figure 9.6c). Probably an important part of the explanation for this comes from the fact that high-rise buildings are often buildings with a large ground area. The small cell size of the cellular space means that such buildings occupy multiple cells. In PARDISIM, agent *PA* satisfies the evaluation of the mixity by dispersing the cells allocated to high-rise residential development (see figure 9.6g).

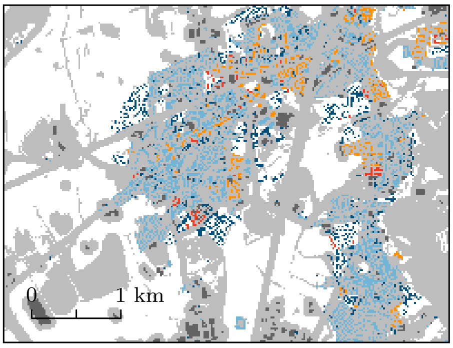
The evaluation functions of agent *RD* have however been set very strict. The index values for both G and H are much lower in case of the optimal spatial configuration of the residential development than in case of the real residential development. On the other hand, the low index values for agent *PA*'s spatial



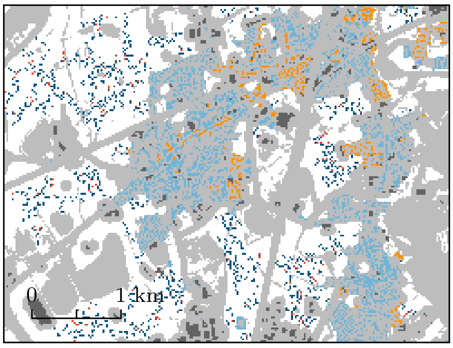
(a) Lingolsheim-Ostwald: optimal spatial configuration for agent *PA*



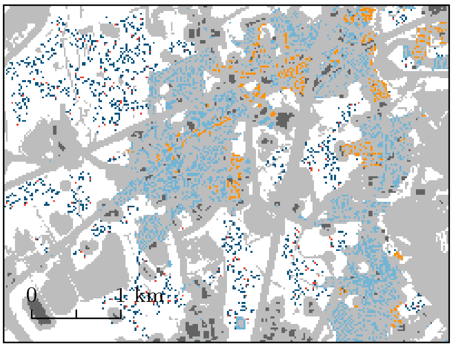
(b) Lingolsheim-Ostwald: optimal spatial configuration for agent *RD*



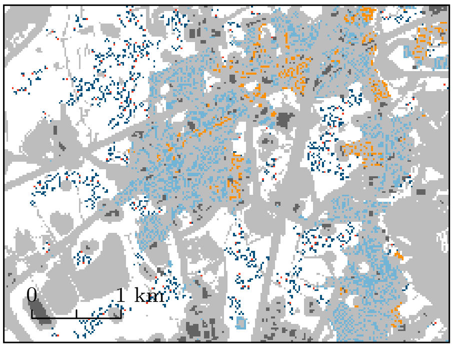
(c) Lingolsheim-Ostwald: real residential development



(d) Lingolsheim-Ostwald: weak negotiation position for agent *PA* ($\eta_{PA} = 0.5$)



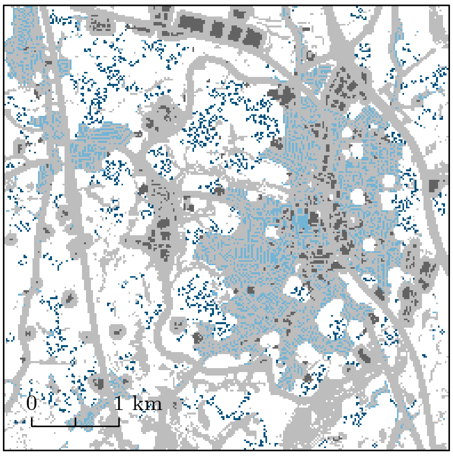
(e) Lingolsheim-Ostwald: normal negotiation position for agent *PA* ($\eta_{PA} = 1$)



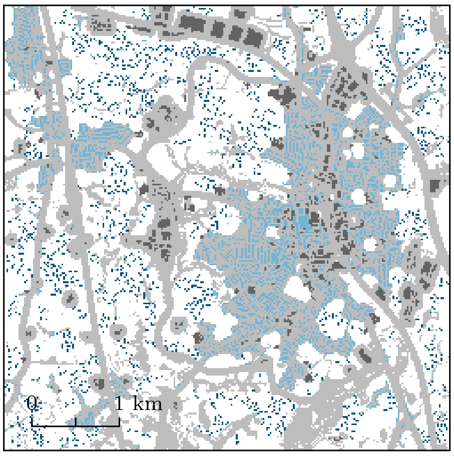
(f) Lingolsheim-Ostwald: strong negotiation position for agent *PA* ($\eta_{PA} = 2$)

existing low-rise residences | existing high-rise residences | other buildings | available for development
low-rise developments | high-rise developments | not available for development

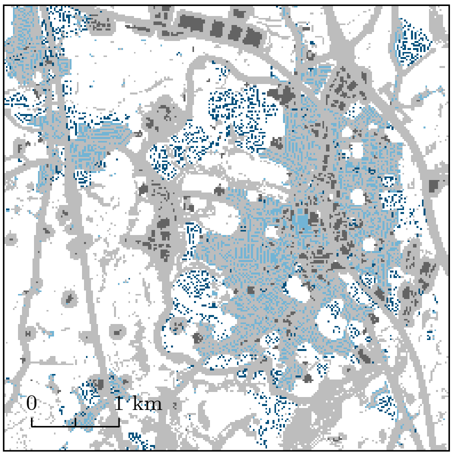
Figure 9.6 *– Comparison of the different scenarios of power balance between the two agents with the real residential development and each agents optimal spatial configuration for Lingolsheim-Ostwald and Chorley*



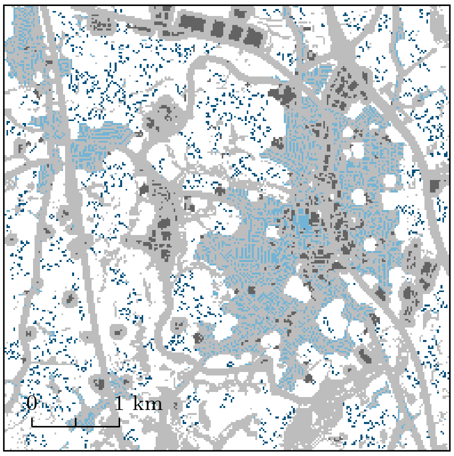
(g) Chorley: optimal spatial configuration for agent *PA*



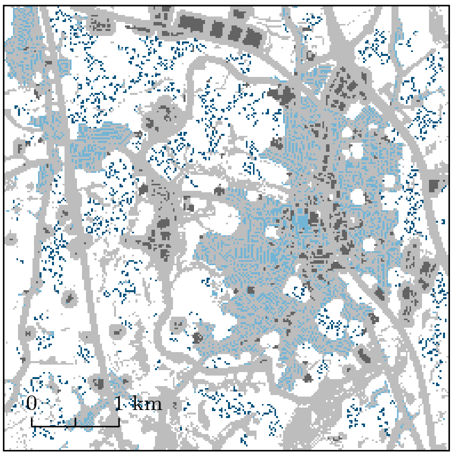
(h) Chorley: optimal spatial configuration for agent *RD*



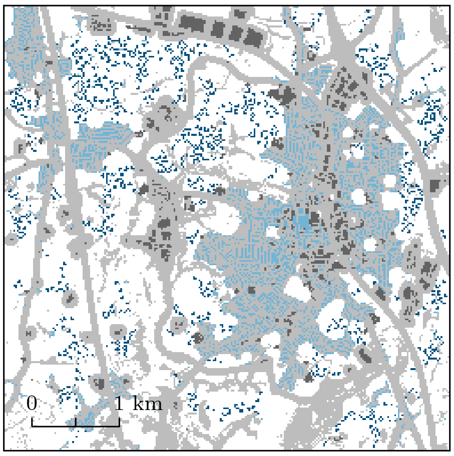
(i) Chorley: real residential development



(j) Chorley: weak negotiation position for agent *PA* ($\eta_{PA} = 0.5$)



(k) Chorley: normal negotiation position for agent *PA* ($\eta_{PA} = 1$)



(l) Chorley: strong negotiation position for agent *PA* ($\eta_{PA} = 2$)

configuration are probably also partly the result of agent *PA*'s loose evaluation functions. Stricter evaluation functions for the indices B and D might result in higher values for G and H in agent *PA*'s optimal spatial configuration.

The quantification of the spatial configuration in case of the real residential development in Lingolsheim-Ostwald and the optimal spatial configuration produced by both agents reveal that few similarities exist. This is a confirmation of the visual analysis.

The optimal spatial configurations of both agents serve as the basis for the negotiation between them. Therefore, the index values calculated based on the optimal spatial configurations are expected to be the extremes and the index values calculated for the final results of the negotiation process are expected to fall between these extremes.

The first five indices in table 9.2 (A, B, C & F, D & E and G) show the expected behaviour. Both the evolution of the total number of patches and the average distance to amenities (index B) diminish with an improvement of the negotiation position of agent *PA*. This means that with an increasing influence of agent *PA* the decrease of the number of patches gets bigger and the ratio of change of the average distance to amenities get smaller. The mixity and density also increase with a stronger negotiation position of agent *PA*. As the negotiation position of agent *PA* improves, the negotiation position of agent *RD* becomes relatively weaker. A consequence of its weaker negotiation position becomes visible through the increase of the average distance to open areas.

For the other indices, the values for the spatial pattern in case of the simulation of residential development and in case of the real residential development do not fall in the range defined by the two optimal spatial configurations. This complicates the comparison between the simulation results and the real residential development. The number of patches of new residential developments in all three scenarios is lower than in the result of both optimisations, which again is lower in case of the real residential development. This behaviour is probably related to the objectives of the agents to cluster developments and the design of the Simulated Annealing algorithm. The algorithm is based on an heuristic that stimulates the forming of clusters. In each iteration of the algorithm a few residential developments are relocated. The algorithm includes a preference to relocate these residential developments near other cells allocated to residential development. In the case of a simulation with several negotiation rounds the Simulated Annealing algorithm will go through more iterations than in the case of an optimisation. The high value for H in the case of a strong negotiation position of agent *PA* illustrates however that the objective functions of both agents still have an influence.

A small number of patches of cells allocated to residential development, that is a number of patches that is a lot smaller than the number of patches in the case of real residential development, would suggest that the residential development is more compact in the simulation results than in the real residential development. However, a visual analysis suggests the opposite. One possible reason for this is the form of the patches. As discussed above, many patches in the simulation results have the shape of ribbons. A long ribbon of residential development forms a single patch, however, it also causes the fragmentation of open area. Another explanation might be that in case of the real residential development small and medium sized patches string patches of existing residences together.

The analysis of the index values in the case of Chorley has many similarities with Lingolsheim-Ostwald. In case of the real residential development in Chorley, the density is lower (the average number of empty cells in a cell's neighbourhood is higher) than in Lingolsheim-Ostwald. The index value falls between the index values that follow from the optimal spatial configuration of both agents. The comparison of the index value for the density of the real residential development with the results from the simulation shows that the density of residential developments in the scenario, in which agent *PA* has a normal negotiation position, is closest to the density in case of the real residential development.

The comparison of the values of index *A* shows that in the scenario, in which agent *PA* has a weak negotiation position, the change in the number of patches is still smaller than the change in the total number of patches of built area in case of the real residential development. This suggests that the negotiation position of the local planning authority is weak when it concerns the control of the fragmentation of the built area. Hereby should be noted that the value of *A* in the scenario with a strong negotiation position of agent *PA* exceeds the value of *A* in the optimal spatial configuration for agent *PA*. Since *A* is also an index that measures the number of clusters of cells, this might be the result of the issue with the heuristic in the algorithm as discussed above for index *H*.

The other indices behave similarily to the indices in the case study of Lingolsheim-Ostwald. Although the differences between the index values are smaller, except for value of the density index (*D* & *E*).

In the case study of Malden-Groesbeek, none of the index values for the real residential development fall within the range defined by the optimal spatial configurations of both agents. All index values, except index *G*, in case of the real residential development are lower than the index values for both optimal spatial configuration. The value of index *G* is much higher in case of the real residential development compared to the agents' optimal spatial configuration. Only the mixity index in case of the real residential development and the optimal spatial configuration of agent *RD* are very close to each other.

Although the value of index *A* in case of the real residential development is smaller than in the results of the optimisation process, the value is larger than in the spatial configuration resulting from the scenario with a strong negotiation position for agent *PA*. In fact, the value in case of the real residential development falls between the index values in case of the scenarios with a normal agent *PA* and a strong agent *PA*. Here, the index values for the result of the optimisation process do not form a range that includes the index values of the other investigated spatial configurations. Previously, this has been attributed to the working of the Simulated Annealing algorithm. However, another reason for this behaviour might be that over the course of the negotiation process a conflict between objectives is resolved. In such a case, the total satisfaction of the agent could be lower than in case of the optimal spatial configuration but, at the same time, one specific index could have a higher value than in case of the optimal spatial configuration.

The comparison of the three case studies reveals some interesting similarities and differences. A remarkable similarity between the three case studies is the discrepancy in the average distance to open area from new residential developments. In all three study areas, the value of G is much bigger in case of the real residential development than for any of the spatial configurations resulting from the optimisation process and simulated scenarios. This confirms the analysis above that a lot of the residential development in the simulated scenarios appear in the shape of ribbon development. The reason for this behaviour of PARDISIM is expected to be related to weak incentives for the agents to allocate large clusters of cells to residential development. In fact the only evaluation function that provides an incentive is $\mu_B(X)$. The index values for B illustrate that the incentive is indeed weak; in all scenarios, the value for B exceeds the value of B in case of the real residential development.

The value of index H shows some remarkable differences when comparing the case studies Lingolsheim-Ostwald and Chorley with the case study Malden-Groesbeek. In case of the real residential development in Lingolsheim-Ostwald and Chorley the number of patches of new development is quite similar and lies around 140. Hereby should be noted that the residential development in Chorley is twice the size of the residential development in Lingolsheim-Ostwald. This means that the patches of new residential development are on average twice as big in Chorley. The value of H is much lower in the spatial configuration resulting from the simulation of the residential development by PARDISIM. In the case study of Malden-Groesbeek the opposite is true. In case of the real residential development, the number of patches of residential development is low, yet the simulation results have a high number of patches. The low number of patches in case of the real residential development might be the result of specific development process, where local authorities have long taken the initiative in the land development process. As previously suggested, the low value in the number of patches of residential development is related to the working of PARDISIM, more specifically, the additional heuristic in the Simulated Annealing algorithm. In the case study of Malden-Groesbeek the number of cells that can be allocated to residential development is much larger than in the other two case studies. At the same time, the number of cells to be allocated to residential development is small compared to Lingolsheim-Ostwald and Chorley. As a consequence, the probability to locate new residential development near existing residential development is smaller. In this case the Simulated Annealing algorithm is less efficient.

Finally, the value of index B differs a lot between the case studies. In Malden-Groesbeek the value of B is low in case of both the real residential development and the result of the optimisation process. Indeed, most public and commercial services are concentrated in a shopping mall centrally located (see figure 8.2e). The distance from residential buildings to this shopping mall is often quite long. This possibly gives an explanation for the low values of B for the spatial configuration that result from the optimisation and simulation. In comparison, the public and commercial services in Chorley and, even more so, in Lingolsheim-Ostwald are dispersed (see figure 8.2a and 8.2c). As a consequence the average distance to public and private services is lower in Chorley and Lingolsheim-Ostwald. Adding residential development with a poor access to public and commercial services has more impact if the accessibility is initially good and less impact if the accessibility is initially poor. This illustrates the possible influence

	real residential development	outcome of the optimisation process: agent PA	agent RD	simulation scenarios: $\eta_{PA} = \frac{1}{2}$	$\eta_{PA} = 1$	$\eta_{PA} = 2$
change in the total number of patches (A)	−14.81 %	−31.48 %	29.63 %	−14.81 %	−14.81 %	−27.78 %
change in the average distance to amenities (B)	12.70 %	44.42 %	71.64 %	64.19 %	63.96 %	50.54 %
mixity of low-rise and high-rise residential development (C & F)	0.002297	0.1603	0.01457	0.04448	0.08819	0.1342
density—average number of empty cells in a cell's neighbourhood (D & E)	5.686	6.028	6.757	6.482	6.400	6.197
average distance to open area from new residential developments (G)	94.87	36.47	29.74	30.88	31.08	33.38
number of patches of new residential developments (H)	137.0	68.00	46.00	32.00	30.00	45.00

Table 9.2 *– The index values of six spatial configuration of the residential development in Lingolsheim-Ostwald: the real residential development, the agent's optimal spatial configuration and three simulation scenarios*

	real residential development	outcome of the optimisation process		simulation scenarios		
		agent PA	agent RD	$\eta_{PA} = \frac{1}{2}$	$\eta_{PA} = 1$	$\eta_{PA} = 2$
change in the total number of patches (A)	-13.64 %	-45.45 %	2.870×10^{-5} %	-18.18 %	-38.64 %	-53.79 %
change in the average distance to amenities (B)	21.48 %	27.06 %	42.07 %	39.08 %	32.39 %	26.93 %
mixity of low-rise and high-rise residential development (C & F)	-	-	-	-	-	-
density—average number of empty cells in a cell's neighbourhood (D & E)	6.210	5.982	6.863	6.432	6.288	6.084
average distance to open area from new residential developments (G)	69.96	36.24	27.69	27.69	31.05	35.32
number of patches of new residential developments (H)	141.0	100.0	100.0	98.00	81.00	73.00

Table 9.3 *– The index values of six spatial configuration of the residential development in Chorley: the real residential development, the agent's optimal spatial configuration and three simulation scenarios*

	real residential development	outcome of the optimisation process		simulation scenarios		
		agent PA	agent RD	$\eta_{PA} = \frac{1}{2}$	$\eta_{PA} = 1$	$\eta_{PA} = 2$
change in the total number of patches (A)	-7.101 %	-6.805 %	15.38 %	2.870×10^{-5} %	-2.663 %	-10.35 %
change in the average distance to amenities (B)	-2.665 %	14.37 %	24.24 %	25.17 %	17.47 %	15.43 %
mixity of low-rise and high-rise residential development (C & F)	0.0008437	0.1593	0.0008469	0.04322	0.08051	0.1356
density—average number of empty cells in a cell's neighbourhood (D & E)	5.944	6.191	6.960	6.544	6.514	6.307
average distance to open area from new residential developments (G)	82.09	27.64	22.68	24.60	26.64	25.04
number of patches of new residential developments (H)	49.00	134.0	127.0	110.0	77.00	109.0

Table 9.4 *– The index values of six spatial configuration of the residential development in Malden-Groesbeek: the real residential development, the agent's optimal spatial configuration and three simulation scenarios*

of the initial urban spatial configuration on the results of the negotiation.

Synthesis of the results

The comparison of the optimisation results and the simulation results with real residential development shows that the simulation outcomes are very different from the real residential development.

In a few occassions, the index value for the real residential development could be compared to the index value for the simulation results. The spatial configuration in case of the real residential development could hence be fruitfully compared to the spatial configurations that resulted from the simulation. Nevetheless, it is not possible to identify which agent has the better negotiation position in the three case studies. It appears rather that the negotiation position of the agents depends both on which characteristic of the spatial configuration is considered and on the initial spatial configuration (e.g. dispersion or concentration of the public and commercial services, initial density and compactness of the built pattern).

The visual comparison of the spatial configuration of residential developments shows that in all scenarios the residential development is quite dispersed. Morever, in case of the real residential development, development is grouped into relatively large blocks in all three case studies. In constrast, residential development in the spatial configurations that result from the simulation with PARDISIM appears in the form of ribbon development. It appears that an incentive to develop in more massive blocks is either weakly defined or missing. Also some aspects of the design, moreover the knowledge informed Simulated Annealing algorithm, is expected to have an influence on the outcome of the simulations. New simulations with different parameters (αs and βs) can possibly give better results or at least give clues as to how PARDISIM can be improved.

Chapter 10

Second series of simulations

The first series of simulations with PARDISIM shows that the spatial pattern of residential development that resulted from the simulation is influenced by the negotiation position of agent *PA*. However, PARDISIM has failed to produce realistic spatial patterns of residential development. The patterns of residential development are dispersed. In the case of Chorley, residential development seems to be almost evenly spread over the available space in the scenario with a weak negotiation position for agent *PA*. In all three case studies residential development often appears in small or larger ribbons. In contrast, the pattern of development in case of the real residential development is compact. It is not possible to compare the simulation results with the spatial configuration of the real residential developments and evaluate the negotiation position of the actors involved in the development process.

This chapter presents a second set of simulations with PARDISIM. The aim is to generate more realistic residential development patterns that will allow us to compare the simulation results with the spatial configuration of the real residential development. This should allow us to provide new insights into relating the power balance between development actors to the resulting form of residential development. Hereto we redefine the evaluation functions of the agent, such that they will better approach the objectives of the residential development actors they represent (i.e. local planning authority and private residential developer).

The first section of this chapter redefines the evaluation functions of the spatial indices, after which the new functions are used in a second series of simulations with PARDISIM. Finally we evaluate the results of both series of simulations.

10.1 Evaluation functions based on the real residential development

As shown in chapter 9 an important reason for the dispersed patterns of residential development in the simulation results of PARDISIM is the lack of an incentive for the agents to generate propositions with compact residential development. This has been attributed to ill-defined parameters of the evaluation functions. The evaluation of the accessibility of open area and the accessibility of public and commercial services are important factors that determine the spatial configuration of the residential development proposed by each agent over the course of the negotiation process. Loosening the agent *RD*'s preferences concerning the access to open area and tightening the agent *PA*'s preferences concerning the access to public and commercial services is expected to result in a more compact spatial configuration of the residential development in the agents' propositions.

The parameters of the evaluation functions have been redefined in an effort to make the simulation results better match the real residential development in the studied areas. Hereto the index values calculated for the spatial configuration of the real residential development serve as a starting point. Moreover, for each index the range within which the values calculated for the simulation results need to fall is defined by index values calculated for the spatial configuration of the real residential development in the study areas. The procedure to define the parameters α and β in each evaluation function is the same as described in section 8.3. The parameters are presented in table 10.1. Figure 10.1 and figure 10.2 give the new evaluation functions. The grey curves are the evaluation functions that have been used in the first series of simulations.

	Index value in case:			
index	$\mu_{\text{index}} = \frac{1}{2}$	$\mu_{\text{index}} = \frac{3}{4}$	α	β
A	0.1	-0.03	2.328	8.451
B	0.1	0.03	4.804	15.69
C: Lingolsheim-Ostwald	1.723×10^{-3}	0.02582	1.082	45.59
C: Malden-Groesbeek	1.265×10^{-3}	0.02906	1.051	39.52
D	-	-	5.5	0.8493
E	-	-	6.5	0.8493
F: Lingolsheim-Ostwald	1.723×10^{-3}	-0.02238	1.082	45.59
F: Malden-Groesbeek	1.265×10^{-3}	-0.02654	1.051	39.52
G	160	100	18.72	0.01831
H	50	35	38.94	0.07324

Table 10.1 *– The definition of parameters α and β based on the index values measured for real residential development.*

In all three case studies the number patches of built area has decreased over the studies period (index A). The rate of decrease varies between 7.1% for Malden-Groesbeek and 14.8% for Lingolsheim-Ostwald. These numbers function as a starting point in the definition of the parameters for $\mu_A(X)$. Two additional aspects need to be considered in the definition of α_A and β_A. First, the optimisation process starts with a random spatial distribution of the cells allocated to residential development. Hence, at the start of the optimisation process, the number of patches of built area is large. If the inclination in the middle of the logistic curve is too steep, the inclination will be too low. This provides little incentive to the agents to group cells allocated to residential development together in larger clusters. Consequently, the evaluation function for index A must provide a sufficiently large range of high evaluation values (i.e. evaluation values higher than 0.5). Second, A is expressed as the relative change in the number of patches. The change rate that has been found found in case of the real residential developments needs to be translated to a change rate for a single simulation round. A change rate of -14% to -12% for the entire simulation means a change rate of about -3% for each simulation round. Considering all these requirements, the values of α_A and β_A are determined based on the following constraints:

- $\mu_A(0.1) = \frac{1}{2}$, which allows the range of high evaluation values to be large enough,
- and $\mu_A(-0.03) = \frac{3}{4}$, which causes the evaluation value to be high (equal to 0.75) if the number of built patches does not change. If the number of built patches decreases, the evaluation value is the best (almost equal to 1).

The value for index B shows more variations among the case studies. The values range from 21.5% in the case of Chorley to -2.7% in the case of Malden-Groesbeek. The average change rate in the three case studies is about 12% (i.e. 3% at each simulation round). In order to define the evaluation function for B the same concerns as for the evaluation of index A related to the inclination of the function and the relative change at each simulation round need to be considered. Hence, α_B and β_B are derived from $\mu_B(0.1) = \frac{1}{2}$ and $\mu_B(0.03) = \frac{3}{4}$.

The analyses of the real residential development in section 9.3 illustrate that the values for the mixity (C & F) in Malden-Groesbeek and Lingolsheim-Ostwald are very low. They are in fact lower than the mixity that has been found in the simulation results. High-rise residential development often concists of buildings with a big ground area. These buildings are represented by clusters of several cells allocated to high-rise residential development in the cellular layer. In the simulation results, a high value of the mixity index is the result of an unrealistic spatial distribution of the cells allocated to high-rise development. For the second series of the simulation, the values of α_C and β_C (and the values of α_F and β_F) are set such that the simulation produces results with a realistic value for the mixity. At the same time the parameters should not be set to strict, since it might hinder the progress of the negotiation process.

In the evaluation function for the density (indices D and E), α_D and α_E are both reduced by 0.25. The density in the real residential development all three case studies now falls in between the optimal density for both agents.

The evaluation of the accessibility of open area from residential development (index G for agent RD) has been relaxed. The simulation results in section 9.3 show that if the evaluation function for G ($\mu_G(X)$) is set to strict, it leads to ribbon development. Relaxing the evaluation function for G is expected to lead to more compact residential development in the simulation results.

Finally, the evaluation function for H (number of patches of new residential developments for agent RD) is left unchanged, because the values that have been used to determine the parameters (see section 8.3) for the previous evaluation function correspond with the values for H that have been found in the case studies.

10.2 Case study results

For all three case studies the same scenarios as in chapter 9 have been simulated using the new evaluation function parameters. Hence, in each scenario, agent *PA* has either a weak negotiation position, a normal negotiation position or a strong negotiation position. The objective of this simulation series is the same as with the simulation series (see chapter 9): compare the simulation results with the real residential development in the case studies. The results of the comparison will be used to identify the negotiation position of the residential developments actors (i.e. the local planning authority and the commercial residential developer) in the residential development process.

Except for the parameters of the evaluation functions, all other parameters remain unchanged. Remarkably, with the new parameters, the agents require less negotiation rounds to reach an agreement. Figure 10.3 gives the spatial configuration of the real residential development and the simulation results for Lingolsheim-Ostwald and Chorley. The spatial configuration of the real residential development and the simulation outcome for Malden-Groesbeek is given in appendix C.

In the case of Lingolsheim-Ostwald, the optimal spatial configuration for agent *PA* sees the residential development grouped in clusters (see figure 10.3a). In comparison with the real residential development in figure 10.3c this optimal spatial configuration still is less compact. However, in comparison to the optimisation result in the previous simulation series (see figure 9.6a) residential development is located closer to existing built areas and open areas remain more open.

In Chorley the optimal spatial configuration for agent *PA* closely approaches compactness of the spatial pattern in case of the real residential development. In the optimisation result residential developments are grouped in clusters located close to existing built area. Also, residential development seems to emerge at similar locations compared to the real residential development. Residential development in the optimal spatial configuration has a more ‘organic form’ whereas in case of the real residential development, patches of residential development have more geometric shapes as the result of planning. Also, the density of the residential development in the optimal spatial configuration of agent *PA* is denser than the density of the real residential development.

In the case of Malden-Groesbeek, the residential development in the optimal spatial configuration of agent *PA* is much more fragmented than in the case of the real residential development, but less fragmented than in the optimal spatial configuration in the first simulation series. In comparison to the optimal spatial configuration for agent *PA* in Chorley and Lingolsheim-Ostwald, the residential development remains more fragmented, This was however also the case in the first simulation series.

Changing the parameters for the evaluation functions has resulted in a more compact pattern of residential developments in the optimal spatial configuration

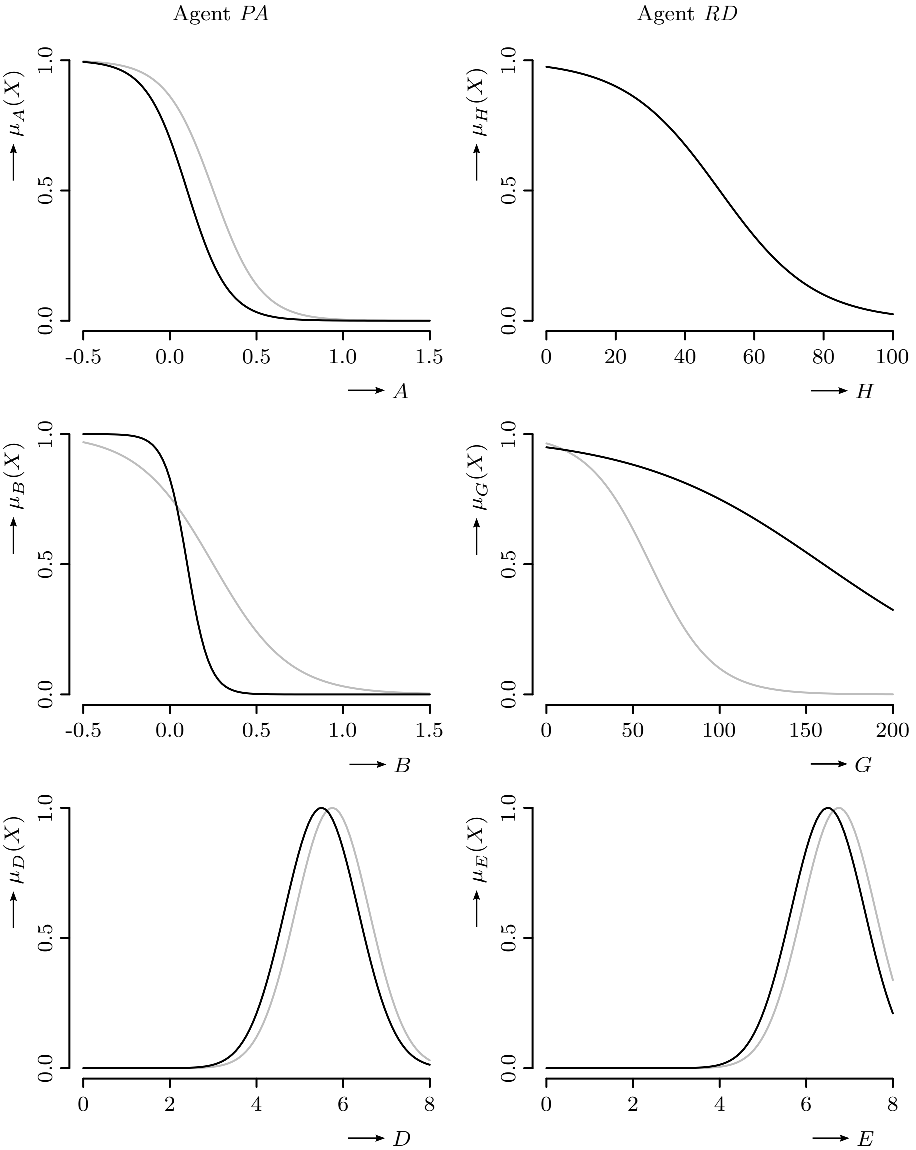


Figure 10.1 *– The agents' new evaluation functions for the indices A (change in the number of patches of built land) and H (absolute number of patches), B (change in accessibility of public services and open area) and G (absolute distance to open area), and D and E (both a proxy for the density of residential development), which are used in the simulation of all three case studies. (The evaluation functions, that are used the previous simulation are given in grey)*

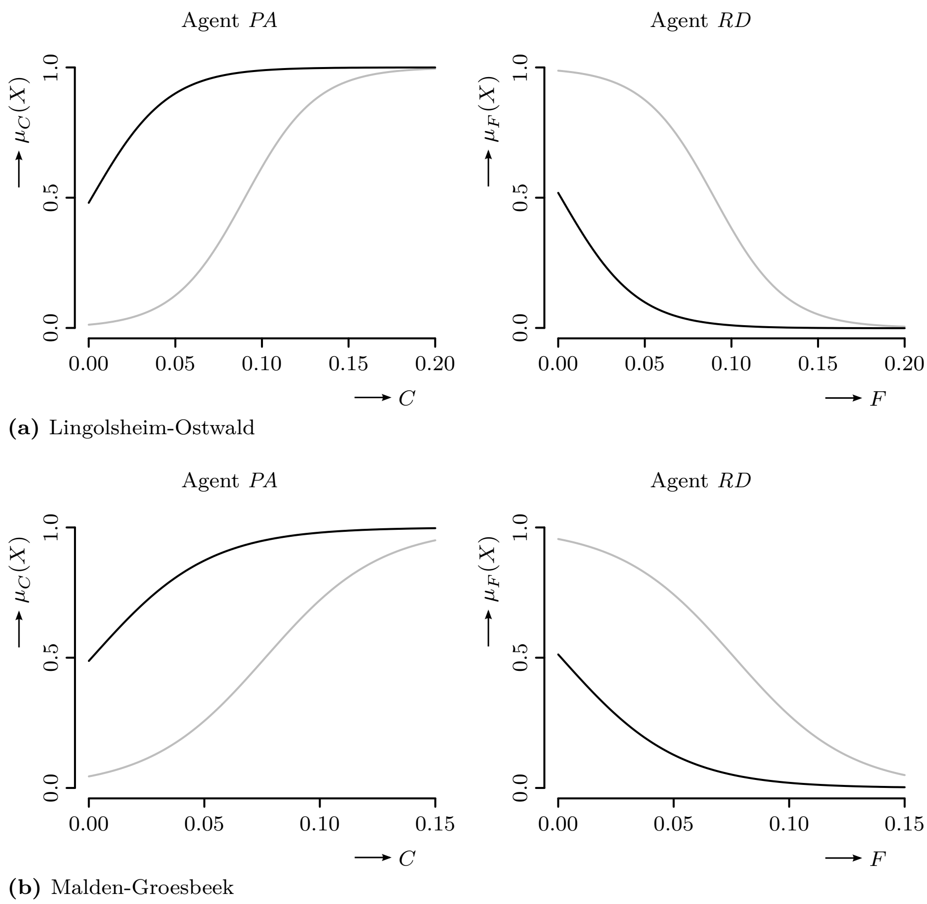


Figure 10.2 *– Evaluation functions for the indices C and F in the case of Lingolsheim-Ostwald and Malden-Groesbeek, measuring mixity between low-rise and high rise residential development. (The evaluation functions, that are used the previous simulation are given in grey)*

of agent *PA*. In contrast, the optimal configuration of residential developments for agent *RD* has changed little and remains similarly fragmented in all three case studies.

More contrast between the agents' optimal spatial pattern of residential development should also result in more contrast between the spatial configuration that result from the three scenarios. However, this seems not to be the case for Lingolsheim-Ostwald. Especially, few differences exist between the outcome of the scenario with a normal negotiation position for agent *PA* (see figure 10.3e) and the outcome of the scenario with a strong negotiation position for agent *PA* (see figure 10.3f). Patches of residential development have similar sizes and are located at similar locations. The most noticable difference concerns the density of residential development.

The spatial pattern of the residential development in the scenario with the weakest agent *PA* (see figure 10.3d) differs from the outcome of the other two scenarios. Residential development is more dispersed; the spatial pattern shows clear resemblances with the spatial configuration in the optimisation result for agent *RD*.

The outcome of the scenarios simulated in the case of Lingolsheim-Ostwald only partly show the expected result. Between the scenario with a weak agent *PA* and the scenario with a strong *PA* a clear constrast exist. In the result of the last scenario the spatial pattern shows more similarities with the optimisation result for agent *PA*. Whereas, in the results of the former scenario, the spatial pattern contains more elements from the optimisation result of agent *RD*. However between the normal scenario and the strong scenario the effect of a stronger negotiation position of agent *PA* is not clearly visible.

The contrast between the results of the three simulated scenarios is better visible in the case of Chorley. In the result of the scenario with a weak agent *PA*, the influence of the objectives of agent *PA* are already clearly visible. In contrast to optimisation result for agent *RD* the spatial pattern contains clear clusters of residential development. And as the negotiation position of agent *PA* increases, the clusters of residential development get denser and move towards existing built area.

In the simulation results of all three scenarios and the spatial pattern of the real residential development have in common that the largest patches of residential development emerge at the same locations, which are as close as possible to public and commercial services (see figure 8.2).

The simulation results of the simulated scenarios for Malden-Groesbeek are very similar. Residential development is grouped in small clusters, which are very dispersed. The difference between the spatial configuration resulting from the three scenarios is similar to the differences between the results of the optimisation processes for both agents. As the negotiation position of agent *PA* increases the average cluster size slightly increases and clusters move more into the direction of existing built up area.

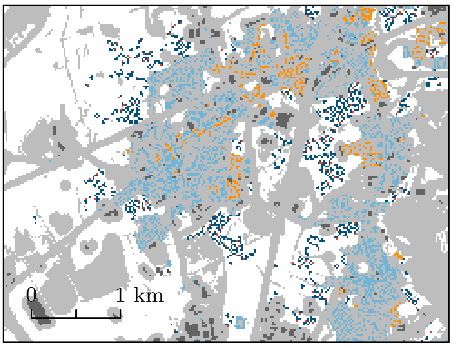
To better understand the emergence of the spatial pattern of residential development in the simulation results, and hence explain the differences in the results, it is necessary to understand the conflicts between the agents. By design, the agents have four different conflicts. For each agent the satisfaction function is built up from four different evaluation functions which each evaluate the value of a spatial index. Moreover, for each index that an agent evaluates the same or a similar index is evaluated by the opposing agent. The subjects of conflict between the agents are compactness (patch count), accessibility, mixity and density. As discussed in section 9.3, the intensity of the conflict differs according to the subject of conflict.

The agents' objectives concerning compactness, accessibility, mixity and density each have a different impact on the spatial configuration of the residential development. A comparison of the simulation results presented in this section and the simulation results presented in section 9.3 illustrates the impact of the evaluation of the accessibility on the spatial pattern of residential development. Loosening agent *RD*'s evaluation function of the access to open area $\mu_G(X)$ allows patches of residential development to become bigger. Tightening agent *PA*'s evaluation of access to public and private services (as well as open area) has resulted in residential development to be located nearer to existing built area. Also, residential development has become more compact as a result of changing the evaluation functions $\mu_D(X)$ and $\mu_E(X)$.

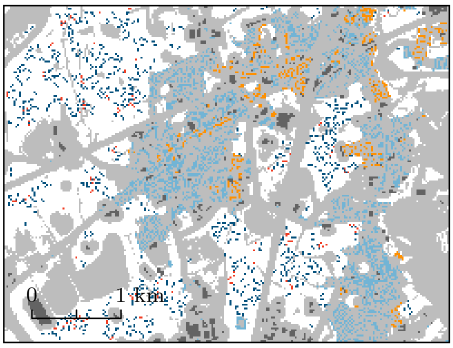
The conflicts, especially between $\mu_B(X)$ and $\mu_G(X)$, help explain the differences observed between the different scenarios, or the lack thereoff. In Chorley, when the negotiation position of agent *PA* improves residential development emerges closer to the built area. This behaviour is attributed to the influence of agent *PA*'s evaluation of the accessibility of public and commercial services. This behaviour is less clear in the cases of Lingolsheim-Ostwald and Malden-Groesbeek.

In Lingolsheim-Ostwald, the centre of the studied area is an open area where in all three senarios a lot of residential development is located. Residences at this location have a good access to public services in the surrounding built area. And as the negotiation position of agent *PA* improves the density of the development also increases; cells allocated to residential development emerge closer to each other. However, the open area at the centre of the studied area is fragmented by zones that are not available for residential development. These zones hinder the location of residential development closer to the built area. This explains the little differences in spatial configuration between the results of the different scenario.

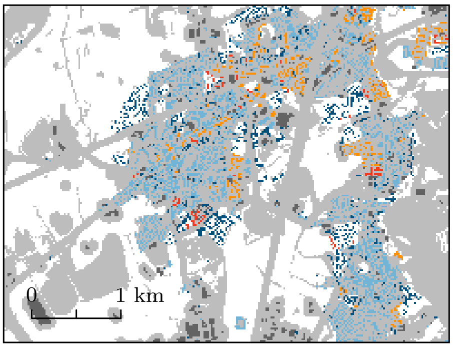
In the case of Malden-Groesbeek, residential development in the simulation results remains fragmented and dispersed. This happens for two reasons. In comparison to the case studies of Lingolsheim-Ostwald and Chorley, the average distance from a residence to the closest three amenities is much larger in Malden-Groesbeek. New residential development can therefore be further away from existing built area and produce the same increase in the average distance to the three closests amentities. On top of that, Malden-Groesbeek is the largest of all three case studies. However, the size of residential development is the smallest of all three case studies. The access to amenities, measured from the residential development in Malden-Groesbeek, has less impact of the global accessibility index (B).



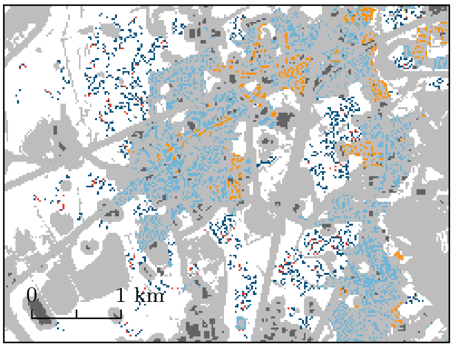
(a) Lingolsheim-Ostwald: optimal spatial configuration for agent *PA*



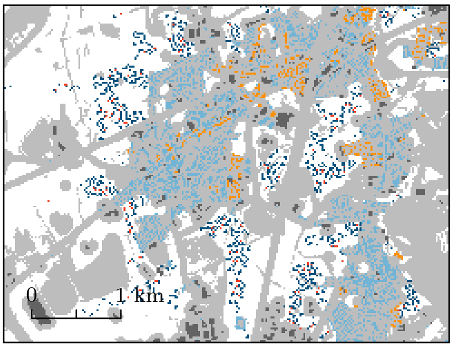
(b) Lingolsheim-Ostwald: optimal spatial configuration for agent *RD*



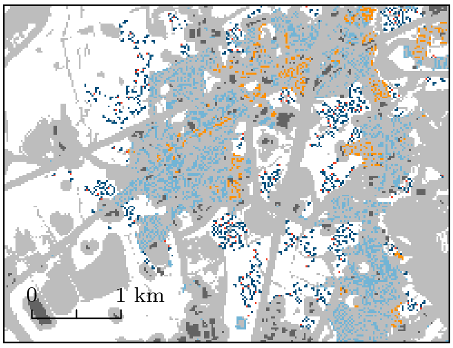
(c) Lingolsheim-Ostwald: real residential development



(d) Lingolsheim-Ostwald: weak negotiation position for agent *PA* ($\eta_{PA} = 0.5$)



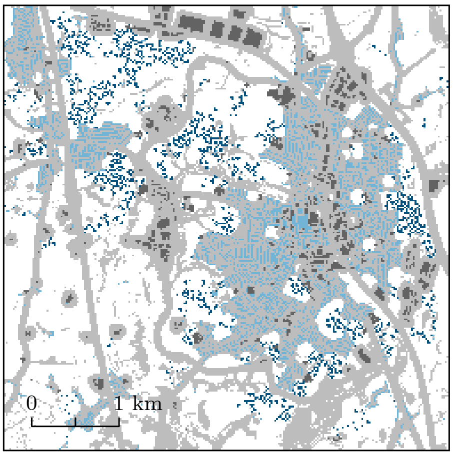
(e) Lingolsheim-Ostwald: normal negotiation position for agent *PA* ($\eta_{PA} = 1$)



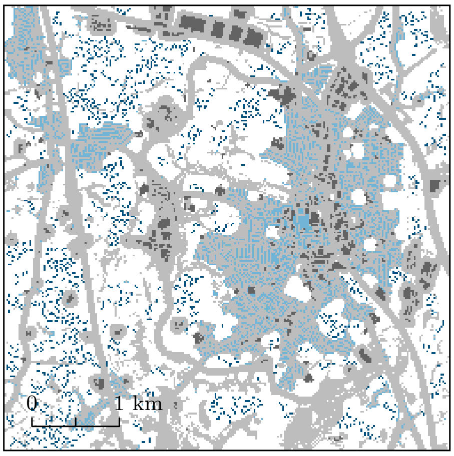
(f) Lingolsheim-Ostwald: strong negotiation position for agent *PA* ($\eta_{PA} = 2$)

existing low-rise residences	existing high-rise residences	other buildings	available for development
low-rise developments	high-rise developments	not available for development	

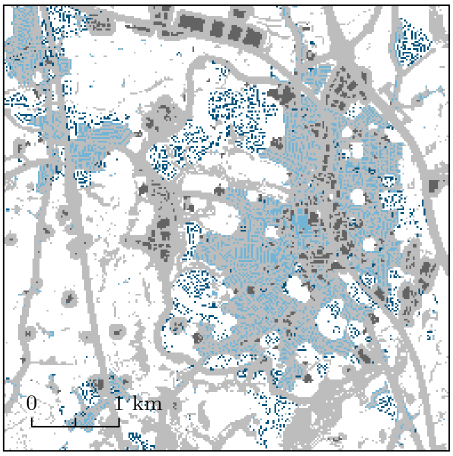
Figure 10.3 *– Comparison of the different scenarios of power balance between the two agents with the real residential development and each agents optimal spatial configuration for Lingolsheim-Ostwald and Chorley*



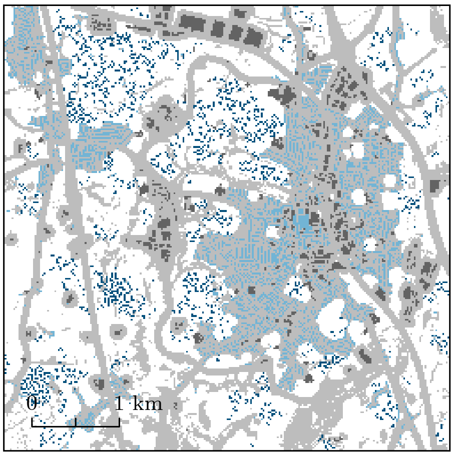
(g) Chorley: optimal spatial configuration for agent *PA*



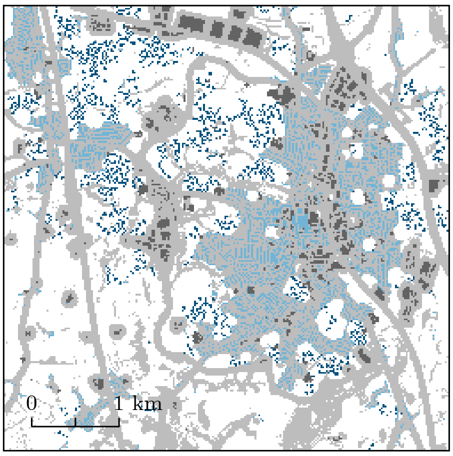
(h) Chorley: optimal spatial configuration for agent *RD*



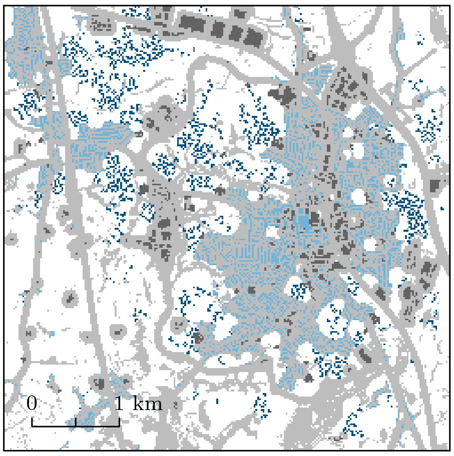
(i) Chorley: real residential development



(j) Chorley: weak negotiation position for agent *PA* ($\eta_{PA} = 0.5$)



(k) Chorley: normal negotiation position for agent *PA* ($\eta_{PA} = 1$)



(l) Chorley: strong negotiation position for agent *PA* ($\eta_{PA} = 2$)

Table 10.2, table 10.3 and table 10.4 give the six spatial indices describing the spatial configuration. Their analysis helps us to confirm the visual analysis discussed above.

In the case of Lingolsheim-Ostwald, the change of the parameters in the evaluation function $\mu_A(X)$ has had only a small effect on the visual outcome, the simulation results look quite similar. But the index values paint a different picture (see table 10.2). We can observe a clearer trend in the number of patches of built area, which is the result of improving the negotiation position of agent *PA*.

The index values for B are rather different from the index values in the first simulation series. The change rate in the average distance to amenities for the optimal spatial configuration for agent *PA* has dropped to about half the value in the first series. The index value of B however still remains bigger than in the case of the real residential development. Agent *PA*'s evaluation of B during the four stages of the optimisation process range from 0.623 to 0.727. The agent is not able to fully optimise the spatial pattern, such that it gets a high value for index B. Furthermore, the index values of the three scenarios show a downward trend with an improving negotiation position of agent *PA*. The values are also much lower than the values that have been found in the first simulation series. This confirms the conclusion of the visual analysis, residential development has emerged closer to the public and commercial services within the built area. Also, the value of B drops significantly with an improved negotiation position of agent *PA*. The latter trend does not appear from the visual analysis of the simulation results.

Moreover, the range between optimal mixity for agent *PA* and the optimal mixity for agent *RD* has become smaller. The index values that emerge from the three scenarios fall within this range, and increase with an improved negotiation position of agent *PA*.

The index measuring the density of the agents' optimal spatial configuration is lower than α in the agents' evaluation function of D and E. A possible explanation is that the density is measured in the number of empty cells in the cell's 8-cell neighbourhood. Moreover, the density at the level of a single cell is discrete. Especially, since $\alpha_D = 5.5$ and $\alpha_E = 6.5$ different average densities could still give the same evaluation. It is however remarkable that the density value remains almost constant with an improving negotiation position of agent *PA*.

The values of G and H remain largely unchanged, compared to the results from the first simulation series. For H this is expected, because the parameters α_H and β_H have not been changed. However, an increase of the values of G is expected. Loosening the evaluation function only resulted in a small increase of the average distance to open area. A possible explanation is that a small average distance to open area from residential development forms only a small constraint for the optimisation of other indices. Moreover, a spatial pattern of residential development can be optimal from many different perspectives at the same time including an optimal average distance to open areas from new residential development.

	real residential development	outcome of the optimisation process		simulation scenarios		
		agent PA	agent RD	$\eta_{PA} = \frac{1}{2}$	$\eta_{PA} = 1$	$\eta_{PA} = 2$
change in the total number of patches (A)	-14.81 %	-25.93 %	37.04 %	-3.704 %	-20.37 %	-27.78 %
change in the average distance to amenities (B)	12.70 %	22.51 %	68.80 %	38.22 %	32.11 %	23.58 %
mixity of low-rise and high-rise residential development (C & F)	0.002297	0.09433	0.001534	0.01227	0.03451	0.08129
density—average number of empty cells in a cell's neighbourhood (D & E)	5.686	5.044	6.205	5.568	5.580	5.476
average distance to open area from new residential developments (G)	94.87	40.90	28.85	38.01	40.34	43.61
number of patches of new residential developments (H)	137.0	43.00	46.00	36.00	37.00	39.00

***Table 10.2** – The index values of six spatial configuration of the residential development in Lingolsheim-Ostwald: the real residential development, the agent's optimal spatial configuration and three simulation scenarios*

	real residential development	outcome of the optimisation process		simulation scenarios		
		agent PA	agent RD	$\eta_{PA} = \frac{1}{2}$	$\eta_{PA} = 1$	$\eta_{PA} = 2$
change in the total number of patches (A)	-13.64 %	-49.24 %	-1.515 %	-31.82 %	-48.49 %	-48.49 %
change in the average distance to amenities (B)	21.48 %	10.62 %	44.60 %	34.13 %	13.68 %	11.01 %
mixity of low-rise and high-rise residential development (C & F)	-	-	-	-	-	-
density—average number of empty cells in a cell's neighbourhood (D & E)	6.210	5.199	6.604	5.644	5.476	5.394
average distance to open area from new residential developments (G)	69.96	48.42	31.92	42.06	47.55	45.48
number of patches of new residential developments (H)	141.0	66.00	86.00	65.00	63.00	72.00

Table 10.3 *– The index values of six spatial configuration of the residential development in Chorley: the real residential development, the agent's optimal spatial configuration and three simulation scenarios*

	real residential development	outcome of the optimisation process: agent PA	agent RD	simulation scenarios: $\eta_{PA} = \frac{1}{2}$	$\eta_{PA} = 1$	$\eta_{PA} = 2$
change in the total number of patches (A)	−7.101 %	−24.56 %	14.50 %	−3.846 %	−12.72 %	−21.60 %
change in the average distance to amenities (B)	−2.665 %	3.250 %	28.14 %	14.56 %	9.541 %	3.817 %
mixity of low-rise and high-rise residential development (C & F)	0.0008437	0.1042	0.	0.01186	0.04068	0.08644
density—average number of empty cells in a cell's neighbourhood (D & E)	5.944	5.286	6.743	6.209	6.169	5.586
average distance to open area from new residential developments (G)	82.09	30.38	22.41	30.25	30.73	33.94
number of patches of new residential developments (H)	49.00	106.0	129.0	109.0	86.00	84.00

Table 10.4 *– The index values of six spatial configuration of the residential development in Malden-Groesbeek: the real residential development, the agent's optimal spatial configuration and three simulation scenarios*

Similar to the case of Lingolsheim-Ostwald, the change of the parameters in the evaluation functions has had only a little effect on the value of A measured in the simulation results in the case of Chorley.

In contrast to the case of Lingolsheim-Ostwald, the value of B (the change of the average distance to amenities) in the optimal spatial configurations of agent PA and agent RD form a range that includes the index value of B found for the real residential development. In comparison to the first simulation series the value of B in the optimisation result of agent PA has decreased. The index value decreases (which corresponds to an improvement of the accessibility to public and commercial services) with an improving negotiation position of agent PA. The visual analysis of the simulation results suggested that a bigger difference between the scenario with a normal agent PA and the scenario with a strong agent PA (see figure 10.3k and 10.3l). Yet the index value of B in case of the real residential development falls between the values of B found for the scenarios with a weak agent PA and a normal agent PA.

The values of indices D and E for the optimal spatial configuration come close to the optimal values (α_D and α_E). For the results of the different simulation scenarios the density index remains almost constant with the changing negotiation position of agent PA. The reason for this behaviour is not clear.

The changes in the values of G and H compared to the values found for the results of the first simulation series are similar to the changes found in the case of Lingolsheim-Ostwald.

In the case of Malden-Groesbeek the index value of A has changed in the optimal spatial configuration of agent PA compared to the first simulation series. This has resulted in a steeper decrease in the number of patches of built area. Where in the first simulation series the index value in the case of the real residential development falls between the scenario with a normal negotiation position of agent PA and the scenario with a strong negotiation position of agent PA. The value now falls between the scenario with a weak negotiation position of agent PA and the scenario with a normal negotiation position of agent PA.

The value of index B has decreased for the optimal spatial configurations of both agents, as well as for the simulation results. Similar to the first simulation series, the value of B in the case of the real residential development remains smaller than the values of the PARDISIM simulation results. The value of B found for the optimisation result for agent PA, as well as the value of B in the scenario with a strong negotiation position for agent PA, get very small.

The optimal spatial configurations for both agents result into values for indices D and E that are close to the optimal values set in the parameters α_D and α_E. The value of the density index decreases (which means the density increases) as the negotiation position of agent PA improves. Malden-Groesbeek is the only case study that shows this behaviour. It is unclear if, and to which extent, this can be attributed to the discrete character of the index at the cellular level: the index value at the cell level is a round figure (e.g. 5 or 6) whereas the target figure at the level of the whole study area is not a round figure (e.g. 5.25 or 5.5). It may occur that PARDISIM always chooses a round figure equal to 5 at the cell level even if the target figure is 5.5 at the level of the whole study area.

The mixity index (C and F) behaves in the case of Malden-Groesbeek in a similar manner as in the case of Lingolsheim-Ostwald. Similarly, the value of G in the simulation results is much lower than found for the spatial configuration of the real residential development, which is similar to Lingolsheim-Ostwald and Chorley. The parameters α_H and β_H remained unchanged and thus the values that resulted from the optimisations and simulations with PARDISIM also remained similar to the results found for the first simulation series.

A comparison of the three case studies reveals similar issues as in the first simulation series, most notably concerning the indices G and H. Figure 10.3f and figure 10.3l illustrate a compact residential development in Lingolsheim-Ostwald and Chorley, while the residential development in the simulations of Malden-Groesbeek remains dispersed. Nevertheless the values of B for Lingolsheim-Ostwald, and to a lesser extent for Chorley, are high, which corresponds to a poor accessibility, whereas the value of B for Malden-Groesbeek is much lower and thus the evaluation is much better (Figure 10.3a and 10.3g).

This seems to contribute to the earlier hypothesis that if for existing residences the accessibility of public and commercial services is good, new residential developments have to be located close to public and commercial services in order not to cause a poor value for B for the simulated residential patterns. Contrarily, if the accessibility of public and commercial services is initially poor, as is the case in Malden-Groesbeek, the location of residential developments far away from public and commercial services have less impact on the value of B. In this last case, the spatial pattern of the residential developments can be dispersed and the value of B remains low.

10.3 Discussion of the results

Two series of simulations with PARDISIM aimed at testing how the negotiation position of agent *PA* affects the spatial configuration of residential development. PARDISIM has been implemented in three case studies: Lingolsheim-Ostwald, Chorley and Malden-Groesbeek. Each case study tests three scenarios in which agent *PA* has either a weak negotiation position, a normal negotiation position, or a strong negotiation position. The simulation results are compared to the optimal spatial configuration of both agents and the spatial configuration of the real residential development.

The comparison of the three senarios for each case study shows that overall the index values change under the influence of a different negotiation position of agent *PA*. The index values also change in the expected direction. This means, that with improving the negotiation position, the values of A, B and D & E decrease and the values C & F and G increase. A notable exception is H, which behaves unexpectedly. For some indices, the index values for one or more simulation results exceed the index values for the optimised spatial configurations.

Moreover, a focus on the simulation results in the second series of simulations reveals for Lingolsheim-Ostwald and Chorley that only small differences exist between the scenario with a normal negotiation position of agent *PA* and the scenario with a strong negotiation position for agent *PA*. Both the visual comparison and the comparison of the index values show that the differences between both scenarios are small. The differences between the scenario with a weak negotiation position of agent *PA* and the scenario with a strong negotiation position of agent *PA* are however stronger.

Increasing the gap between the agents' negotiation position may lead to more contrast in the simulation results. However, at this stage of the research the values $\eta_{PA} = \frac{1}{2}$ and $\eta_{PA} = 2$ are the limits of the negotiation position of agent *PA*. weakening the negotiation position further will result in agent *PA* immediately accepting the optimal spatial configuration of agent *RD*. A better negotiation position of agent *PA* will restrict the model too much in finding counter propositions in the negotiation process.

In the first series of simulations the spatial pattern of residential development is dispersed in all three cases and in all scenarios. After changing seven of the eight evaluation functions, the optimisations and simulations of residential development for Lingolsheim-Ostwald and Chorley produce realistic spatial patterns. This behaviour is mostly attributed to the change of the evaluation of the change in the average distance to public and private services and open areas (index B). These two cases therefore allow us to realistically compare the simulation results with the spatial pattern of real residential developments. Nevertheless, the index values found for the real residential development and the index values found for the simulation results remain quite different.

In Malden-Groesbeek, the change of the evaluation functions has not the desired effect. The reason for this is that the accessibility to public and commercial services in Malden-Groesbeek is initially much worse than in Lingolsheim-Ostwald and Chorley.

Other changes to the evaluation functions also have an effect. A small shift in the evaluation functions $\mu_D(X)$ and $\mu_E(X)$ results in a dramatic drop in the average number of empty cells in the neighbourhood of a cell allocated to residential development. The reason for this behaviour is unclear, however, it is assumed that it can be partly attributed to the discrete nature of the index at cellular level. The mixity index (C and F) cause the high-rise residential development to disperse. This results in a unrealistic spatial pattern of high-rise developments. Changing the evaluation function in the second series of simulations does not change that. The behaviour of the change of the number of patches of built area (A) and the number of patches of residential development (H) need further investigation.

Chapter 11

Conclusion

In this thesis, we suggest that the form of residential developments can be linked to local, regional and national institutions. Development actors, e.g. planning athorities, residential developers, financer, are responsible for the planning, development and implemenation of new residences, which serve as a possible location for residents to settle.

Based on this hypothesis, we took an institutional approach in the development of PARDISIM. Rather than the bottom up approach characteristics of many micro-simulation models of the residential development process, PARDISIM takes a top down approach. The land use in cells is decides upon at a global level.

PARDISIM is tested in three case studies in France, England and the Netherlands. The results of the first simulations proves that PARDISIM is capable of producing realistic spatial patterns of residential development. However, we have not yet been able to simulate and analyse the effect of the negotiation position of agents on the spatial pattern of residential development.

Several reasons may explain the inability to identify the negotiation position of the development actors. Identifying them may allow us to overcome some of the model limitations. First, PARDISIM produces raster maps which present the spatial pattern of simulated residential developments. Here we have visually analysed these maps and have compared them using the spatial indices used in PARDISIM. These analyses are unsufficient to investigate the link between the power balance between development actors and the form of residential developments. A spatial analysis using other more accurate spatial indices would perhaps help to better analyze the simulation results.

Second, the model only implements the negotiation between agents. However, development actors are assumed to influence each other through different means. In particular, the definition of planning zones, which restrict or favour residential developments at certain locations, clearly influences the process of residential development. It would be interesting to discuss the difference between simulated and real forms of residential development in view of all other actor tools and actions that could have an influence.

Third, in chapter 4 the agent-role model is used to identify and analyse the behaviour of the agents in the residential development processes in France, England and the Netherlands. This agent-role model presents the residential development process as a system of many negotiation processes. It divides the development process in specific stages and argues that in each stage the power balance differs between the agents. PARDISIM simplifies this process to a single negotiation process. Adding a multi-scalar definition of the residential development process concept to PARDISIM might improve the interest of the simulation results.

We believe the development of PARDISIM has contributed to the modelling and simulation of urban processes. PARDISIM takes a top down approach, rather that the bottom up approach in traditional micro-simulation models. It illustrates that an institutional approach in the simulation of residential developments can produce realistic spatial patterns without the implementation of residential location choices. Like in micro-simulation models, the decision rules are derived from real world objectives. Moreover, the decision rules of the agents in the model are based on indices that are calculated at either cellular level or global level.

PARDISIM is designed to be used in France, England and the Netherlands. These three countries have different planning systems and institutions. Par default, the model is designed as a universally applicable simulation model of the residential development process. It is expected that, PARDISIM can be used for the simulation of residential development in many more planning systems, or at least can easily be adapted to do so. Moreover, it is designed to be simulate, analyse and compare the residential development under the influence of different planning systems and their related institutions.

Finally, PARDISIM uses a uniquely small cell size. The size of a cell corresponds to the size of an individual parcel. Hence, the subject of negotiation between agent *PA* and agent *RD* is the allocation of cells to individual houses. As a result, building density is measured based on the spatial distribution of the cells in the raster.

PARDISIM has illustrated that it is capable of producing a realistic spatial patterns of residential developments. However, there remain many limitations. The interaction between actors in the residential development process can appear in many forms; actors can exchange land, compete over land, cooperate in a land development, etc. In addition, local planning authorities have public planning tools, like zoning, that allow them to restrict the behaviour of residential developers. Moreover, development actors can spatially differentiate their interactions. In PARDISIM, these interaction are abstracted to negotiation between agents. Based on the actors' ascendancy in the different interactions, the agents in PARDISIM obtain a negotiation position. As a result actors with a very different behaviour are represented by the same type of agent.

Also, PARDISIM distinguises between cells that represent different building types, but does not take into account the number of homes or households that exist within the space of one cell. The number of homes per cell can vary from one or two in case of detached or semi-detached houses to many in case the cell represents part of an apartment building. PARDISIM threre measures building density, however, the actors represented by the agents in the model rather are interested in the density of individual homes or households. Moreover, independent of their location, whether in the city centre or in rural area, no distinction exists between the cells.

Finally, in PARDISIM the growth of the number of cells is fixed in the model. Each negotiation round, the agents negotiation on the allocation of the same number of cells to the allocation of residential development. By design, the agents always come to an agreement. PARDISIM misses an important characteristic of the residential development process (and can be found in many interactions). Normally, the number of developments the agents agree on should drop in case one of the agents get to restrictive.

Simulations with PARDISIM show some promising results, the model has the potential to simulate the residential development process with different negotiation positions of development actors. However, thorough testing of PARDISIM still remains necessary. The presented simulations and analyses only briefly explore the limits and capabilities of PARDISIM. A starting point for further testing is a quantitative analysis of the simulation results. A quantification of the simulation results with the use of spatial indices allows the comparison of different scenarios and objectively determine of the negotiation position has an impact. Furthermore spatial statistics can in a second stage determine the significance of the differences between the simulation results of the different scenarios.

Also, a sensitivity analysis could contribute to the interpretation of the simualtion results. Such an analysis can test if PARDISIM consequently produces similar results and how the simulation results are affected by changes in the parameters. These analyses will contribute to making PARDISIM more robust. But it also allows to determine if differences between the simulation results of different scenarios can be attributed to the differences in the parameters or to a variation caused by the working of PARDISIM.

The agents' evaluation of the spatial configuration is central to PARDISIM. Moreover, the analysis of the simulations results illustrate that the accurate definition of the evaluation of the spatial pattern is important to produce results. The analysis and evaluation of the spatial pattern by agents in PARDISIM can be improved in several ways.

Chapter 10 illustrates the impact of changing the parameters in the evaluation functions. PARDISIM was capable to produce a realistic spatial pattern in two of the three case studies. In the case of Malden-Groesbeek, the spatial pattern remained dispersed because the definition of some of the spatial indices depend on the existing spatial pattern. More specifically, indices that are defined as the relative change of a spatial characteristic of the global spatial configuration depend on the existing spatial pattern. Hence to produce a realistic pattern of residental development, the value of the parameters in the evaluation function needs to be adapted to the spatial configuratie in the tested study area. Moreover, in the case of Malden-Groesbeek, the values of α_B and β_B (where B measures the relative change in the average distance to public and commercial services) should have been adapted to the case study.

Alternatively, the agents' analysis and evaluation of the spatial pattern of residential developments would better use spatial indices that are independent of the spatial structure. This will make the comparison of the simulation results between case studies easier, as it excludes the parameters as a cause for the differences in the simulation results. Hence, in future iterations of PARDISIM, focus should be on testing different spatial indices for the agents' analysis and evaluation of the spatial pattern. Besides the independence from the existing spatial structure, testing should focus on indices that measure a relevant aspect of the spatial pattern of the residential development.

Finally, attention of future design and tesing of spatial indices and evaluation functions should be on the link between the spatial objectives of agents and spatial indices. The spatial objectives of the agents in PARDISIM are defined based on literature research. The spatial objective of local spatial planning authorities can also be retreived from local policy documents. However, the available information is scarce, especially on the spatial objectives of commercial residential developers. The further development of PARDISIM would benefit from an alternative approach, which combines the simulation and analysis of a case study with an investigation into the behaviour of local residential development actors. Information on the local behaviour can be obtained from surveys among the development actors and interviews of local experts.

A final issue we would like to discuss is the link between the agents' spatial objectives and the power balance between the agents. In the tested scenarios, the agents in PARDISIM both had equal interest in all four (or three in the case of Chorley) spatial objectives. In contrast, the real residential development in the case studies areas seem not to be the result of an interaction between agents with a uniform interest for all spatial objectives. For example, the mixity in the real residential development is very low, whereas the form of the spatial pattern seems very important. Moreover, the implementation of the satisfaction function as the weighted mean of the agent's evaluations of the spatial pattern suggests that the agent's spatial objectives are interchangable. In PARDISIM, agent *PA* is indifferent to an increase of the fragmentation of the built area if at the same time mixity increases. It is however the question if a local planning authorities will be indifferent.

The agent-role model, and other models of the residential development proces, suggest that the residential development process is rather a multi-scalar process. Decisions concerning the spatial pattern of residential developments are taken at different scales, whereby decisions at a higher scale set the framework for decisions at a lower scale. For example, the location of residential developments is taken before the design of the residential development, which determines the density of residential development, is initiated. Moreover, based on the conclusion of the analysis of the planning systems of France, England and the Netherlands, the hypothesis is that the balance in the negotiation positions of development actors is different at the different scales in the development process. Future developments on PARDISIM could focus on the implementation of the multi-scalar power balance between development actors.

Appendix A

Simulation parameters

parameter	Lingolsheim-Ostwald	Chorley	Malden-Groesbeek
α_A	6.240251467	6.240251467	6.240251467
β_A	7.324081924	7.324081924	7.324081924
α_B	3.140518145	3.140518145	3.140518145
β_B	4.5775512	4.5775512	4.5775512
α_C	79.27380429	-	21.523365063
β_C	48.50624431	-	40.177820843
α_D	5.75	5.75	5.75
β_D	0.8493218	0.8493218	0.8493218
α_E	6.75	6.75	6.75
β_E	0.8493218	0.8493218	0.8493218
α_F	79.27380429	-	21.523365063
β_F	48.50624431	-	40.177820843
α_G	27	27	27
β_G	0.054930614	0.054930614	0.054930614
α_H	38.940738398	38.940738398	38.940738398
β_H	0.073240819	0.073240819	0.073240819

Table A.1 *– Parameters of the evaluation functions in the first set of simulations*

Lingolsheim-Ostwald		Chorley		Malden-Groesbeek	
$\rho_1 = 0.25$	$\sigma_1 = 0.00$	$\rho_1 = 0.33$	$\sigma_1 = 0.00$	$\rho_1 = 0.25$	$\sigma_1 = 0.00$
$\rho_2 = 0.25$	$\sigma_2 = 0.00$	$\rho_2 = 0.33$	$\sigma_2 = 0.00$	$\rho_2 = 0.25$	$\sigma_2 = 0.00$
$\rho_3 = 0.25$	$\sigma_3 = 0.00$	$\rho_3 = 0.00$	$\sigma_3 = 0.00$	$\rho_3 = 0.25$	$\sigma_3 = 0.00$
$\rho_4 = 0.25$	$\sigma_4 = 0.00$	$\rho_4 = 0.33$	$\sigma_4 = 0.00$	$\rho_4 = 0.25$	$\sigma_4 = 0.00$
$\rho_5 = 0.00$	$\sigma_5 = 0.25$	$\rho_5 = 0.00$	$\sigma_5 = 0.33$	$\rho_5 = 0.00$	$\sigma_5 = 0.25$
$\rho_6 = 0.00$	$\sigma_6 = 0.25$	$\rho_6 = 0.00$	$\sigma_6 = 0.00$	$\rho_6 = 0.00$	$\sigma_6 = 0.25$
$\rho_7 = 0.00$	$\sigma_7 = 0.25$	$\rho_7 = 0.00$	$\sigma_7 = 0.33$	$\rho_7 = 0.00$	$\sigma_7 = 0.25$
$\rho_8 = 0.00$	$\sigma_8 = 0.25$	$\rho_8 = 0.00$	$\sigma_8 = 0.33$	$\rho_8 = 0.00$	$\sigma_8 = 0.25$

Table A.2 *– Weight factors satisfaction functions*

parameter	Lingolsheim-Ostwald	Chorley	Malden-Groesbeek
number of low rise developments	1169	2027	1091
number of high rise developments	137	0	95
ϵ	0.025	0.025	0.025
η_{PA}	1	1	1
η_{RD}	1	1	1
starting agent	agent RD	agent RD	agent RD
number of simulation rounds	4	4	4

Table A.3 *– Negotiation parameters*

parameter	Lingolsheim-Ostwald	Chorley	Malden-Groesbeek
proximity coefficient	100	100	100
stages	30	30	30
iterations	40	60	40
s_0	0.001	0.001	0.001
r	0.9	0.9	0.9
swap probability	0.0067	0.0067	0.0067
number of processors	8	8	8

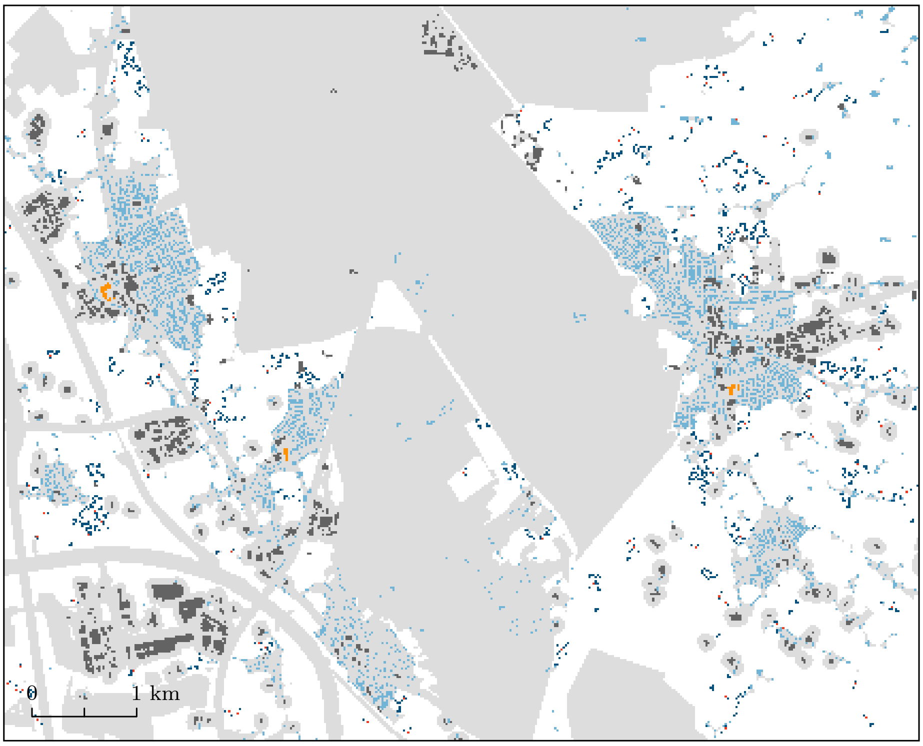
Table A.4 *– Knowledge informed simulated annealing parameters*

parameter	Lingolsheim-Ostwald	Chorley	Malden-Groesbeek
α_A	2.32818	2.32818	2.32818
β_A	8.45086	8.45086	8.45086
α_B	4.804	4.804	4.804
β_B	15.6945	15.6945	15.6945
α_C	1.08169	-	1.05125
β_C	45.5856	-	39.5197
α_D	5.5	5.5	5.5
β_D	0.8493218	0.8493218	0.8493218
α_E	6.5	6.5	6.5
β_E	0.8493218	0.8493218	0.8493218
α_F	1.08169	-	1.05125
β_F	45.5856	-	39.5197
α_G	18.72075441	18.72075441	18.72075441
β_G	0.018310204	0.018310204	0.018310204
α_H	38.940738398	38.940738398	38.940738398
β_H	0.073240819	0.073240819	0.073240819

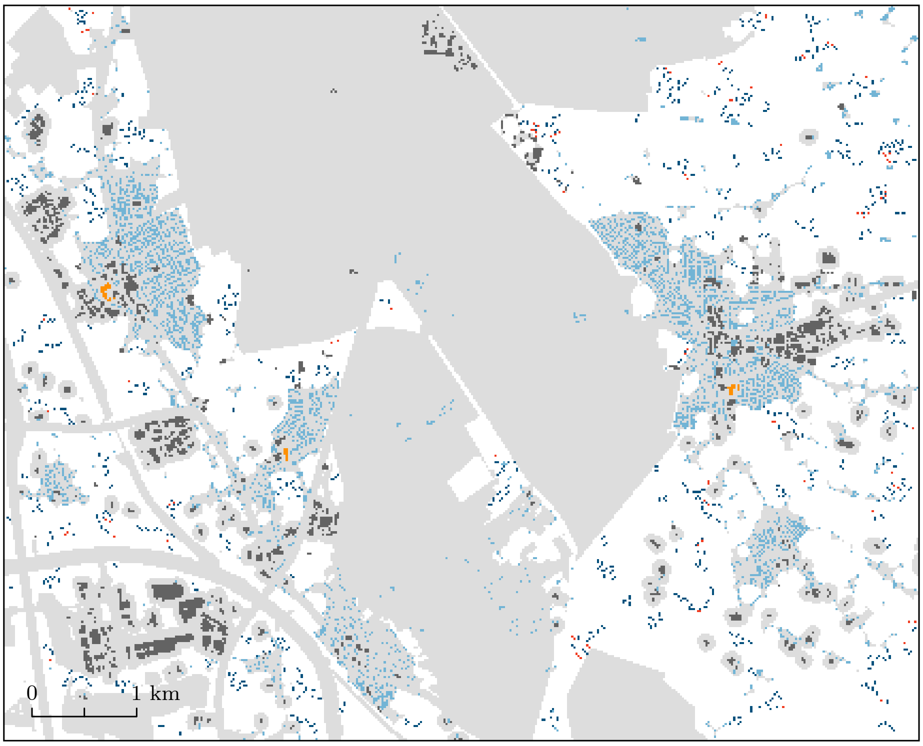
Table A.5 *– Parameters of the evaluation functions in the second set of simulations*

Appendix B

Results first set of simulations: Malden-Groesbeek

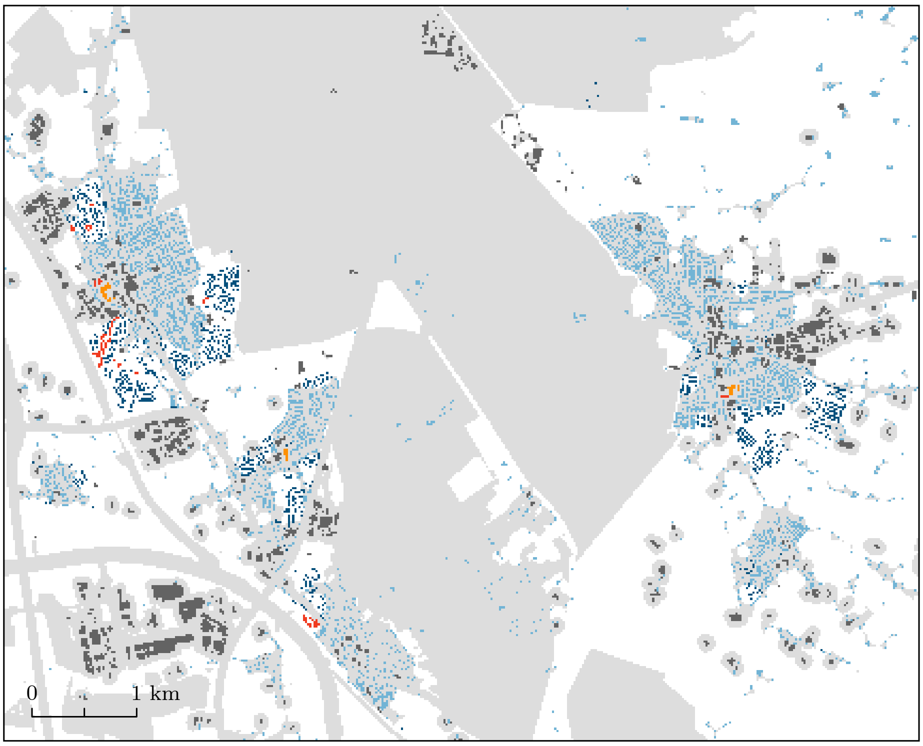


(a) Malden-Groesbeek: optimal spatial configuration for agent *PA*

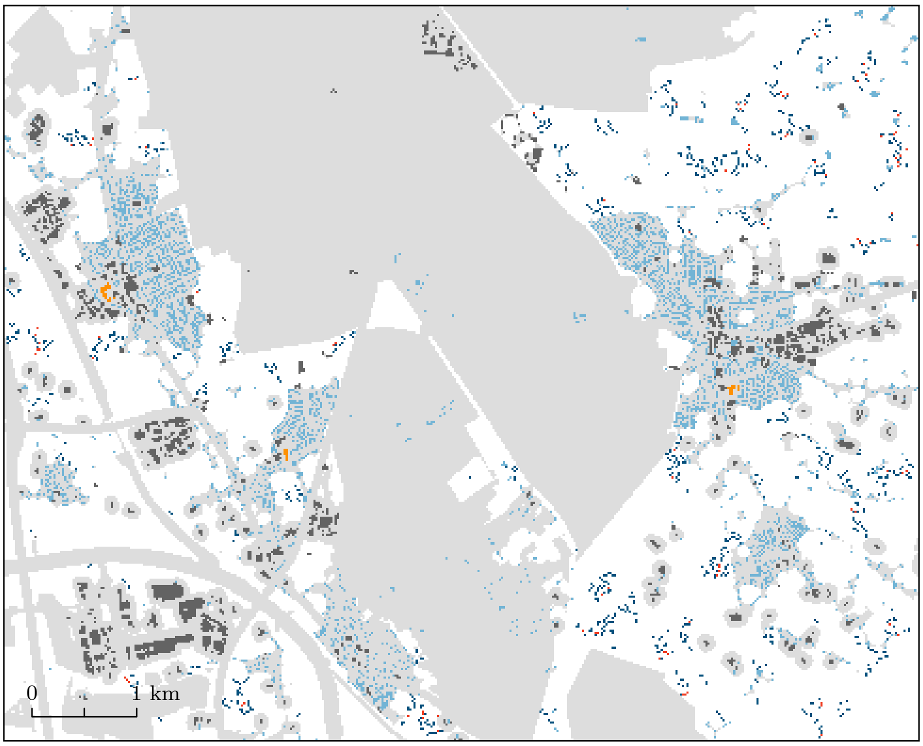


(b) Malden-Groesbeek: optimal spatial configuration for agent *RD*

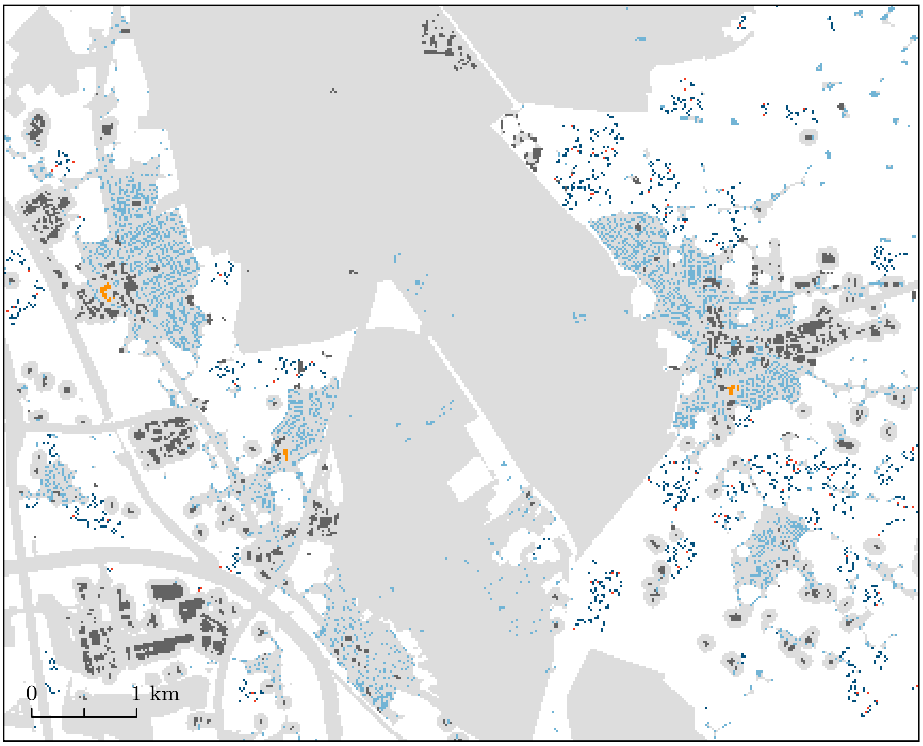
Figure B.1 *– Simulation results for Malden-Groesbeek*



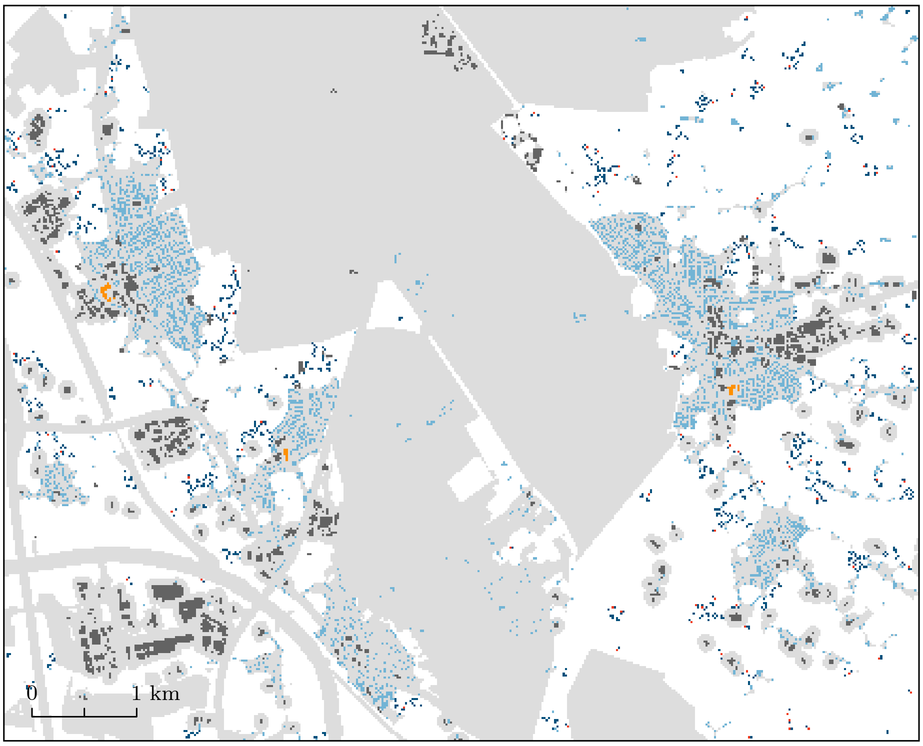
(c) Malden-Groesbeek: real residential development



(d) Malden-Groesbeek: weak negotiation position for agent PA ($\eta_{PA} = 0.5$)



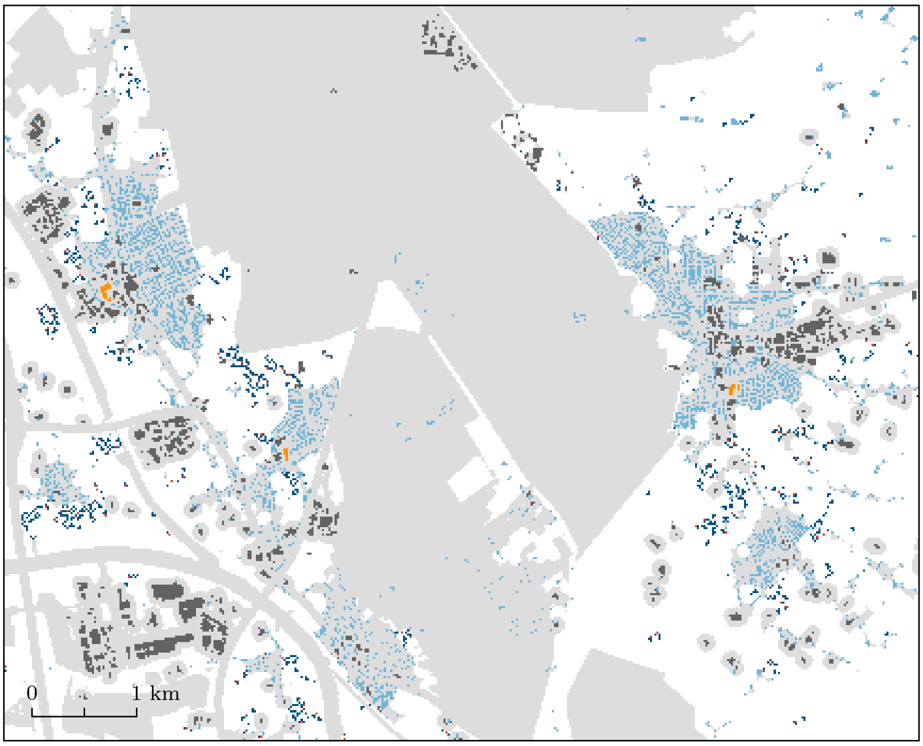
(e) Malden-Groesbeek: normal negotiation position for agent *PA* ($\eta_{PA} = 1$)



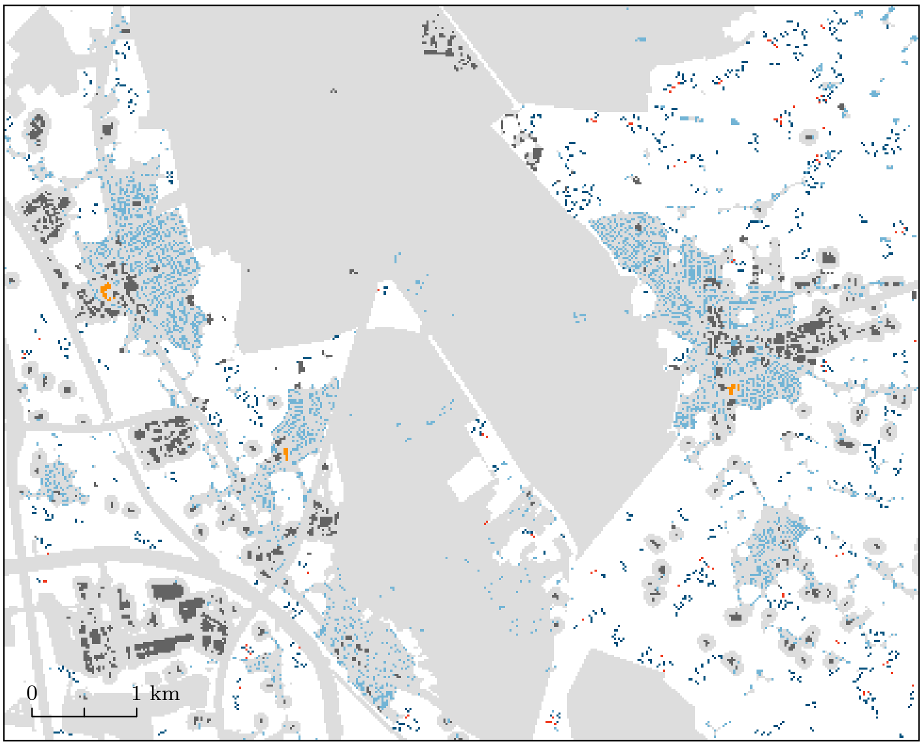
(f) Malden-Groesbeek: strong negotiation position for agent *PA* ($\eta_{PA} = 2$)

Appendix C

Results second set of simulations: Malden-Groesbeek

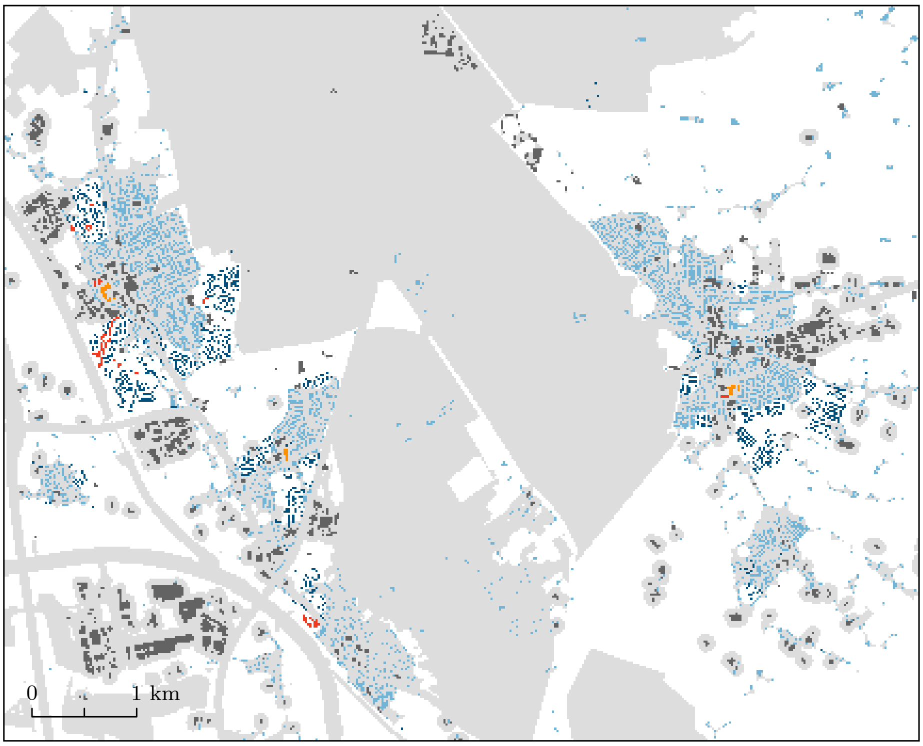


(a) Malden-Groesbeek: optimal spatial configuration for agent *PA*

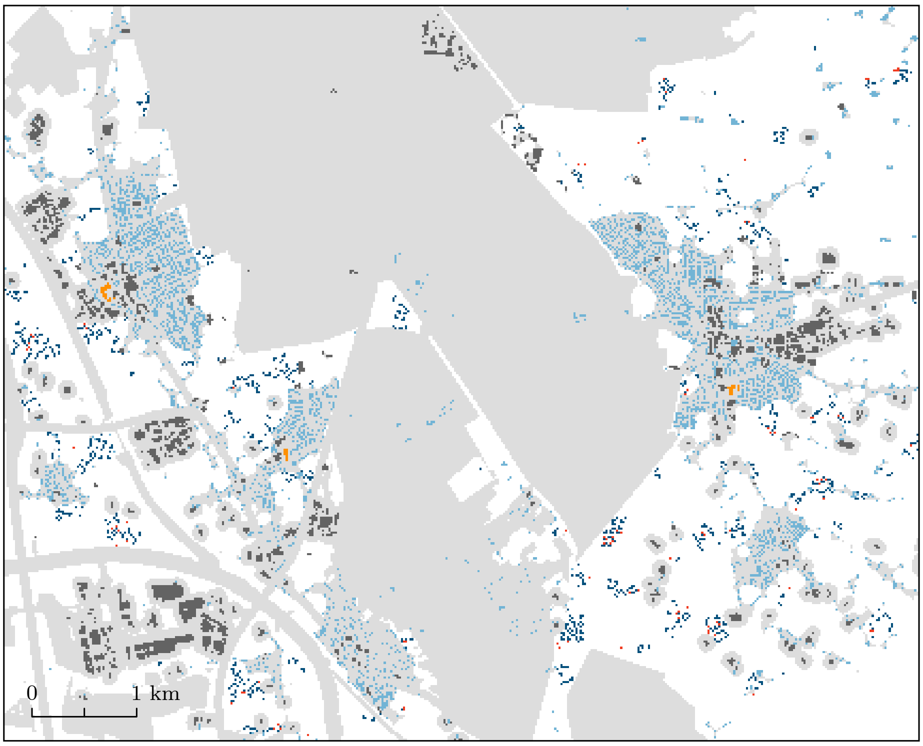


(b) Malden-Groesbeek: optimal spatial configuration for agent *RD*

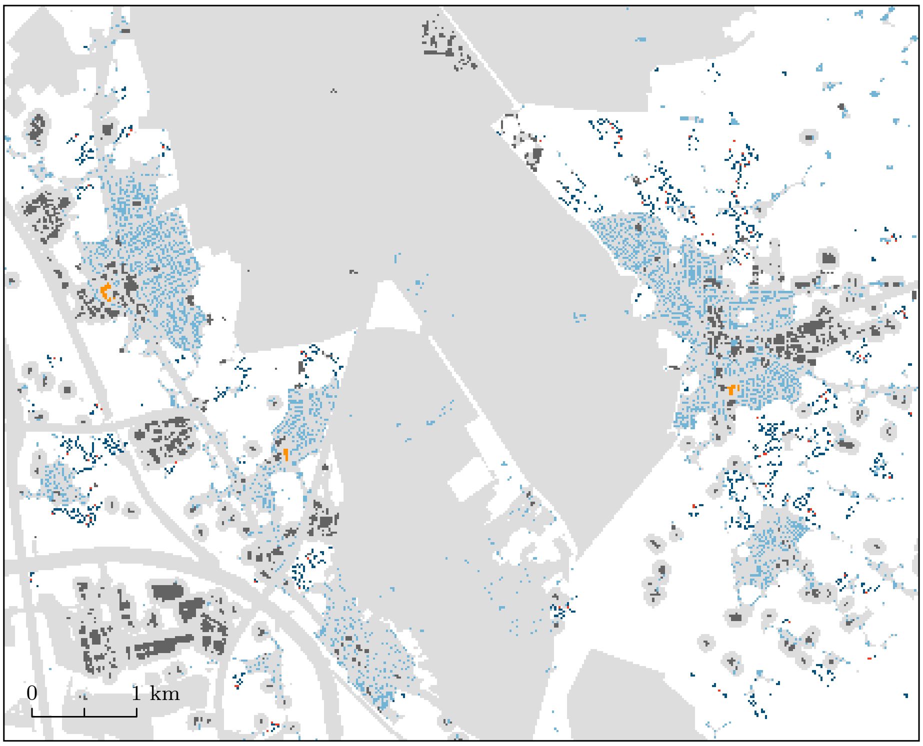
Figure C.1 *– Simulation results for Malden-Groesbeek*



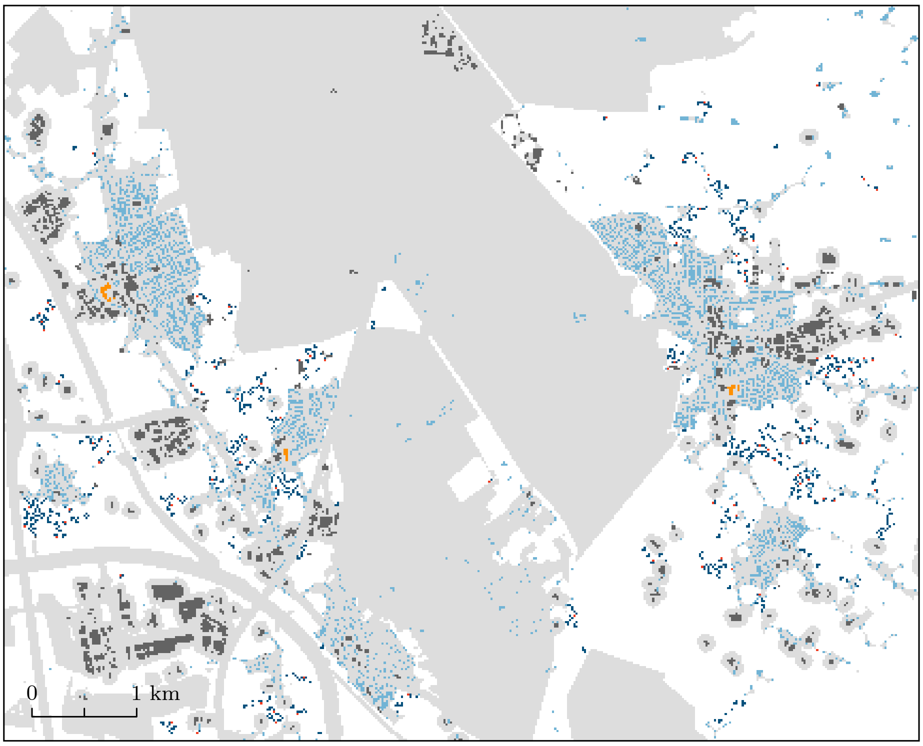
(c) Malden-Groesbeek: real residential development



(d) Malden-Groesbeek: weak negotiation position for agent *PA* ($\eta_{PA} = 0.5$)



(e) Malden-Groesbeek: normal negotiation position for agent *PA* ($\eta_{PA} = 1$)



(f) Malden-Groesbeek: strong negotiation position for agent *PA* ($\eta_{PA} = 2$)

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Abstract
This thesis presents PARDISIM, a simulation model that takes an institutional economic approach in the simulation of the residential development process. Rather then modelling the residential development as the result of location choices at household level, PARDISIM focusses on the objectives and interactions of development actors. The idea behind this approach is that development actors, including public planning authorities, play an important role in the process of residential development. The model is top-down whereas the most recent efforts by other scholars focus instead on a bottom-up approach. Initial testing shows that PARDISIM is capable of producing realistic spatial patterns.

Keywords: Urban Planning, Residential Development, Modeling, Simulation, Multi-Agent System

Résumé
Cette thèse présente PARDISIM, un modèle de simulation qui propose une approche économique institutionnelle pour la simulation du processus de développement résidentiel. Plutôt que de modéliser le développement résidentiel comme le résultat de choix de localisation au niveau des ménages, PARDISIM met l'accent sur les objectifs et les interactions des acteurs du développement résidentiel. L'idée est que les acteurs du développement, y compris les autorités publiques d'aménagement, jouent un rôle important dans le processus de développement résidentiel. L'approche est donc top-down et se démarque des approches habituelles bottom-up. Les premiers résultats obtenus montrent que PARDISIM est capable de produire des configurations spatiales réalistes.

Mots Clés: Aménagement Urbain, Développement Résidentiel, Modélisation, Simulation, Système Multi-Agents

Samenvatting
Dit proefschrift presenteert PARDISIM, een simulatiemodel dat een institutioneel economische benadering toepast in de simulatie van de ontwikkeling van woningbouw. In plaats van deze ontwikkeling te definiëren als gevolg van locatie keuzes op huishoudniveau, richt PARDISIM zich op de doelstellingen en de interacties van actoren met een professioneel belang in de stedelijke ontwikkeling. Het idee achter deze aanpak is dat deze actoren, waaronder ondermeer locale overheden, een belangrijke rol spelen in het proces van de ontwikkeling van woningbouw. Het model is top-down terwijl de meest recente inspanningen in de literatuur een bottom-up benadering toepassen. Uit de eerste testresultaten blijkt dat PARDISIM in staat is realistische, ruimtelijke configuraties te produceren.

Sleutelwoorden: Stedelijke Planning, Woningbouw, Modellering, Simulatie, Multi-Agent Systeem