PLUREL

Sustainability
Impact Assessment

Module 4

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PERI-URBAN LAND USE RELATIONSHIPS – STRATEGIES AND SUSTAINABILITY ASSESSMENT TOOLS FOR URBAN-RURAL LINKAGES, INTEGRATED PROJECT,
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D4.2.1

Agent narratives within ABMland

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SIXTH FRAMEWORK PROGRAMME

Contents

Abstract

Objectives / aims

This document aims to provide an overview of the framework for the construction of ABMland, with further details about the generic agent categories and model implementation strategy.

Methodology

This report provides the outcomes of an initial scoping study of the key agents who will make up the PLUREL ABM, ABMland. It describes the principles of each generic agent group and provides the first thinking about how, technically, to construct the model.

Findings

We recognise a range of hierarchically-related land use classes, including residential properties, infrastructure, commercial buildings, urban open space, rural uses, public buildings. ABMland will be designed to simulate change in the classes within the category of the built environment.

We recognise two generic groups of agents who will affect the land use classes presented above: consumers and mediators. Consumer agents actively use the land for different activities and are sub-divided into: residents, service suppliers and business people. Mediators affect the supply of land for consumers to engage in their land use activities. They are sub-divided into developers, planners and pressure groups. The dynamics of land use change is determined by the supply and demand of land which is controlled by the relationships between these different groups of agents.

Classification of results/outputs:
For the purpose of integrating the results of this deliverable into the PLUREL Explorer dissemination platform as fact sheets and associated documentation please classify the results in relation to spatial scale; DPSIR framework; land use issues; output indicators and knowledge type.

Spatial scale for results: Regional, national, European	Regional/European
DPSIR framework: Driver, Pressure, State, Impact, Response	Driver/Pressure/State/Impact/Response
Land use issues covered: Housing, Traffic, Agriculture, Natural area, Water, Tourism/recreation	Housing, Traffic, Agriculture, Natural area, Water, Tourism/recreation
Scenario sensitivity: Are the products/outputs sensitive to Module 1 scenarios?	No
Output indicators: Socio-economic & environmental external constraints; Land Use structure; RUR Metabolism; ECO-system integrity; Ecosystem Services; Socio-economic assessment Criteria; Decisions	Socio-economic & environmental external constraints; Land Use structure; RUR Metabolism; ECO-system integrity; Ecosystem Services; Socio-economic assessment Criteria; Decisions
Knowledge type: Narrative storylines; Response functions; GIS-based maps; Tables or charts; Handbooks	Tables and charts

How many fact sheets will be derived from this deliverable:	**0**

General introduction

1 The ABM concept in PLUREL

1.1 Preamble

Multi-agent systems, a concept that originated in the computer sciences (i.e. artificial intelligence research) in the 1970s, have recently gained popularity in the social sciences. Some of the recent applications of Agent-Based Modelling (ABM) include: (a) reproducing spatial and demographic features to understand the evolution of society (e.g. Gilbert and Doran 1994; Kohler and Gumerman 2000; Axtell et al. 2002); (b) evaluating economic systems when rational agents and equilibrium conditions are not limiting assumptions (e.g. Axtell 1999; Duffy 2001; Axtell 2002); (c) simulating production decisions to assess adoption of new agricultural practices (Balmann 1997; Berger 2001; Polhill et al. 2001; Balmann et al. 2002, as cited in Parker et al. 2003); and (d) linking human and natural systems at different spatial and temporal scales to understand land use and land cover change (e.g. van der Veen and Rotmans 2001; Parker et al. 2003; Huigen 2004; Evans and Kelley 2004).

The strength of the ABM approach is that it allows modelled representations of the behaviour of a range of different agents that act on the system under consideration. These local agent interactions then generate the system dynamics that result in emergent properties at an aggregate level. The concept of an agent includes not only those individuals who make direct decisions about land use, but also planners and institutions that seek to encourage or constrain certain types of land use development (Acosta-Michlik and Rounsevell, 2005). Thus, a key innovation of the use of ABM in PLUREL will be the aim of '*endogenising'* policy and planning processes within the modelled system. This means that the simulated, future evolution of land use (scenario based) will result in policy responses that guide the evolving urban development in a certain direction.

1.2 The research questions

Module 4 of the PLUREL project will explore the use of ABM in modelling urban land use change in selected case study areas. The purpose of the model is to simulate the transition of land use from being '*non-built'* to '*built'* and from 'built' to 'non-built' by addressing the research question:

How does the real estate market develop as a product of the communication between, and actions of, different group of agents?

Within this overarching question we will also address the questions:

- How do agents behave in terms of their decision-making, interactions, goals and conflicts?
- How can insight into agent behavioural processes inform future scenarios of land use change in Rural-Urban Regions (RUR)?

- Can the ABM be applied to understand change processes as well as spatial patterns in RUR?

This report provides the outcomes of an initial scoping study of the key agents who will make up the PLUREL ABM, *ABMland*. It describes the principles of each generic agent group and provides the first thinking about how, technically, to construct the model.

1.3 Land use classes

In designing *ABMland*, we recognise a range of hierarchically-related land use classes, including:

- Residential properties - houses, apartments
- Infrastructure - transport networks (roads, rail), airports, dumps, water treatment, sea ports
- Commercial buildings - offices, manufacturing industry, hotels, leisure
- Urban open space - parks, cemeteries, allotments, sports grounds, forests, water
- Rural uses - agriculture, forestry, tourism, life style blocks, horticulture
- Public buildings – schools, public offices, libraries, hospitals

ABMland will be designed to simulate change in the classes within the category of the built environment as well as from non-built to built and vice versa, as indicated in Figure 1.

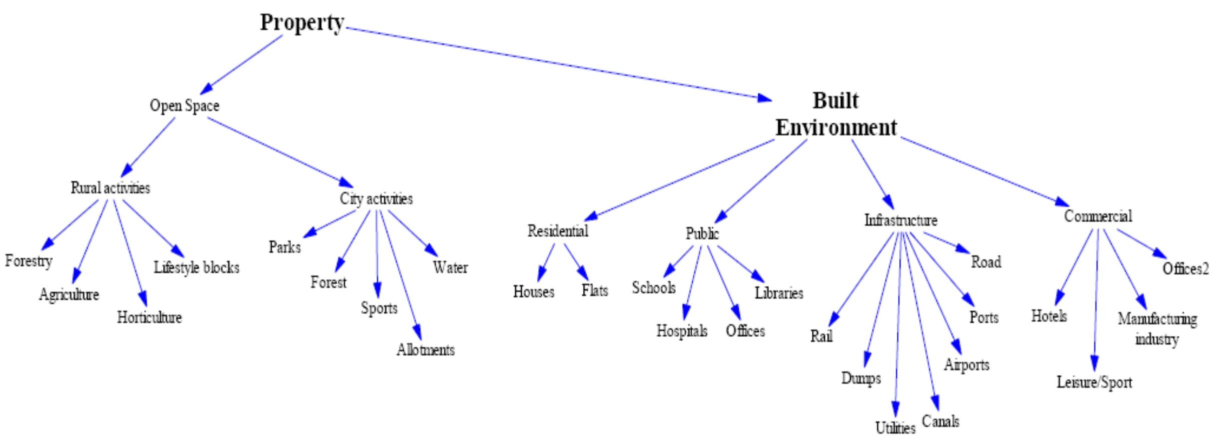
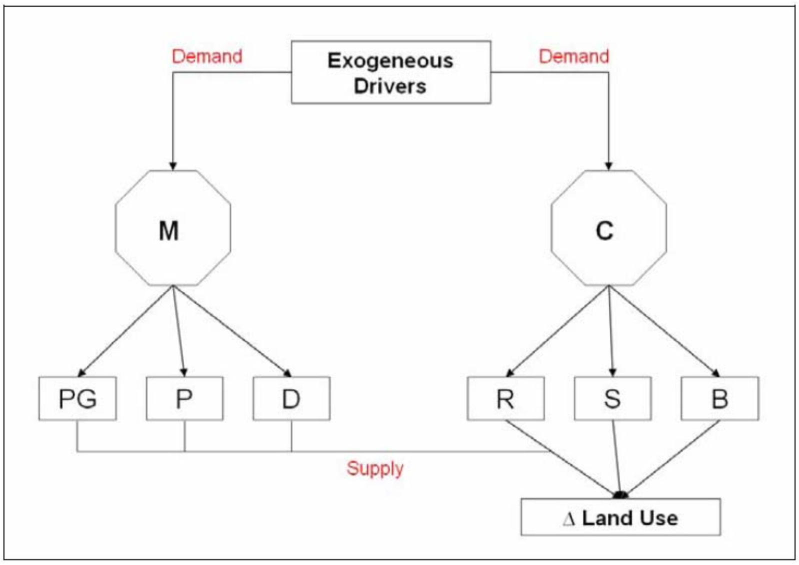


Figure 1. Built and non-built land use categories

1.4 Agents in ABMland

We recognise two generic groups of agents who will affect the land use classes presented above: *consumers* and *mediators* (see Figure 2). Consumer agents actively use (consume) the land for different activities and are sub-divided into: residents, service suppliers and business people. The consumers are responsible for the creation of a demand for land use. Mediators affect the supply of land (in terms both of quantity and location) for consumers to engage in their land use activities. They are sub-divided into developers, planners and pressure groups.

The dynamics of land use change is determined by the supply and demand of land which is controlled by the relationships between these different groups of agents (see Figure 3).



M = Mediator, C = Consumer, PG = Pressure Group, P = Planning Policy, D = Developer, R = Resident, S = Service Supplier, B = Business People

Figure 2. Generic types of agents and their roles in *ABMland*

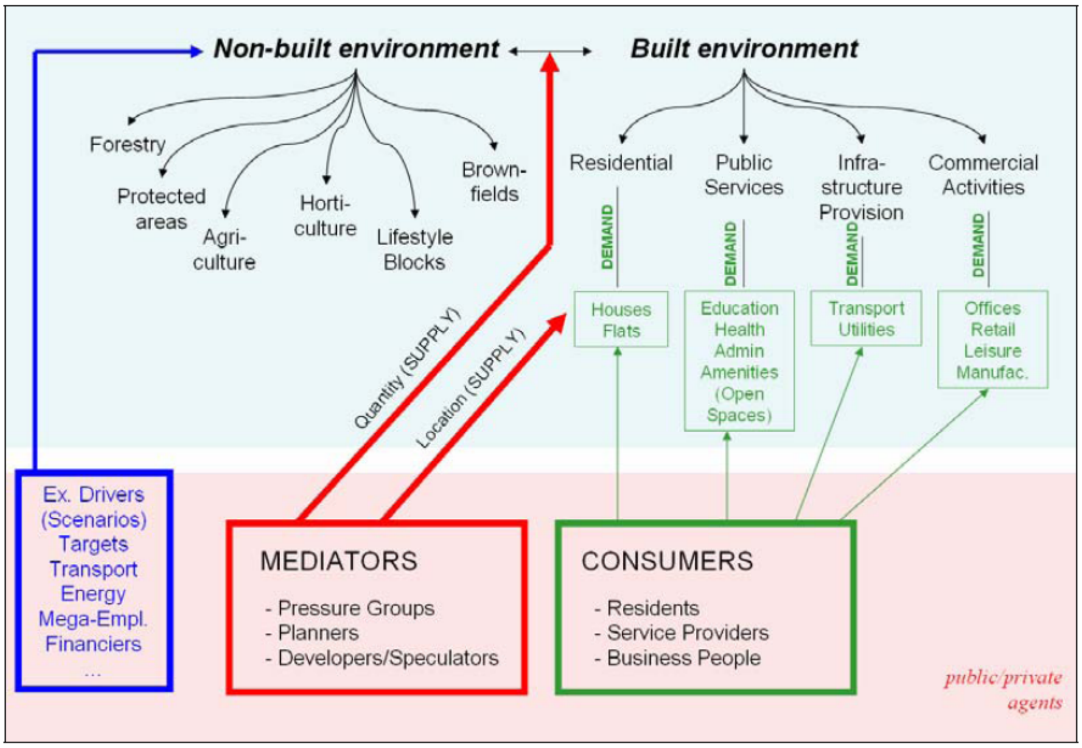


Figure 3. The relationships between mediators and consumers in *ABMland* and their effect on land use

1.5 Agent profiles

The generic categories of *ABMland* agents and their principal interactions are indicated in Figure 4. The following sections provide further discussion of the concepts that underpin each of these agent categories, and how we might treat their behaviour and rules within the model.

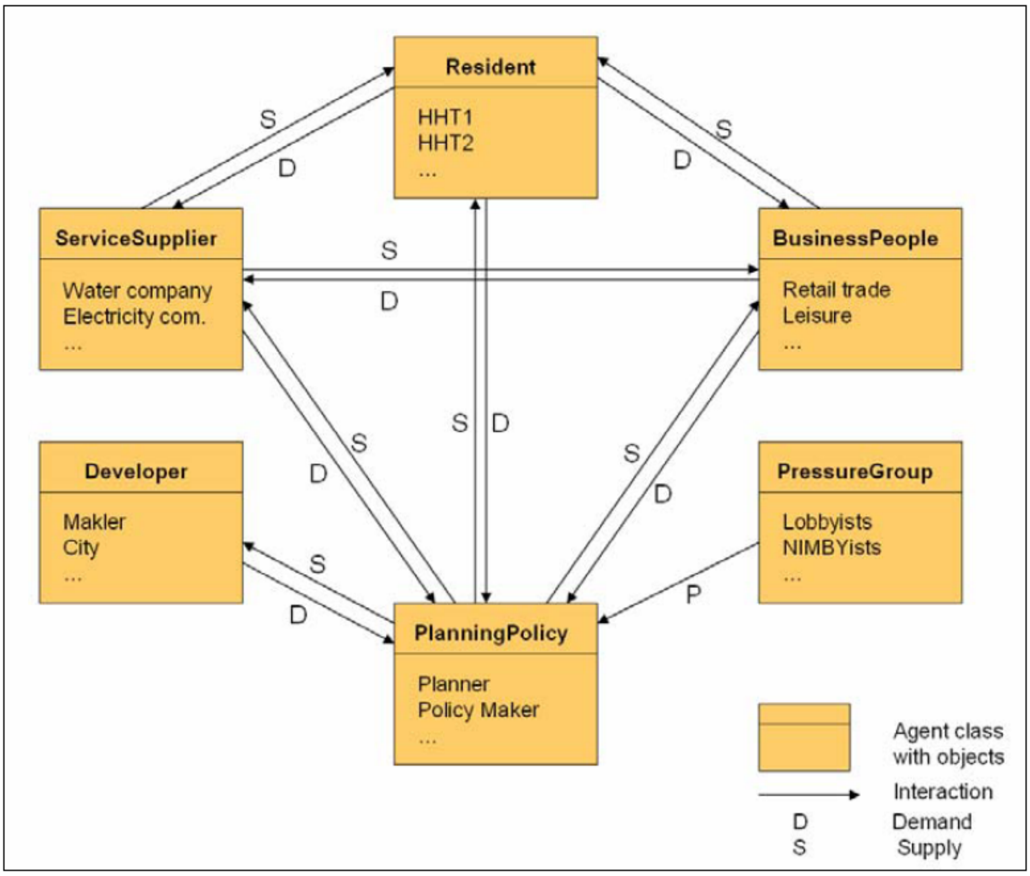


Figure 4. Generic categories of agents and their principal interactions within *ABMland*

Agent descriptions

2 Planning Agents & Planning Policy

2.1 Function within ABMland

Planning Policy and Planning Agents need to be considered together, since although Planning Policy is mostly external to the model, it forms the basis upon which Planning Agents make their decisions about whether or not to grant permission for development.

2.1.1 Planning Policy – Function within ABMland

In ABMland each cell represents a patch of land whose properties after initialisation will depend on a variety of different inputs. The role of the Planning Agents is to mediate those inputs, in accordance with Planning Policy and thus to retain a limited measure of control over the use of any given patch of land. Planning Policy itself would take the form of a look up table which is referred to at runtime by other agents. There is a sense, then, in which for the purposes of ABMland, Planning Policy is exogenous.

In this way, Planning Policy can easily be changed, since it is a case of changing the lookup table rather than the model itself. Each of the cells would also have the Northing and Easting of its south-west corner recorded in the look up table, providing a means of geocoding each cell, and providing a means for each of the other agents to situate themselves geographically on the collection of patches, which would effectively be a dynamic raster map. The remainder of this document deals with Planning Agents. A flow chart showing how planning policy might work may be found in the appendices.

2.1.2 Planning Agents – Function within ABMland

Planning Agents act as the sole mediators between Planning Policy and the other agents in ABMland. Thus while other agents, for example developers, can get information about the current Planning Policy, they cannot influence that policy except by going through the Planning Agents. The Planning Agents are in effect the “human bridge” between the legal documentation that comprises Planning Policy and other human agents.

This in turn means that Planning Agents can vary from completely unbiased conduits for policy to corrupt, bribable, probably murderous entities who would stop at nothing to make a quick dollar, and who would willingly sell their own grandmothers if it meant a free meal in an expensive restaurant. More likely, they will fall somewhere between these two extremes. The point is that within the model, the possibility for planning agents to have a wide range of attributes must be built in.

2.2 *Planning Agent Types & their Profiles*

2.2.1 Overall agent class

Planning Agent types have the following methods:
computeDemandFor*LandUse (will need to compute demand for all land uses, or use a look up table which keeps a record of key indicators)
computeDemandForPermitted*LandUse (will need to compute demand for potential changes of use that would be granted planning permission)
permitChangeOfLandUse (grant planning permission for development)
forbidChangeOfLandUse (do not grant planning permission for development)
negotiateChangeOfLandUse (for the bribable types - may need to be broken down into sub-catiegories)

2.2.2 Agent Types

There is a single Planning Agent Type.

2.3 *Data Import & Export during Runtime*

2.3.1 Data Import

2.3.1.1 …from other agents within ABMland

Data import from other agents will be limited, since Planning Agents will for the most part look to the aggregate statistics (e.g. on housing demand) to understand what is going on. Such data would be sent to look up tables from individual agents. The primary data import from other agents will thus be requests for planning permission, but secondary to this will be offers of finance for infrastructure provision and so forth that might be demanded as a condition for the granting of planning permission.

getRequestForPlanningPermission (from any agent requiring planning permission. In ABMland this will probably only be developers and service providers, but a more fine-grained model would allow anyone, including individuals, to apply for planning permission)
getOfferOfFinance (for example, from a commercial developer)
getOfferOfServices (for example, from a service provider)
getLevelOfSatisfactionOfServiceSuppliers
getLevelOfSatisfactionOfHousingDevelopers
getLevelOfSatisfactionOfPropertyDevelopers
getLevelOfSatisfactionOfHouseholds
(if satisfaction with the process and/or decisions is low, then lobbying will be harder from other agents.)

2.3.1.2 …regarding land use

getLandUseType (this would have to be geocoded - perhaps from the look up table)
getSuitabilityForDevelopment (from look up table)
getPermittedLandUse (from look up table)
In all three cases here, the Planning Agents are in effect surveying the land and then referring back to Planning Policy to find out what would be the permitted development. Planning

Agents would not need to get the adjacent land use type because what is and is not permitted is set out in the look up tables that comprise Planning Policy.

2.3.1.3 …regarding other factors

Other factors are unlikely to directly affect Planning Agents, with the possible exception of a willingness to negotiate, which would be part of the culture (itself exogenous).

2.3.2 Data Exchange within Agent Class

There is only a single type of agent within the Planning Agent Class, although it is possible for there to be multiple instances of this agent type (for example if the geographical area includes more than one planning regime).

2.3.3 Data Export

2.3.3.1 …for other agents in ABMland

Other agents would refer to Planning Policy rather than directly to the Planning Agents. In the event of lobbying, the Planning Agent's willingness to negotiate (see section 2.3.1.3) would be a key consideration, but this would express itself to other agents in terms of it becoming easier to obtain planning permission for a particular development. In other words, Planning Agents would change Planning Policy as a consequence of lobbying by pressure groups (which are coalitions of other agents).

2.3.3.2 …for land use change

Changes to land use would be reflected through Planning Policy.

2.4 Decision Making

2.4.1 Scope of Decision Making

Agent Type	Scope of Decision Making	Influence on Land Use
Planning Agents	Change of Land Use	Change of Planning Policy

2.4.2 Decision Process

2.4.2.1 Trigger of the decision process

Agent Type	Trigger of the Decision Process
Planning Agents	Application for Planning Permission; Proposal to Develop

2.4.2.2 Decision algorithm

Agent Type	Decision Algorithm
Planning Agents	Respond to other agents, either by reference to look up table, or by direct interaction

2.4.2.3 Decision criteria

Agent Type	Decision Criteria
Planning Agents	Can planning permission be granted according to Planning

2.5 Conclusions for Time & Space

2.5.1 Space

Relatively small cells will be needed, perhaps as small as 50 metres by 50 metres (which is still quite large at a quarter of a hectare). Cells this size would require all new housing and commercial development to be on a relatively large scale, so urban infill of small plots, for example, would not feature in the model.

2.5.2 Time

Suggest one year steps.

3 Developer Agents

3.1 Function within ABMland

Developers seek to change land use with the aim of making a profit. They change land use from any use to any other use if such a change of use is:

a) permitted by planning regulations; and,
b) expected to generate a profit.

3.2 Developer Agent Types & their Profiles

3.2.1 Overall agent class

Developer agent types have the following methods:
computeDemandForPermittedLandUse (no point in developing if there is no demand)
computeExpectedProfitForPermittedLandUse (no point in developing if there is no profit to be made – this will need to be broken down further: how much to invest? what rate of return is required? These could possibly be included in the form of look up tables containing current base rates, exchange rates, state of the economy and so forth)
computeExpectedProfitTime (calculates how long it will take to make the required profit. This will probably need to be little more than a simple arithmetical calculation at this stage of ABMland. For example, if the developer spends one million Euro in three years and wants profits of 500,000 Euro, then if they sell the development at the end of three years there would be a three year profit time. Probably it could be even simpler than that!)

3.2.2 Agent Types

Housing Developer
Office Developer

3.3 Data Import & Export during Runtime

3.3.1 Data Import

3.3.1.1 …from other agents within *ABMland*

getPermittedLandUse (or possibly from a look up table)
getDemandForHousing (HousingDevelopers only)
getDemandForOffices (Office Developers only)
More detail might include some of the items in the section describing the ServiceProvider agents.

3.3.1.2 …regarding land use

getLandUse (can this Land Use Type be developed? If no, then look elsewhere; if yes, then proceed)
getAdjacentLandUse (if an empty plot of land is next to a sewage works, housing is much less likely to be profitable; an empty plot of land next to a beautiful park is likely to be very profitable for housing)

getSuitabilityForDevelopment (perhaps from a look up table?)
getPermittedLandUse (This may have to come from a look up table too. The intention here is to reflect the fact that a written document containing planning policy may also contain maps showing which types of development will be permitted where)
NOTE: It may at this stage be best to assume (admittedly simplistically) that an individual cell either is or is not suitable for development (see also section 4).

3.3.1.3 …regarding other factors

The state of the economy is obviously hugely important to developers, since what they are engaged in is, to a considerable extent, speculative. This means that the relevant key indicators will need somehow to be made available to agents, probably in the form of a look up table. The question is what these should be, but they would likely include:
getCurrentRateOfInflation
getCurrentInterestBaseRate
getChangeInEmploymentSinceLastYear (will give an idea of whether unemployment is rising or falling year on year - rising unemployment would send a signal that the economy is not doing well, and that developers will find the going tougher. The construction industry is usually the first industry to suffer in a recession).

3.3.2 Data Exchange within Agent Class

For the purposes of early trials of *ABMland*, Housing and Office developers would not exchange information with one another. However, a more complete ABM would have to allow for this.

3.3.3 Data Export

3.3.3.1 …for other agents in *ABMland*

Developers would need to apply for planning permission, and so would need to export their intentions to the Planning Policy agent(s) and perhaps to Service Providers too.
sendRequestForPlanningPermission (to planning agents, dependent upon whether or not it is worth developing a project. This may need breaking down into sub-categories. (Is send the right term?))

3.3.3.2 …for land use change

Developers can change land use to either housing or offices (depending upon which type of developer they are) if:

- such a change is permitted by planning policy;
- such a change is sufficiently profitable for the developer;
- the developer can obtain permission from the planning agents to develop.

3.4 Decision Making

3.4.1 Scope of Decision Making

Agent Type	Scope of Decision Making	Influence on Land Use
Office Developers	Change of Land Use to Offices	Change Land Use to Offices
Housing Developers	Change of Land Use to Housing	Change Land Use to Housing

3.4.2 Decision Process

3.4.2.1 Trigger of the decision process

Agent Type	Trigger of the Decision Process
Office Developers	Opportunity Arises (implies polling? - NG.)
Housing Developers	Opportunity Arises (implies polling? - NG.)

3.4.2.2 Decision algorithm

Agent Type	Decision Algorithm
Office Developers	Polling for available opportunities; Rational choice algorithm based on potential return on investment.
Housing Developers	

3.4.2.3 Decision criteria

Agent Type	Decision Criteria
Office Developers	What is the potential profit that can be made over what time frame?
Housing Developers	

3.5 Conclusions for Time & Space

3.5.1 Space

Relatively small cells will be needed, perhaps as small as 50 metres by 50 metres (which is still quite large at a quarter of a hectare). Cells this size would require all new housing and commercial development to be on a relatively large scale, so urban infill of small plots, for example, would not feature in the model.

3.5.2 Time

Suggest one year steps.

4 Residents

4.1 Function within ABMland

Resident agents occupy settlement area in *ABMland*. They can change land use as follows:

- Open space (rural activities, city activities) to built area (flat, house)

4.2 Resident agent types and their profiles

Residents are created by a population model (fertility, mortality, migration → cohorts). For calculation purpose, let $\vec{N}$ be a vector of age cohorts *n* of the population at time *t*, and $\vec{N}(t)$ is the transition matrix for each age cohort:

$$\vec{N}(t+1) = S \cdot \vec{N}(t) + \vec{M} = \begin{pmatrix} n_1 & \cdots & n_n \\ s_1 & & \vdots \\ \vdots & \ddots & 0 \\ 0 & \cdots & s_{n-1} \end{pmatrix} \cdot \vec{N}(t) + \vec{M}$$

where $N_i(t)$ is the number of persons in age cohort *i* at time *t*, s_i is the survival (infant mortality) of the cohorts $1,\ldots,n$ (*n* covers an interval of 5 years) and the net-migration *M*. For the implementation of the household type concept defined (partially stochastic) parts of each age-cohort are transferred into a distribution *Φ* of the total population *N* are sorted into *m* household types (agents) with the properties given in Table 1 in the form:

$$H_j(t) = \sum_{i=1}^{n} \Phi_{i,j} N_i(t) \qquad \text{with } \sum_{i=1}^{n} \Phi_i \leq 1$$

where *H* is the number of households, *Φ* the distribution of *n* age cohorts of a population *N* time *t*. Total population number and age cohort distribution can be derived from the household pattern at a time *t* to check the plausibility of the household formation algorithm.

4.2.1 Overall agent class

Residents, based on their overall properties (Table 1) have several methods in common such as:

Housing

- computeDemandForHousesOnCell()
- computeDemandForFlatsOnCell()
- computeNewResidentialBuildingOnCell() *(→ if land owner)* and computeDemandNewResidentialBuildingPermitOnCell()

Service Supply

- computeDemandForEnergyServiceSupplyOnCell()
- computeDemandForWaterServiceSupplyOnCell()
- computeDemandForTransportServiceSupply/DistancePublicTransportOnCell()
- computeDemandForAdministrationSupplyOnCell()

Business

- computeDemandForShoppingSupplyNumberSupermarketsOnCell()
- computeDemandForMedicalSupplyNumberDoctorsOnCell()
- computeDemandForEducationSupplyNumberSchoolsOnCell()

- computeDemandForCulturalSupplyNumberRestaurants/Cinemas/SportStudios/OnCell ()

Attractiveness / Preferences

- computeSatisfactionOnCell() → level of (dis-)satisfaction with current state on a cell, index relates to demand and supply of settlement area, degree of mixing with other residential agent types weighted by tolerance, priorities …

4.2.2 Agent types

At the moment, resident agents are divided into:

- Land owners and non land-owners and than into;
- seven household types (which are assumed to make a choice for a flat/dwelling or a new house → building permit): Young Singles (<45 y), Young Cohabitation households (<45 y), Elderly Singles (>45 y), Elderly cohabitation households (>45 y), Families with depenent children (<18 y), Single Parent Families with dependent children (<18 y), Flat sharers (<45 y).

Agent types differ with respect to certain parameters such as the amount of settlement area needed for an individual (in m² per capita), tolerance for other household types, housing preferences, persistence times within one flat and adaptation mechanisms. Furthermore, they differ in terms of their decision making scope (extreme ends: Whereas better-of Young Singles act, more or less deprived families react.)

Table 1. Household types (HHT) – demographic properties, number of persons and average persistence time (years) of staying in one place (in one flat)

Household type	**Age classes involved**	**Number of persons**	**Persistence time of HHT existence (years) - t_M**
(1) Young single	18 - <45	1	5
(2) Young cohabitation	18 - <45	2	5
(3) Elderly single	>45	1	20
(4) Elderly cohabitation	>45	2	30
(5) Family	18 - <45; <18	3 – 5	18
(6) Single parent family	18 - <45; <18	1 – 3	12
(7) Flat-sharer	18 - <45	2 – 4	5

4.3 Data import and export during runtime

4.3.1 Data import

4.3.1.1 … from other agents within ABMland

Agents import the following data from other agents:

- ServiceSupplyForResidents
- SupplyOfHousing
- BuildingPermissions

- BusinessSupply

4.3.1.2 … regarding land use

All resident agents import information on suitability of cells (vectors) for settlement, using our typology those are in particular:

- Houses,
- Flats,
- Open space (with building permission).

Furthermore, the suitability of these settlement types in terms of

- (Accessibility of services and business → will be delivered by other agents?),
- Green supply and
- …

is needed.

4.3.1.3 … regarding other factors

None.

Data exchange within agent class

For each agent type within the resident class, the total number of individuals per cell is communicated, leading to seven data exchange interfaces:

- getTotalNumberOfYoungSinglesPerCell() [no.]
- getTotalNumberOfYoung CohabitationsPerCell() [no.]
- getTotalNumberOfElderlySinglesPerCell() [no.]
- getTotalNumberOfElderlyCohabitationsPerCell() [no.]
- getTotalNumberOfFamiliesPerCell() [no.]
- getTotalNumberOfSingleParentFamiliesPerCell() [no.]
- getTotalNumberOfFlatsharersPerCell() [no.]

Data export

4.3.1.4 … for other agents in *ABMland*

Especially planners and developers need to know where residents currently live. Therefore they need to know the total number of each resident agent type.

- getTotalNumberOfYoungSinglesPerCell() [no.]
- getTotalNumberOfYoung CohabitationsPerCell() [no.]
- getTotalNumberOfElderlySinglesPerCell() [no.]
- getTotalNumberOfElderlyCohabitationsPerCell() [no.]
- getTotalNumberOfFamiliesPerCell() [no.]
- getTotalNumberOfSingleParentFamiliesPerCell() [no.]
- getTotalNumberOfFlatsharersPerCell() [no.]

Furthermore, they export their demand for housing.

Also, service suppliers need to know where residents currently live. Therefore they need to know the total number of each resident agent type (see above). Furthermore, they deliver their demand for service supplies.

Residents export their demand of business services.

Residents export their (dis-)satisfaction as pressure for lobby groups.

4.3.1.5 … for land use change

All resident agent types can change open space to their respective settlement area:

- Houses
- Flats.

4.3.1.6 … for result logging

Main results for the residents are:

- getSatisfactionOfYoungSinglesPerCell() [0 … 10]
- getSatisfactionOfYoungCohabitationsPerCell() [0 … 10]
- getSatisfactionOfElderlySinglesPerCell() [0 … 10]
- getSatisfactionOfElderlyCohabitationsPerCell() [0 … 10]
- getSatisfactionOfFamiliesPerCell() [0 … 10]
- getSatisfactionOfSingleParentFamiliesPerCell() [0 … 10]
- getSatisfactionOfFlatsharersPerCell() [0 … 10]

Furthermore, the total number of the residents per cell is necessary to log results:

- getTotalNumberOfYoungSinglesPerCell() [no.]
- getTotalNumberOfYoungCohabitationsPerCell() [no.]
- getTotalNumberOfElderlySinglesPerCell() [no.]
- getTotalNumberOfElderlyCohabitationsPerCell() [no.]
- getTotalNumberOfFamiliesPerCell() [no.]
- getTotalNumberOfSingleParentFamiliesPerCell() [no.]
- getTotalNumberOfFlatsharersPerCell() [no.]

4.4 Decision making

4.4.1 Scope of decision making

Agent type	**Scope of decision making**	**Influence on land use**
Young Singles	Finding an optimal flat for a defined persistence time t_M Finding an optimal place for a house for a defined persistence time t_M	Open space to residential area.
Young Cohabitation	Finding an optimal flat for a defined persistence time t_M Finding an optimal place for a house for a defined persistence time t_M	Open space to residential area.
Elderly Singles	Finding an optimal flat for a defined persistence time t_M Finding an optimal place for a house for a defined persistence time t_M	Open space to residential area.
Elderly Cohabitation	Finding an optimal flat for a defined persistence time t_M Finding an optimal place for a house for a defined persistence time t_M	Open space to residential area.
Families	Finding an optimal flat for a defined	Open space to

	persistence time t_M Finding an optimal place for a house for a defined persistence time t_M	residential area.
Single Parent Families	Finding an optimal flat for a defined persistence time t_M Finding an optimal place for a house for a defined persistence time t_M	Open space to residential area.
Flatsharer	Finding an optimal flat for a defined persistence time t_M Finding an optimal place for a house for a defined persistence time t_M	Open space to residential area.

4.4.2 Decision process

4.4.2.1 Trigger of the decision process

Agent type	Trigger of the decision process
Young Singles Young Cohabitation Elderly Singles Elderly Cohabitation Families Single Parent Families Flatsharer	Households differ between two options: • building a house (where a building permission exists) and • looking for an already existing house or flat. In case of the second option, households migrate if a place $\vec{y}$ is more attractive than a location $\vec{x}$ and, further, when they exceeded their temporal limit for persisting in one flat (given in Table 1). The resulting migration choice, e.g. the migration M of households H_j the household from one flat to another is given by: $M_j(\vec{x},\vec{y}) = \left\{ \begin{array}{ll} 1 & A_j(\vec{y}) > A_j(\vec{x}) \text{ and } t - t^* > t_M \\ P_{\max} & A_j(\vec{y}) > A_j(\vec{x}) \text{ and } t - t^* < t_M \\ 0 & A_j(\vec{y}) \le A_j(\vec{x}) \end{array} \right\}$ where, M_j the migration of a household type at a place $\vec{x}$ and P_m the persistence of a household H, t^* the number of time steps since the last migration and t_M the maximum persistence time of a household type in a flat (cf. Table 1).

4.4.2.2 Decision algorithm

Agent type	Decision algorithm
Young Singles	Rational choice algorithm. Maximum utility of a site. Weighted sum of satisfaction for all housing choice relevant variables.
Young Cohabitation	Rational choice algorithm. Maximum utility of a site. Weighted sum of satisfaction for all housing choice relevant variables.
Elderly Singles	Rational choice algorithm. Maximum utility of a site. Weighted sum of satisfaction for all housing choice relevant variables.
Elderly Cohabitation	Rational choice algorithm. Maximum utility of a site. Weighted sum of satisfaction for all housing choice relevant variables.
Families	Rational choice algorithm. Maximum utility of a site. Weighted sum of satisfaction for all housing choice relevant variables.
Single Parent Families	Rational choice algorithm. Maximum utility of a site. Weighted sum of satisfaction for all housing choice relevant variables.
Flatsharer	Rational choice algorithm. Maximum utility of a site. Weighted sum of satisfaction for all housing choice relevant variables.

4.4.2.3 Decision criteria

Agent type	Decision criteria
Young Singles **Young Cohabitation** **Elderly Singles** **Elderly Cohabitation** **Families** **Single Parent Families** **Flatsharer**	The attractiveness A_j of a place (for a household to live) is formally: $A_j(\vec{x}) = \sum_{k=1}^{l} w_k I_k\left(U_r(\vec{x})\right)$ with $\sum w_{j,k} = 1$ where A_j is the attractivity of a place $\vec{x}$ for a household h, w the weight of preference descriptor I, and $I_{1 \ldots k}$ the preference descriptors (detailed given in Table 2). For the use of an agent-based simulation approach, it is crucial to create differentiated and, at best, “real” behavioural agent profiles for the household types. Randomly chosen values from deterministic ranges of weights w are dedicated to each of the descriptor $I_{1,\ldots,k}$. Those ranges of weights w are derived using the ordination (rating, ranking) values adopted from empirical data of a range of questionnaire surveys or a choice-based conjoint analysis.

4.5 *Conclusions for time and space*

4.5.1 Space

Vectors with residential land use (houses, flats), infrastructure (water, energy, culture, shopping, education, medical care, green …).

From vector data different grids could be derived (aggregation process) using a summary or mean / median statistics.

4.5.2 Time

Currently one year.

Table 2. Weights of the attractivity *A* of a location $\vec{x}$ (= decision criteria) for the household types *1…m*

	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	V_9	V_{10}	V_{11}	V_{12}	V_{13}	V_{14}	V_{15}	V_{16}	V_{17}	V_{18}	V_{19}	V_{20}
1. Young single <45 yrs.	0.25	0.075	0.2	0.075	0.1	0.1	0.15	0.13	0.14	0.19	0	0	0.22	0	0.11	0.15	0.1	0.05	0	0
2. Young cohab. <45 yrs.	0.2	0.075	0.25	0.075	0.1	0.15	0.15	0.14	0.14	0.14	0.13	0.06	0.11	0.01	0.11	0.2	0.1	0.1	0	0
3. Elderly single >45 yrs.	0.05	0.3	0.1	0.3	0.1	0.1	0.1	0.14	0.14	0.15	0.02	0.12	0.12	0.09	0.10	0.05	0.2	0.25	0	0
4. Eld. cohab. >45 yrs.	0.05	0.3	0.1	0.3	0.1	0.1	0.1	0.08	0.08	0.08	0.13	0.16	0.06	0.21	0.11	0.05	0.2	0.25	0	0
5. Families	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.08	0.08	0.07	0.2	0.14	0.09	0.14	0.13	0.2	0.15	0.2	0	0
6. Single-parent families	0.15	0.1	0.1	0.1	0.25	0.25	0.1	0.12	0.12	0.07	0.2	0.09	0.08	0.07	0.11	0.2	0.15	0.1	0	0
7. Flatsharer	0.2	0.05	0.15	0.05	0.25	0.1	0.3	0.08	0.08	0.01	0.06	0.05	0.25	0.18	0.07	0.15	0.1	0.05	0	0

	V_{21}	V_{22}	V_{23}	V_{24}	V_{25}	V_{26}	V_{27}	V_{28}	V_{29}	V_{30}	V_{31}	V_{32}	V_{33}	V_{34}	V_{35}	V_{36}	V_{37}	V_{38}	V_{39}	V_{40}
1. Young single <45 yrs.	0	0.1	0	0.2	0.1	0.25	0.05	0.05	0.05	0.05	0.05	0.1	0.25	600	0.1	0.2	0.1	0.25	tbi*	tbi
2. Young cohab. <45 yrs.	0	0.15	0	0.25	0.1	0.2	0.1	0.1	0.1	0.01	0.05	0.1	0.2	1200	0.05	0.25	0.1	0.2	tbi	tbi
3. Elderly single >45 yrs.	0	0.2	0	0.1	0.1	0.1	0.2	0.05	0.05	0.05	0.25	0.2	0.05	450	0.2	0.05	0.2	0.05	tbi	tbi
4. Eld. cohab. >45 yrs.	0	0.2	0	0.2	0.2	0.1	0.2	0.05	0.05	0.05	0.25	0.2	0.05	700	0.2	0.1	0.2	0.05	tbi	tbi
5. Families	0	0.15	0	0.1	0.25	0.05	0.2	0.3	0.3	0.3	0.2	0.15	0.1	1200	0.1	0.25	0.15	0.1	tbi	tbi
6. Single-parent families	0	0.15	0	0.1	0.2	0.05	0.2	0.4	0.4	0.4	0.15	0.15	0.1	500	0.15	0.1	0.15	0.1	tbi	tbi
7. Flatsharer	0	0.05	0	0.05	0.05	0.25	0.05	0.05	0.05	0.05	0.05	0.1	0.25	300	0.2	0.05	0.1	0.25	tbi	tbi

V_1= young single
V_2= young cohabitation
V_3= elderly single
V_4= elderly cohabitation
V_5= families
V_6= single-parent families
V_7= flat-sharer
V_8= city centre
V_9= multi-storey 1960ies
V_{13}= tenement blocks 1870-1920ies
V_{14}= villas
V_{15}= multi-storey suburbia 1990ies
V_{16}= sport, leisure

V_{19}= cemetery
V_{20}= open land, farmland
V_{21}= pastures, grassland
V_{22}= forest
V_{23}= brownfields
V_{24}= rivers
V_{25}= lakes
V_{26}= crime rate > mean
V_{27}= crime rate < mean
V_{31}= shop < 250m
V_{32}= shop < 500m
V_{33}= shop > 500m
V_{34}= maximum flat/land price (€)

V_{37}= public transport < 500m
V_{38}= public transport > 500m
V_{39}= distance to work low
V_{40}= distance to work high
V_{12}= single house area
V_{17}= parks
V_{35}= rent < 5€/m^2
V_{18}= allotments
V_{36}= rent > 5€/m^2
V_{30}= school > 500m

* to be implemented

V_{10}= prefab estates GDR
V_{11}= residential park 1990ies

V→ still missing: costs for service supply (water, energy)

V_{28}= school < 250m
V_{29}= school < 500m

5 Service Supplier Agents

5.1 *Function within ABMland*

Service provider agents occupy built-up area related to infrastructure in *ABMland* (e.g. roads, utilities, …). They can change land use as follows: open space to built-up area (public, infrastructure, commercial) and back to open space.

5.2 *Service Provider agent types and their profiles*

5.2.1 Overall agent class

Service providers have the following methods of their own:

- computeEnergyServiceSupplyOnCell()
- compute(Waste)WaterServiceSupplyOnCell()
- computeTransportServiceSupplyOnCell()
- computeAdministrationSupplyOnCell()

Service providers have the following method in common:

- computeSatisfactionOnCell() → level of (dis-)satisfaction with current state on a cell according to the service suppliers' specific demand-supply requirements …

5.2.2 Agent types

- Energy Company (either municipal or private)
- (Waste) Water Company (either municipal or private)
- Transport Company (either municipal or private)
- Administration (mainly municipal)

5.3 *Data import and export during runtime*

5.3.1 Data import

5.3.1.1 … from other agents within *ABMland*

Agents import the following data from other agents in general:

- getResidentsDemandOfServicesPerCell()
- getBuildingPermissionForServicePerCell()
- getPressureOnServiceForEnlargingInfrastructurePerCell()
- getDemandOfServiceFromBusinessPerCell()

In detail this means for example:

- getTotalNumberOfYoungSinglesPerCell() [no.]
- getTotalNumberOfYoung CohabitationsPerCell() [no.]
- getTotalNumberOfElderlySinglesPerCell() [no.]
- getTotalNumberOfElderlyCohabitationsPerCell() [no.]
- getTotalNumberOfFamiliesPerCell() [no.]
- getTotalNumberOfSingleParentFamiliesPerCell() [no.]

- getTotalNumberOfFlatsharersPerCell() [no.]
- getTotalNumberOfBuildingPermissionsPerCell() [no.]
- getTotalNumberOfBusinessPerCell() [no.]

5.3.1.2 … regarding land use

All service provider agents import information on suitability of cells (vectors) for built environment, using our typology. In particular these are:

- Residential,
- Commercial,
- Public and
- Infrastructure.

5.3.1.3 … regarding other factors

None.

5.3.2 Data exchange within agent class

There are interactions between some of the service providing agents in the following situations:

a) preparation of new built-up land → communication between energy provider, water supplier and transport service [and externally: planning policy].
- getTotalLengthOfEnergyNetworkPerCell() [no.]
- getTotalLengthOfChannelNetworkPerCell() [no.]
- getTotalLengthOfTransportNetworkPerCell() [no.]

b) Demolition of houses / housing estates → communication between energy and water provider [and externally: planning policy].
- getTotalLengthOfEnergyNetworkPerCell() [no.]
- getTotalLengthOfChannelNetworkPerCell() [no.]

5.3.3 Data export

5.3.3.1 … for other agents in ABMland

Service Providers export their supply for residents and business as well as their demand for building permissions. Furthermore, Service Providers export their (dis-)satisfaction as pressure for Planning Policy and for lobby groups:

- getServiceSupplyForResidentsPerCell()
- getSupplyOfServiceForBusinessPerCell()
- getDemandOfBuildingPermissionForServicePerCell()
- getLevelOfSatisfactionOfServiceSuppliers()

5.3.3.2 … for land use change

All service provider agents can change land use as follows: open space to built area (public, infrastructure, commercial). All service provider agents can cut / shorten their networks and therefore convert an area to brownfield land.

5.3.3.3 … for result logging

Main results for the service provider are:

- getSatisfactionOfEnergyProviderPerTotalArea() [0 … 10]
- getSatisfactionOf(Waste)WaterProviderTotalArea () [0 … 10]
- getSatisfactionOfTransportProviderTotalArea () [0 … 10]
- getSatisfactionOfAdministrationProviderTotalArea () [0 … 10]
- getSatisfactionOfWasteTreatmentProviderTotalArea () [0 … 10]

Furthermore, the total number of the respective networks per cell is necessary to log results:

- getTotalLengthOfEnergyNetworkPerCell() [no.]
- getTotalLengthOf(Waste)Water/ChannelNetworkPerCell() [no.]
- getTotalLengthOfTransportNetworkPerCell() [no.]
- getTotalDensityOfAdministrationPerCell() [no.] OR
  getTotalNumberOfAdministrationPerCell() [no.]
- getTotalLengthOfWasteTreatmentPerCell() [no.]

5.4 Decision making

5.4.1 Scope of decision making

Agent type	Scope of decision making	Influence on land use
Energy provider		
Water provider	Provide and increase/shorten network while maximising profit and minimising costs.	Open space to built-up land. Built-up land to brownfield.
Waster Water Treatment supplier		
Transport supplier		
Administration provider		

5.4.2 Decision process

5.4.3 Trigger of the decision process

Agent type	Trigger of the decision process
Energy provider	New/extended demand. Building Permission is given by Planning Policy. Demolition of houses.
Water provider	New/extended demand. Building Permission is given by Planning Policy. Demolition of houses.
Waster Water Treatment	New/extended demand. Building Permission is given by Planning Policy. Demolition of houses.

supplier	
Transport supplier	New/extended demand. Building Permission is given by Planning Policy. (De-)Densification of settlement areas. Demolition of houses.
Administration provider	New/extended demand. Building Permission is given by Planning Policy. (De-)Densification of settlement areas. Demolition of houses.

5.4.3.1 Decision algorithm

Agent type	Decision algorithm
Energy provider	Rational choice algorithm. Maximum utility for total area.
Water provider	Rational choice algorithm. Maximum utility for total area.
Waster Water Treatment supplier	Rational choice algorithm. Maximum utility for total area.
Transport supplier	Rational choice algorithm. Maximum utility for total area.
Administration provider	Rational choice algorithm. Maximum utility for total area.
Energy provider	Rational choice algorithm. Maximum utility for total area.
Water provider	Rational choice algorithm. Maximum utility for total area.

5.4.3.2 Decision criteria

Agent type	Decision criteria
Energy provider **Water provider** **Waster Water Treatment supplier** **Transport supplier** **Administration provider** **Energy provider** **Water provider**	o Costs o Investment o Cost-effectiveness o Quality (of water for water supplier for example) o …

5.5 Conclusions for time and space

5.5.1 Space

Vectors with residential land use (houses, flats), business land use, public built-up land use and infrastructure (water, energy, culture, shopping, education, medical care, green …). From vector data different grids could be derived (aggregation process) using a summary or mean / median statistics.

5.5.2 Time

Currently one year.

PLUREL

6 Pressure Groups

6.1 *Function within ABMland*

Pressures groups represent a disparate group of agent types that may act both within and outside of the region. They may be a collective of individuals or they may be an organisation. They are characterised by goals that seek to limit or encourage urban development at specific geographic locations in response to their perception of changes in the social or morphological characteristics of these locations. Within *ABMland*, Pressure Group agents are an emergent property of the system that seeks to influence either planners or developers in achieving their goals.

6.2 *Pressure group agent types and their profiles*

6.2.1 Overall agent class

Pressure groups play two roles in *ABMland*: a) they are emergent properties of the system, which arise from actual or perceived urban development pressures; b) after emergence they influence planning and urban development decisions. Further development of *ABMland* needs to find an appropriate mechanism for these groups to emerge <u>and</u> to determine their capacity to influence planning decisions.

6.2.2 Agent types

We recognise five Pressure Group agent types:

1. Political lobbyists
2. NIMBYists
3. Community groups
4. Conservationists
5. Social reformers (e.g. housing associations)

6.2.2.1 Political lobbyists

Typical attributes: representatives of private sector companies; environmental organisations
Goal: seek to influence political decisions at a national or regional governmental level concerning development objectives
Effects/interactions: influence government planning decisions such as housing targets, or measures to mitigate environmental problems
Note: Exogenous to the modelled system. Not to be modelled explicitly, but treated through exogenous variables such as housing targets, conservation targets, …

6.2.2.2 NIMBYists

Typical attributes: local residents (at a mid to late stage of their life cycle) who are concerned by new development in their neighbourhood
Goal: resist new urban development within their neighbourhood
Effects/interactions: influence local planning decisions and possibly developers

6.2.2.3 Community groups

Typical attributes: local residents (at an early to mid stage of their life cycle) who are unhappy with the low state of development of their neighbourhood
Goal: encourage investment in local infrastructure and urban development projects
Effects/interactions: influence local planning decisions and possibly developers

6.2.2.4 Conservationists

Typical attributes: organisations with a concern for urban development pressures on natural or cultural heritage
Goal: resist new urban development pressures within conservation areas (nature reserves, historic buildings, …)
Effects/interactions: influence local planning decisions and possibly developers

6.2.2.5 Social reformers (e.g. housing associations)

Typical attributes: organisations with concerns for inequitable social development in certain neighbourhoods
Goal: encourage affordable housing, or other improvements in social welfare.
Effects/interactions: influence local planning decisions and possibly developers

6.2.3 Pressure group emergence

All pressure groups have a common trait: their emergence in response to an actual or perceived urban pressure. These groups emerge either as clusters of individual residents within a specific neighbourhood or as new organisations (conservation or social reform groups). Members of emerging organisations are not necessarily resident within the region, and so must be treated as a whole. Thus, we can expect Pressure Group agents to originate among the existing agents of *ABMland*: that is, a member of a pressure group is also a householder, or a service provider, or a developer. To become a member of a pressure group, an agent will need to be sufficiently dissatisfied with a process or situation that they change their behaviour from responding to outside events to trying to influence them via the medium of a pressure group. This in turn means that each agent would have to have a satisfaction attribute (Service Providers already have this, and something similar will be built into the Developer agents), whereby if satisfaction drops below a certain level, agents will start to explore other ways of achieving their goals.

Local residents who become members of a pressure group can be identified explicitly and ‘flagged’ as such. The number of flagged individuals is a function of the magnitude of the urban pressure and its geographic location with respect to the spatial distribution of agents at different stages of their life cycles. The demand for housing (and infrastructure) could be used to quantify the urban development pressure. NIMBYists and conservationists would emerge in response to higher demands for urban development in their neighbourhoods or in a conservation area. Community groups would emerge in response to a decline in the demand for urban development. Social reformers would respond if urban development demand is ‘unsatisfied’. This implies, for example, that higher demand would push up property prices and therefore reduce affordability.

6.2.4 Capacity to achieve goals

There are two key factors that determine the capacity of pressures groups to achieve their goals. These are: a) the number of emerging groups and or individuals that are flagged as part of a group, b) assumptions about the relative ‘political’ strength of these emergent groups. The relative strength of these groups is probably best implemented through the scenario assumptions. So, for example:

- NIMBYists are stronger in an individualistic world that lacks a sense of community, sharing and the equitable distribution of resources;
- Community groups are stronger in a world that values social cohesion;
- Conservationists are stronger in a world with high environmental concerns;
- Social reformers are stronger in an equitable world with high social responsibility that tends to the welfare needs of the whole population.

Thus, a pressure group with a high political strength will achieve its goals, but a weak group will not. Pressures groups with intermediate strength levels may partially achieve their goals.

6.3 Data import and export during runtime

6.3.1 Data import

6.3.1.1 … from other agents within ABMland

Pressure groups are based on:

- perception of urban pressure, from Residents
- perception of urban needs, from Business
- perception of permit needs, from Developers
- Global planning plans and response to previous pressures, from planners

NOTE: Services suppliers have no lobbyist action. The “import” line will be removed from exchange table…

Agent type	**Other agents “source”**
NYMBYist	Residents; Business
Community groups	Residents; Business; Developers
Conservationists	Residents
Social reformers	Residents

6.3.1.2 … regarding land use

Agent type	**LU import**
NYMBYist	[Urban density; urban morphology] @ local scale
Community groups	[Urban density; urban morphology] @ local scale
Conservationists	[Urban density; urban distribution*] @ global scale
Social reformers	[Density of social housing] @ global scale

*: to measure patterns and fragmentation

6.3.1.3 … regarding other factors

Agent type	**Non-LU import**
NYMBYist	[planning permissions] @ local scale
Community groups	[planning permissions, economy level*] @ local scale
Conservationists	[planning permissions] @ global scale
Social reformers	[economy level*] @ global scale

*: economy level = jobs, infrastructure and services provisions

6.3.2 Data export

6.3.2.1 … for other agents in *ABMland*

PGs send pressure messages for planning adaptation at two different scales:

Agent type	**Scale of action**
NYMBYist	Local
Community groups	Local
Conservationists	Global
Social reformers	Global

6.3.2.2 … for land use change

PGs cannot change any LU directly. They only act through the planning agents and their direct action with developers is considered to be negligible.

6.3.2.3 … for result logging

- size of lobby groups (number of agents)
- change in number of planning permissions

6.4 Decision making

6.4.1 Scope of decision making

Three step decision process:

1) AWARNESS/CONSCIOUSNESS of each individual agent, according to the different "perception" types – this preliminary step is necessary because PGs are emergent from the system
2) ORGANISATION of individual agents into a PG that will take action. This is the actual emergence of a PG
3) ACTION of PG over planning: press for changing permissions

PGs can only influence planning permissions

6.4.2 Trigger of the decision process

1) Trigger for AWARNESS

Agent type	
NYMBYist	Agent lifecycle = mid to late stage Urban density increases

	Urban morphology changes Planning permissions do not restrict urban development
Community groups	Agent lifecycle = early to mid stage Urban density remains low Urban morphology does not change Planning permissions are strict / will let that trend goes on All of [jobs, infrastructure, services] provisions remains low / stays still
Conservationists	Urban density increases urban pattern disperses, landscape fragmentation increases Planning permissions do not restrict urban development
Social reformers	Density of social housing is low All of [jobs, infrastructure, services] provisions remains low / stays still

2) Trigger for ORGANISATION

Agent type	
NYMBYist	Min number of agents with the same awareness within a neighbourhood*
Community groups	Min number of agents with the same awareness within a neighbourhood*
Conservationists	Min number of agents with the same awareness within the region
Social reformers	Min number of agents with the same awareness within the region

*: note that an agent could be part of different local PGs

3) Trigger for ACTION

Several thresholds of the number of agents define several strengths of the PGs. For example, 100 nimbyists might not have any impact but a million conservationists would.

6.4.3 Decision algorithm

1) Agent changes lifecycle stage ⇨ Agent gains potential to be a PG member ⇨ Agent is flagged as being a particular PG type
2) Realisation of PG as number of flagged agents reaches the minimum threshold ⇨ PGs start pressing on planners as soon as the threshold pressure is reached

6.4.4 Decision criteria

Thresholds of agents – *to be defined*

6.5 Conclusions for time and space

6.5.1 Space

Two levels of “spatial pressure” are to be considered: local and global, which can easily be adapted to other agent requirements.

6.5.2 Time

The same time step as for urban LU change and the updates to the planning permissions.

7 Technical implementation

7.1 Challenges

When implementing *ABMland* into programming code, four main challenges need to be tackled:

1. **Level of model detailed**. Each agent will be implemented in its own sub-model, resulting in a total of six agent-based sub-models for *ABMland*. Each model is very complex, as each agent has several sub-types representing different actors. They have different characteristics, behavioural rules etc., and will be very complex. As each sub-model will be conceptualised and implemented by a single project partner, understanding the respective other sub-models in all details will be very difficult.
2. **Agent interactions**. Agents belonging to different sub-models will interact directly (communication) and indirectly (by changing land uses). Therefore, agents need a means of direct communication as well as acting on the same land patches, which in turn can lead to conflicts.
3. **Project partners across Europe**. Scientists who are developing the sub-models work in institutions across Europe and not in a single working group. This hinders easy code sharing and communication.
4. **Project partners who are not computer scientists**. Researchers who are developing the sub-models are specialists in their respective disciplines but not necessarily experts in computer science.

7.2 Proposed technical solutions

Figure 5 depicts how these challenges can be tackled.

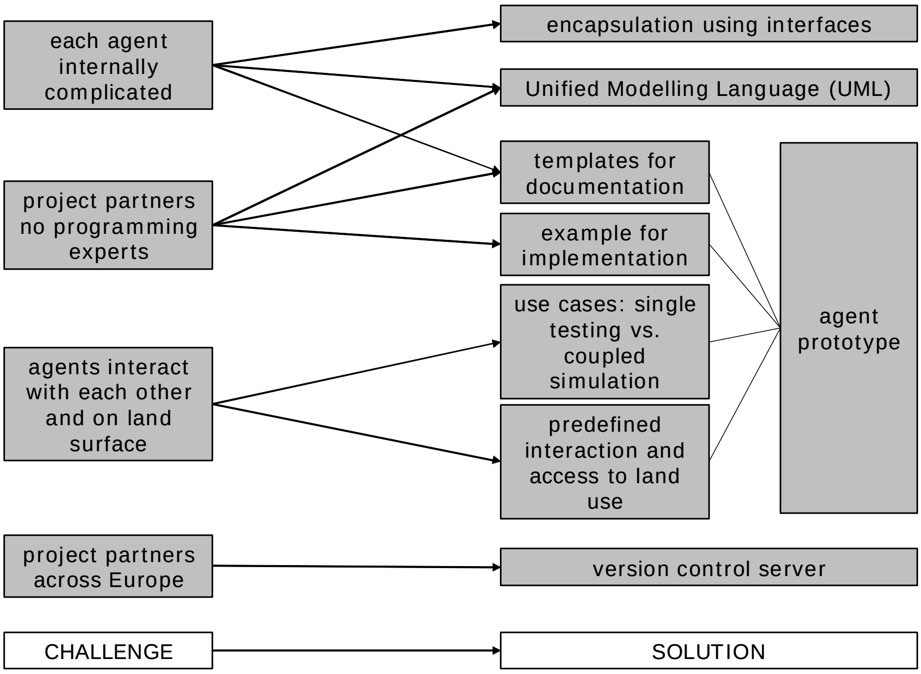


Figure 5 Challenges and technical solutions for ABMland

7.2.1 Encapsulation

Encapsulation (or hiding of uncommon data) means that all project partners develop their own agent-based sub-models. The respective partners are responsible for conceptualising agent types, their characteristics (=profiles) and their behavioural rules. There is no need for the other project partners to understand all the details within the single sub-models. Project partners rather agree upon definitions of interfaces between their models. Interfaces are the crucial information that is necessary to build linkages between the respective models: They define the data exchange in terms of values, their spatial and temporal resolution and units.

7.2.2 UML

A conceptual view of the sub-models is presented using the Unified Modelling Language (UML). Representing complex programming code in this graphical way facilitates communication between non-computer scientists. An example is given in Figure 6.

7.2.3 Agent prototype

UFZ, as the partner responsible for technical integration, will provide a prototype for implementing the respective sub-models. This prototype will include:

- Templates showing how to document programming code within the model (e.g. Javadoc). Documentation is essential for such complex models, and providing templates helps scientists who are no programming experts.

- Examples for implementation. This is another feature supporting scientists with less of a programming background.
- Facilitation of several use cases. Project partners will have the possibility to either test their single sub-model (keeping all other agents constant, as dummies) or to perform integrated simulation runs with all agents running simultaneously. This is necessary because agents of the single sub-models considerably interact with each other.
- Predefined interaction between agents and access to land use. Without such specifications, no interaction would be possible.

The delivery of the first version of the agent prototype is planned as Milestone M4.2.4 in month 20.

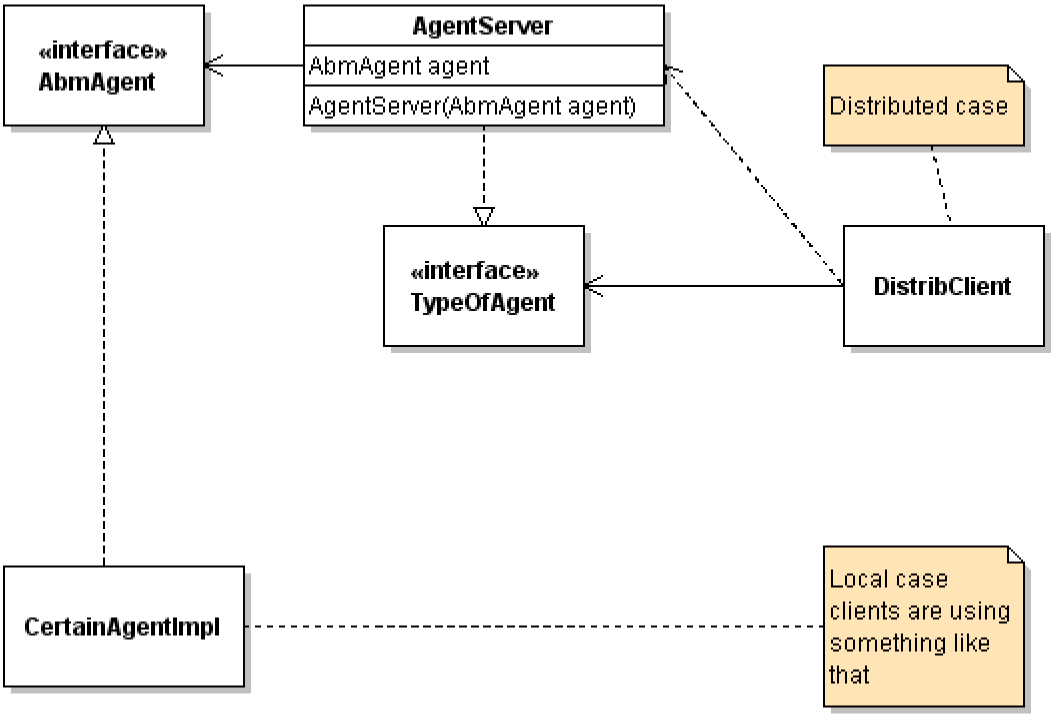


Figure 6 UML diagram depicting the structure of the agent prototype.

Figure 6 shows a sketch of the agent prototype and the framework necessary for performing simulation runs with different agent types. There are two cases in which the model simulations will run: A characteristic local (1) and its distributed counterpart (2). (1) When a simulation runs locally, all agents are active within the simulation run. In that case, the sub-models are bound only to circumstances defined there. (2) In the distributed case, only one or a few agents are active, all other agents are passive insofar as they do not compute during runtime. This is necessary for testing single models or for computing scenarios with only a limited number of agents. To manage the needed knowledge about the overall heterogeneous system, there are (enforcement) strategies adapted by the computer science field to agree on a computational level about the kind and amount of data. This agreement is called “interface”. In the distributed case, a client instantiates any one of the agent implementations of the sub-models. Then the client uses that instance to construct an instance of a server which returns (internally resolved by a link on the overall agents type, i.e. AbmAgent) a type. That means the server returns an interface description (protocol) providing the access methods for the many possible agents, which supply data according to that protocol.

7.2.4 Version control server

In order to facilitate code-sharing between project partners, UFZ will provide a version control server. All project partners can upload and download source code and data necessary to run the models, cashing in on synchronization of their changes. Changes are also recoverable traced, which means partners can not only review them at any time step, but also revert the associated source code and data to their states at a certain point in time.

Conclusions

8 Conclusions and next steps

This document has provided an overview of the framework for the construction of *ABMland*, with further details about the generic agent categories and model implementation strategy. The next steps in the project will be to implement a general version of the model that will operate in an abstract, virtual world according to the technical implementation plans outlined in section 7 . This will allow us to test the proposed interactions between agents, and well as refining the behavioural rule base for the decision processes of each individual agent.

Once the virtual model has been tested, it will be applied to a case study area in the region of Koper. This will involve calibration of the key model parameters and refinement of the agent behavioural rules using information and insight derived from conjoint analysis, social survey/questionnaires and from the analysis of existing socio-economic databases. Further testing of the models will involve sensitivity and uncertainty analyses. The case study specific ABM will then be used to explore the implications of a range of environmental change scenarios for the evolution of future urban land.

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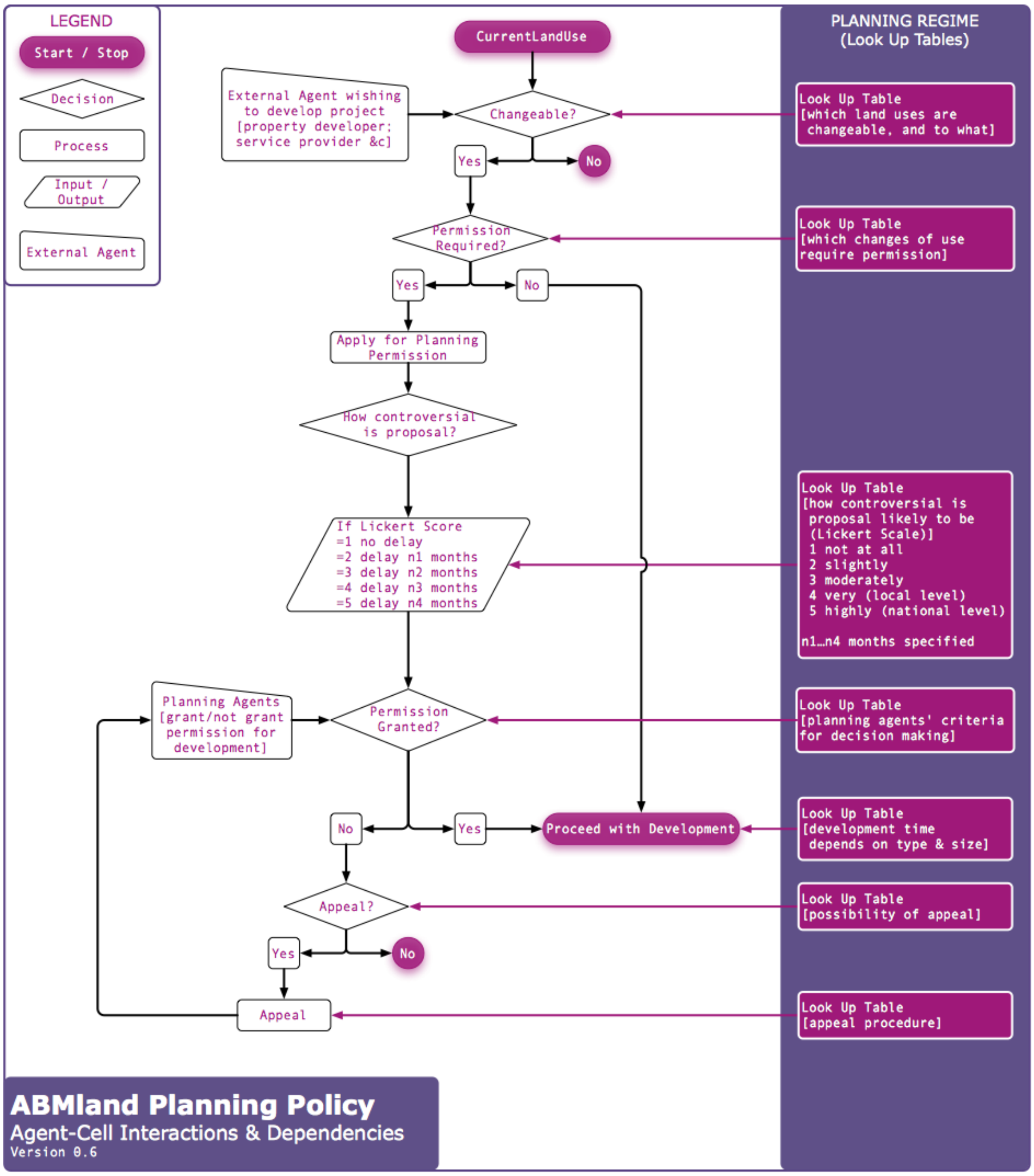
Appendix 1: Sample LUT for Land Use

Cell No	1	2	3
Northing			
Easting			
Current Use Code	A1	A1	A2
Changeable	1	1	1
Permission required	1	1	1
Proposed Use Code	0	0	0
Time since Proposed Change of Use	0	0	0
Status of Proposal	0	0	0
Proposed Use in Local Plan	A1	A1	A2
Controversy Score (Lickert Scale)	0	0	0
Development TIme	0	0	0
Possibility of Appeal (Lickert Scale)	0	0	0
0 in any cell equals "not applicable" and/or "ignore".			

Appendix 2: Flow Chart for Planning Policy



Appendix 3: Land Use Types & Sub-types with Use Codes for LUTs

Use Type	Use Sub-Type	Use Code
Residential Buildings	Houses	A1
	Family Apartments	A2
Commercial Buildings	Offices	B1
	Manufacturing Industry	B2
	Hotels	B3
	Bars & Restaurants	B4
	Retail	B5
	Other leisure	B6
Public Buildings	Schools	C1
	Public Offices	C2
	Libraries	C3
	Hospitals	C4
	Universities	C5
Transport Infrastructure	Roads	D1

	Railways	D2
	Waterways	D3
	Airports	D4
	Seaports	D5
Other Infrastructure	Power Supply	E1
	Waste Disposal	E2
	Water treatment	E3
	Electricity networks	E4
	Gas & Oil networks	E5
City Open Space	Parks	F1
	Cemeteries	F2
	Allotments	F3
	Sportsgrounds	F4
	Woodland	F5
	Water	F6

Commercial Rural Activities	Agriculture	G1
	Forestry	G2
	Tourism	G3
	Horticulture	G4
	Other Leisure	G5
Protected Rural	Nature reserve	H1
	SSSI or equivalent	H2
	Green Belt	H3