A Multi-agent Planning System: A Tool for Ensuring Public Interest in Planning

Rachel Katoshevski-Cavari* Theo Arentze** Harry Timmermans**
Ministry of Interior
Israel
Technical University
Eindhoven
Technical University
Eindhoven

Within the domain of public planning activity, public interest has had various interpretations at different times. The postmodernism concept, characterized by two fundamental aspects, creates the basic conditions for a tailor-made plan. The recognition of differences, which is the first aspect, leads to the requirement to plan based on understanding the specific needs of the target population. The second aspect, the rejection of universalism deals with the awareness that any urban plan has to be unique and unbound to the legitimacy of universalism. When dealing with the link between urban planning and public interest the important question is whether it is possible to create a planning tool that guards issues of public interest. In addition, when looking at a smaller scale, this concept of pluralism and differences raises more questions of how to distinguish and define specific public interest of the population. And even if we are able to do that, what is the optimized plan reflecting this interest? This paper suggests a planning tool that is able to create a tailor-made plan for a group of people, and also serves for comparing different planning scenarios based on various indicators, responding thus to the above questions. The tool is a computerized multi-agent-based system that proposes a land use plan and plot facilities employing empirical data.

Keywords: *Urban Planning, Public Planning, Public Interest, Multi-agency, Tailor-made Plan.*

In the last decade different computerized planning models were developed aiming at simulating urban dynamics and evolution and create a usable planning system. The conceptual idea is that planning models can support systematic planning which limits the influence of the planner, takes more aspects into account and uses differ-

* Planning Department, Ministry of Interior, and Department of Structural Engineering, Ben-Gurion University of the Negev, Beer-Sheva, 84105, Israel. E-Mail: krachel@bgu.ac.il
**Department of Architecture, Building and Planning. Technical University Eindhoven Den Dolech 2, P.O Box 513, 5600 MB Eindhoven, The Netherlands. E-mail: T.A.Arentze@tue.nl, H.J.P.Timmermans@tue.nl

ent data. All these aspects should be the basis for creating a good plan that is relevant for the planned population. Among these different models, Cellular Automata (CA) has been a dominant modelling approach, used to simulate urban dynamics. The literature in urban planning and related disciplines has evidenced an explosion in the development and application of these CA models (e.g. Tobler, 1979; White and Engelen, 1993, 1997; Batty and Xie, 1994; Itami, 1994; Cecchini, 1996; Couclelis, 1988; Yeh and Li, 2001; Wu and Martin, 2002). These models are based on a set of transition rules which represent the influence of a particular land use on changes in another type of land use. These rules are applied to simulate land use change. In addition to these CAs, another well-developed line of research concerns integrated land use transportation models which represent land use as a function of accessibility. The spatial configuration of land use influences traffic flows which, in turn, influence accessibility. Taking into account this interaction, the dynamics in land use and accessibility can be modeled (e.g. Wegener, 1982; Putman, 1983; Hunt, 1994; Veldhuisen et al., 2000; Alberti and Waddell, 2000; Timmermans et al., 2001; Waddell, 2002; Pendyala et al., 2004).

However, we argue that these existing models cannot escape essential criticism that their behavioral basis is weak. Consequently, these models are limited in their ability to take into account needs and behavior of a target population. This fundamental drawback actually limits their relevance as a tool for achieving equity in planning and public interest. *The multi agent*-based approach which is used in this study suggests a planning tool that potentially overcomes the behavioral weakness of cellular automata and traditional integrated land use- transportation models (Arentze and Timmermans, 2004; 2007). As described here its essence, which includes the use of data concerning people's preferences and behavior, can lead, to creating a unique outline plan, relevant to a defined population and free from universalism. As of that, we claim that the suggested system is a relevant tool for planners for creating a relevant targeted plan and ensuring that the public interest is maintained in planning.

In the course of this paper we will now discuss the issue of public interest in planning. This will be followed by the description of the multi-agent system, which we suggest as a tool for maintaining public interest in planning as well as for assessing its actual maintaining in outline-plans. Then, the case study will be described, and finally a discussion on the relevance of this tool and summarizing conclusions will be presented.

PUBLIC INTEREST IN PLANNING

The legitimacy of planning in the last decades is based on the idea that public planning is necessary to protect the public from private and sectional interests. Consequently the questions of what is public interest in planning, how can it be defined, or how can one assess the achievement of that interest are fundamental questions for those dealing with urban planning. Different conceptions concerning public interest in general and, in specific, in planning were common along the years. The concepts which Campbell and Marshall (2002) distinguished using different categorizations, can be divided by the "point of view", that is, whether subjective or objective, the "interest base" which is whether individual or collective or whether the conception of the public interest is "outcome focused" or "procedurally focused". Regardless of the public interest focused-way of looking, a fundamental dilemma is always on the agenda, that is, how to identify public interest, especially the interest of those distinctive groups and how to asses the sustenance of that interest. We present here a tool for solving this dilemma.

The postmodernism concept deals with the recognition of differences and the rejection of universalism in favor of plurality and the importance of the recognition of the diversity of people for honesty in planning (for example Beauregard, 1991; Milroy, 1991; Slater, 1997; Fainstein, 2000; Campbell and Marshall, 2002). Also Epstein (1997), when dealing with the question of how we are shaping the future of our communities, talks about the fundamental point of relevant planning, and states that each local government should try to respect the wishes of their citizens. These statements point out the way planners should develop plans that is, to focus on the importance of the development of a unique plan, independent from universalism and relevant to the future expected population.

Today, when a planner deals with creating outline plans, data concerning the relevant-targeted population is very limited and planning is based on general knowledge concerning this population in addition to planning norms. The plan is thus created for an anonymous population, where no information is available concerning their actual spatial behavior, activity patterns or preferences. The planning process today results in an outline plan, which defines the land use in the planned area and enables to open facilities gradually with the development of the area. None of the stages of this long process of planning and building involve an investigation concerning the comfort or the suitability of the developed environment to the population. This is especially obtrusive in the built environment of distinctive groups of people, for example the Bedouin population in Israel or the Jewish ultra orthodox. For instance, the planning of neighborhood playgrounds in the Bedouins towns is based on the general Israeli norms. It does not take into account the fact that from a very young age, the Bedouin's children are not accompanied by adults to the playgrounds, which should require a different deployment of these facilities. One can argue that these developed plans match the general aspects of pubic interest: protecting the public interest against private and sectional interest, provision of housing, and enable the development of facilities, roads green areas, etc. But then some questions are raised whether the relevant interests of the specific group of people reflected in the plan are reflected and whether the planner was able to create the unique suitable and relevant plan. We argue that the existing planning process might miss the very core focus of the relevant public interest, and may be responsible for the creation of various environments not suitable for the dwellers. Hence, we argue further that only a combination of the existing planning norms, which reflect the general public interest, with a careful study of the preferences and behavior of a specific future targeted population, and using this data in the planning procedure, is the adequate way to get to the core aspect of public interest.

THE MULTI-AGENT SYSTEM

The Idea

The multi-agent system, which will be shortly described, bases the planning on characteristics of a specific population, i.e. the target population. The model takes into account the population preferences concerning the built environment and actual spatial behavior. By doing so, it is definitely creating an exclusive plan, unique for the targeted population.

The model is based on the dynamics of the decisions of three groups of actors: (1) the planning authority; (2) supplier agents; and (3) individuals and households. The assumption is that decisions and behavior of these three actors are the drivers of the development of the built environment. For each actor the system implies a specific sub-model. First, the *planning authority* makes urban decisions about the allocation of land use across locations. This stage is governed in the developed system by the *land use model*. The parameters for this land use model are determined partially based on the results of a conjoint study which is aimed at learning people's preferences concerning different aspects of their built environment. This stage results in a plan, dividing the study area into zones of allowed land uses. However, in the system, the actual development of facility locations and, therefore, the implementation of a plan depend on location decisions of firms, the *supplier agents,* which are the second group of actors, whose role in the system is to open and maintain facilities, based on different planning norms that are relevant for the targeted population. These activities are determined by the *facility location model*. *Individuals and households*, the potential people which will live in the planned area are the third group of actors, who occupy work places and use facilities. Their behavior is regulated by the *facility use model*. This sub-model is based on people's actual spatial behavior as it was revealed in a time-use survey. Obviously, there are many interactions between the decisions of the three groups. The land use plan constrains the choices of suppliers as it allows only certain developments in certain zones. On the other hand, the feasibility and economic viability of development generally depends on usage patterns of facilities and, therefore, on the decisions of households and individuals. Suppliers respond to actual usage patterns by making adaptation decisions regarding the viability and size of individual facility outlets. This may again lead to changes in allocation of demands. The cycles of adaptations are repeated until convergence is attained.

Figure 1: Process description.

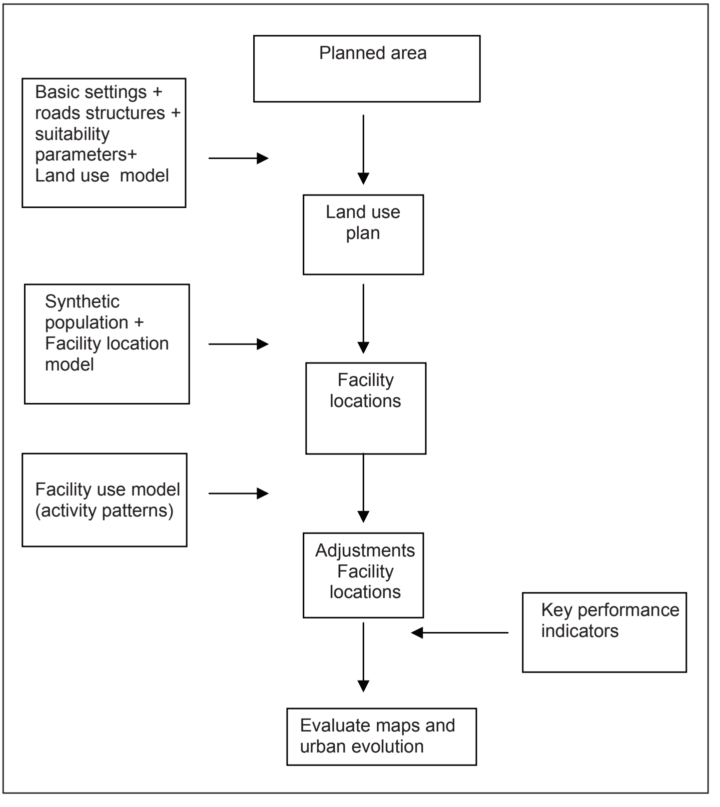


Figure 1 describes the outline of the multi-agent system. As portrayed and explained above, in each step the system involves a specific sub-model. In this paper we will not describe the model in detail, but rather concentrate on the nature of the different stages in order to portray in general the use of this system as a tool for a tailor made plan (for further information refer to Arentze and Timmermans, 2007; Katoshevski-Cavari, 2007). This will be the background and basis for the discussion below.

In the following sections we demonstrate the system through a hypothetical example concerning the development of a plan, and by that example show how to evaluate the different emerged alternatives.

THE STUDY

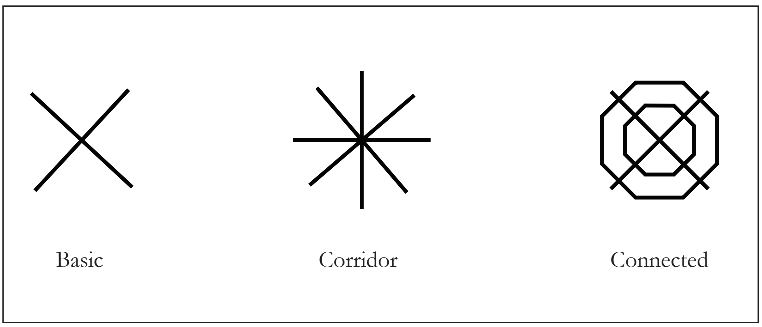
The Three City Forms

The study includes three city-form scenarios which differ in their main road structures, as displayed graphically in Figure 2. The scenarios which were chosen are relevant for a city of 150,000 inhabitants. We will examine the degree to which these forms create an urban environment that performs better for the targeted population. These three forms will now be shortly described.

The "Basic" city

In this form, two main roads intersect at the centre of the planned area, forming an "x" shape. This layout is envisioned to produce a spread-out non-dense city with a main focal point at the centre, although local neighborhood centers may also be developed along the roads. Housing should develop outward from the center along the roads, creating “fingers” of development radiating from the centre but leaving undeveloped green areas between the roads. As this structure imposes only very limited development constraints, it is termed the "Basic" city in this study.

Figure 2: The three urban form scenarios.



The "Corridor" City

In this form two axial roads are added to the Basic city, also intersecting at the centre of the area, and dividing the city into eight sections. This road layout should produce a drastic increase in overall city density, as development may be expected to spread outwards from the centre along the roads. In this "Corridor" form a strong focal point should emerge at the centre, but some neighborhood centers may also be developed along each road.

The "Connected" City

This form envisions the addition of several circular main roads to the “Basic city” layout, dividing the city into sections surrounded by roads. Such a layout is likely to result in a more constrained development and hence the emergence of a very compact city. As shown later, it facilitates relatively favorable mobility patterns. In addition, the construction of a large central area in the city is envisioned, limiting the development of other centers. Using these three city-form scenarios we now move on to developing the city.

Developing the Land-use Map: The Land-use Model

In the first step of the simulation, as explained above, a land use plan is developed. One way of doing this would be that planners decide directly on the allocation of different land use categories. Alternatively and applied in the suggested approach and especially for developing a unique targeted plan, planners decide on underlying principles, which lead to the development of a land use plan. In this study, these principles or, technically, suitability function parameters, are based on two different kinds of information: results of a conjoint study, and planner's expert knowledge.

In order to distribute land uses in the planning area, a suitability function is used. All equations used in the system are described elsewhere (Katoshevski-Cavari, 2007), and here we show only the suitability equations for a demonstrative purpose:

$$z_{lg} = \sum_i w_i^g \sum_j x_{ij}^g \chi_{ij}^g(l) + \sum_{h \in G} z_{gh} \chi_h(l) \qquad (1)$$

$$\chi_{ij}^g(l) = \begin{cases} 1, & if \;\; c_{i,j-1}^g \le d_i(l) < c_{i,j}^g \\ 0, & otherwise \end{cases} \qquad (2)$$

where,

G - is the exhaustive set of land use type

z_{lg} - suitability of cell l for land use g

w_i^g - weight of the i-th distance variable for g

x_{ij}^g - suitability score assigned to the j-th interval of the i-th distance variable for g

z_{gh}- suitability of presence of land use h adjacent to g

$\chi_h(l)$- equals 1, if land use h is adjacent to l and 0 otherwise

$d_i(l)$- value of l on the i-th distance variable

$c^g_{i,j}$ - j-th cut-off-point on the i-th distance variable defined for land-use g ($c_{i,0}$ = 0, $c_{i,6}$ = ∞)

As described in the above equations, the suitability of a cell for a particular land-use g in this model is assumed to depend on: (1) Accessibility to main roads, city center and specific land use categories h. In the model the latter refers to a function of distance to land use h for a given land use g. It is measured as a minimum distance across all other cells in the plan area that contain land-use h; and (2) Adjacency (land use in neighborhood cells), referring to any direct negative or positive effect one land use may have on another, adjacent land use (for example- noise, traffic load, decrease of visibility etc.). The latter involves the four direct neighboring cells and four diagonal ones. It is noted that, given the purpose of our analysis, suitability factors related to land (e.g., slope, soil) are left out of consideration.

The land uses are allocated to cells using a heuristic search technique. Suitability of a cell for a specific land use is assumed to depend on accessibility to main roads, city center and all other land use categories, and adjacency of land uses in neighborhood cells. Thus, the objective of the land use plan is to allocate a pre-defined amount of space to a set of cells based on specific settings of the planner.

As people have certain preferences concerning the location of different land uses and facilities around their houses, determining the suitability parameters based on people's revealed or stated preferences is fundamental for achieving satisfaction from the living environment. If the neighborhood/city reflects these preferences, the satisfaction driven from the living environment is increased. Based on this idea, a conjoint questionnaire was developed aimed to measure preferences for facilities and related locations. It included studying people's preferences concerning different aspects of their environment, such as preferences for housing type, air quality and greenery, and people's willingness to travel to different places. For example, conjoint results related to attributes of relative location provide information about preferences for walking or driving to most of the key locations such as kindergarten, elementary school, main shopping area and place of work.

The results of the conjoint analysis in general indicated that the population included in the study is looking for large houses, a neighborhood with a lot of greenery, good air quality and short driving time to work (Katoshevski and Timmermans, 2001 Katoshevski-Cavari 2007). These findings of the conjoint study were used to define the settings of the accessibility parameters. However, in addition to preferences of individuals and households, the suitability parameters should also reflect heuristics that planners use to find the spatial arrangements of land-uses that meet planning standards. Hence the suitability parameters in this study were determined based on planners' heuristics in addition to people's preferences. For example, assigning high scores to locating industrial land-use at long distances from the city center would not represent a basic preference, but rather helps to find the spatial arrangement of land- uses where, in the end solution, high–order user-oriented facilities are located in or near the city center and, hence, at locations that are well-accessible to users. We now move to describing the settings used in this study to develop the land use map.

The Settings

The following seven land-use categories were distinguished: (i) Housing High density (to be denoted further as Housing-*H*); (ii) Housing Low density (to be denoted further as Housing-*L*); (iii) Industry High Tech (Industry-*H*); (iv) Industry Low Tech (Industry-*L*); (v) Commercial; (vi) Recreation, and (vii) Nature. The plan area consists of an array of 2404 cells of 125x125m divided as follows: 760 cells for Housing *H*, 400 cells for Housing *L*, 96 cells for Industry *H*, 96 cells for

Industry *L*, 96 cells for Commercial land use, 80 cells for Recreation and 972 cells for Nature. The CBD is located in the geographical center of the city. These proportional land use requirements are derived from an anticipated Israeli city population size of 150,000 people and planning standards.

The planners' decisions concerning accessibility and adjacency are, as explained above, based on planners' heuristics and a conjoint study. For example, for the housing land-uses, the accessibility parameters indicate a preference of Housing cells to be in short distance to other Housing cells (Housing-*H* and Housing-*L*), and particularly, each Housing type to the same type. For Housing cells to Industry-*H* cells, an optimal distance was determined (500-1,000 m) and in terms of distance to Industry *L*, a clear preference was fixed for the longer distances. The accessibility parameters concerning the distance to Commercial land use cells show indifference for some distance (up to 500m) and from that point on it is monotonically increasing, with distance. The distance to Recreation and Nature cells, based on the estimated part-worth utilities found in the conjoint model, which indicated a preference for some distance separation between dwelling cells and recreation cells, the parameters are showing preference for a certain distance and then decreasing preference with distance.

In addition to accessibility to different land uses, the suitability of a cell is also influenced by accessibility to the City Centre, and accessibility to the transportation system. Accessibility to other land uses is related to the notion of utility of a location for households and picks up benefits of agglomeration and costs of spread at some distance (distance decay effects). In contrast, accessibility to the City Centre and the road networks should be primarily viewed as accessibility to modes of transportation. The function, reflecting preferences regarding distance of housing to the City Centre is unchanged up to 1500m and then decreases with increasing distance. For the main transportation system, that is, main roads, we assumed some optimal distance (400 m).

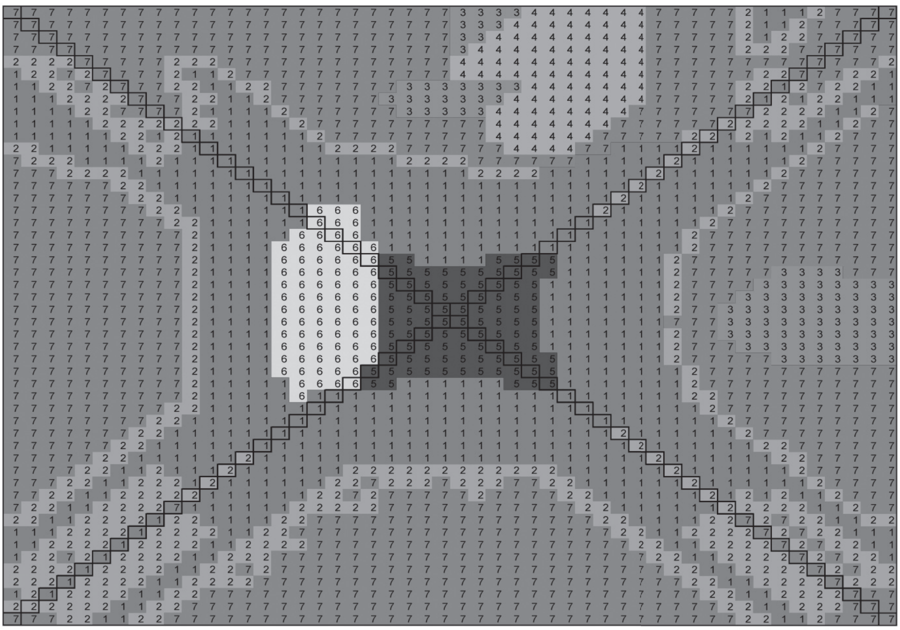
The adjacency parameters which are indicating the advantage or disadvantage for a cell to be adjacent to any other cell show, in this study, an advantage for a Housing cell to neighbor Recreation and Nature cells and a disadvantage to neighbor an Industrial cell, especially, Industry-*L*.

Using the above method and notions, the accessibility and adjacency values for all other land uses were determined (see Katoshevski-Cavari, 2007). The heuristic algorithm was used to allocate the required cells for each land use based on those determined suitability parameters. This results in a land use pattern- a land-use plan. Each of the three urban forms leads to different spatial land use patterns that define the context for conducting activities. These patterns constitute the starting point for the next step of the multi-agent system that is, determining facility locations. Before describing the next stage of the model, which is the facility distribution, we discuss now the three emerged city maps.

Land Use - City Maps

The results of the land-use model for the *Basic City* are portrayed in Figure 3. It shows the creation of a city center with primarily Commercial land use and the development of Housing along the arterial road, with high density development closer to the center. Industrial areas appear in the periphery of the area, while Recreational land use is allocated closer to the city center. Finally, Nature fills up space. Overall, then, this basic urban form with X shaped roads emerges as a finger-type configuration of urban land use.

Figure 3: Basic City – emerging land use pattern.



1- Housing-H, 2- Housing–L, 3-Industry–H, 4-Industry–L,

5- Commercial, 6- Recreation, 7-Nature

The land use pattern that emerges for the *Corridor City* is displayed in Figure 4. It is characterized by a large central part, which is dense and includes Housing, a shopping area, a park, and an outer part situated at some distance from the center where development is less dense. To some extent it develops similarly to the Basic City, in the sense that Housing development takes place along the main roads. However, since the number of roads is doubled, the developed area concentrated in the center of the city is larger. Penetration of Nature cells also takes place, but only on a limited scale, and the "fingers" of development into the nature areas are found only at some distance from the center. Compared with the Basic City scenario, the Industrial cells, which are developed in three different places – all in the outer part of the city – are closer to the Housing cells. However, Housing-*L* cells are never adjacent to Industry cells and in most cases are adjacent to the green areas.

Figure 4: Corridor City – emerging land use pattern.

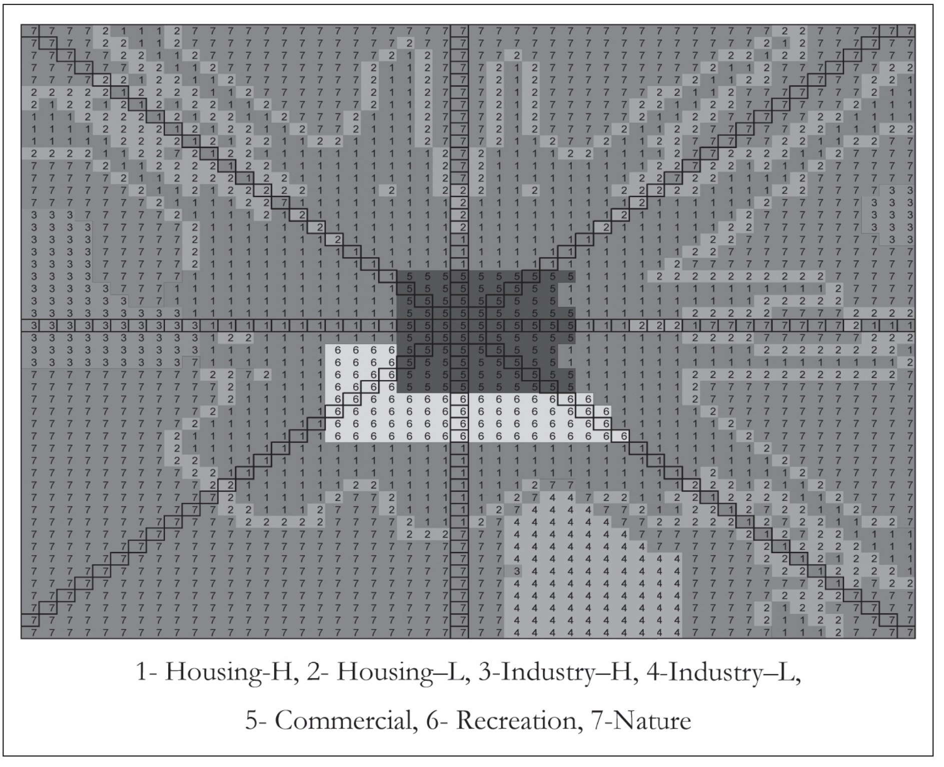
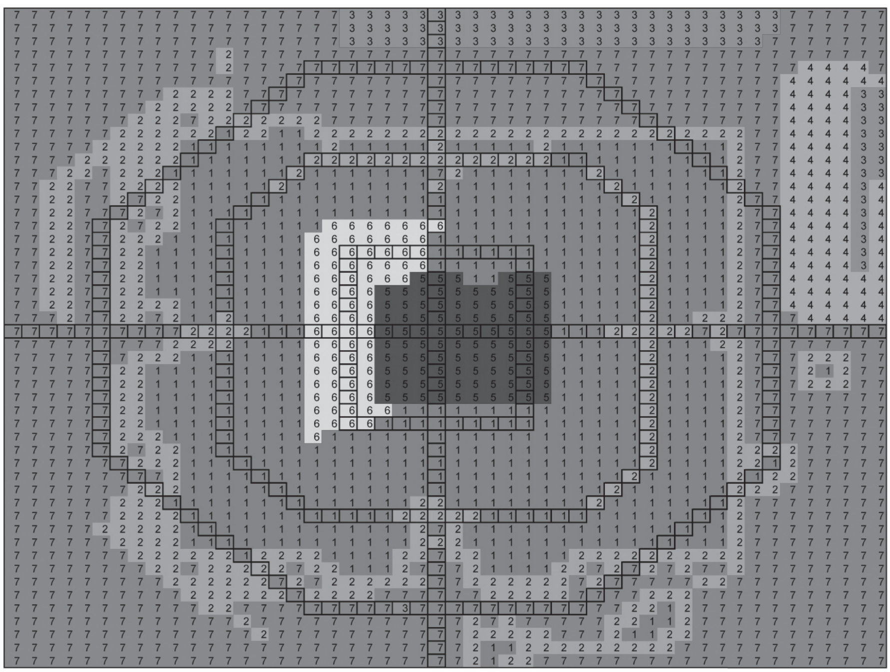


Figure 5 portrays the emerging land use pattern for the *Connected City* scenario. This layout is based on circular as well as radial roads, creating a different developmental structure in which the city evolves as a single dense area. Some Housing-*L* cells are developed along the roads, emphasizing the road structure. There is no penetration of Nature areas into built-up inner areas, and only limited development has occurred in the outer areas. Although the city is compact, Industrial areas, which are situated in two separate locations, develop at some distance away from housing.

A comparison of these emerging patterns suggests some similarities and some differences. Common to all scenarios is that Commercial cells are clustered in the center of the city, creating a city business center. This is expected because the accessibility functions and adjacency scores favor city center for this type of land use. Common to all scenarios is also the emergence of clustered recreational cells in one area adjacent to the central commercial area, creating a city level park. In addition, across scenarios, Industrial cells are clustered in a few industrial areas, at the edges of the city, and mostly away from housing and adjacent to Nature areas. Nature cells are located mostly on the outskirts of the city, while Housing-*L* is located mostly towards the edges of the city, although the latter finding is less prominent for the Basic City scenario.

Figure 5: Connected City – emerging land use pattern.



1- Housing-H, 2- Housing–L, 3-Industry–H, 4-Industry–L,

5- Commercial, 6- Recreation, 7-Nature

Differences in the road network, however, are mainly responsible for differences in the land use patterns. For the Basic City it has a dense part in the center comprised of a Commercial area with an adjacent Recreation. The city is evolving outwards from the center, creating strips of development along the main roads, allowing penetration of Nature cells into the city. The central area is surrounded by Housing-*H* cells. There is also clear-cut development of Housing-*L* cells in the outlying parts of the city, where development is surrounded by Nature cells, producing a less dense area. Industry is located in two areas, neither of which is adjacent to housing cells. Because of more roads in different directions, the development along the radial roads is less articulated in the Corridor City scenario, creating a more extensive core area and this is even more observable for the Connected City. As a result, the spatial distribution of the other land uses also differs.

Developing Facilities

The next stage in the model deals with implementing facilities in the city, using the created land use maps. This is done by two other actors in the system: the supplier agents and the individuals and households. Table 1 gives an overview of the facilities that were included in the model.

Table 1: Classification of facilities.

Main class	Subclass
Daily shopping	Neighborhood level
	City level
Non-daily shopping	Neighborhood level
	City level
Schools S	Kindergarten
	Elementary school
Schools H	High school
Medical	Neighborhood level
	City level
	Hospital
Leisure	Restaurant
	Activity centre
	Theatre
Services	Post
	Bank
	Library
	Synagogue
Sport	Pool
	Sport hall small
	Sport hall big
Parks	Neighborhood
	City

The development of facilities is at first based on a synthetic population and norms of the Israeli planners and on the activities of individuals and households obtained from Israeli time-use survey.

The Sample Population

The sample of the Israeli time-use survey (CBS, 1995) consists of 3082 people in the age of 14 years and older spread across 86 localities living permanently in Israel. These include the cities of Jerusalem, Tel-Aviv and Haifa and another 83 different Jewish and Non-Jewish cities and settlements. All persons aged 14 years and older belonging to the sampled households were included. In total, 1801 dwellings were sampled. Data was collected by using two types of diaries: (1) a recall diary and (2) a self-recorded diary. Information on less frequent activities was collected using a retrospective questionnaire. In addition, demographic and socio-economic data was obtained for each member of the household as well as for the household as a whole. Table 2 includes some information on the sample.

Information about activities and travel was derived from the time use diary which was used for extracting decisions trees. These indicate under which sets of conditions particular choices underlying these activity- travel pattern are made. The resulting set of decision trees make up a rule-based model of activity travel demand.

Facility-location Model + Facility-use Model: Implementing an Activity–based Model

First, the facility-location model simulates the behavior of the supplier agents, the second group of actors, in terms of their decisions to open outlets. Then, the third group of actors, individuals and households are acting in the planned area and use the facilities based on the activity-travel choices. Their activities and use of facilities create the drive for the facility supplier to re-evaluate the developed facilities and make adaptation decisions, in terms of closing or re-sizing facilities.

In the facility-location model (the first stage), each supplier agent specializes in a certain facility type. All agents evaluate candidate facility locations based on the number of visitors a (new) facility would attract in a given time period (e.g. a day), which they estimate based on a catchment area analysis. In each time step in the system, agents have the opportunity to submit development proposals specifying the location, square meter floor space and the type of the facility. Agents base their proposals on market assessment. The application of the facility location model requires setting parameters for each facility type, as listed and explained in Table 3. This market analysis is aimed to create a perceived value of a site in order to identify the preferred location for a facility.

All operational decisions regarding settings of the facility location model were set the same for the different planning scenarios, as they are all based on Israeli planning norms and standards and are relevant for the target population. For example, in terms of the radius of the primary catchment area, a small catchment area was chosen for all neighborhood facilities. This is to keep these facilities at a short distance from housing and spread them across the city. The primary catchment area has a radius of 500m for neighborhood facilities. For the city level, the radius varies between 1550 m for the non-daily shopping, and 2350m for hospital and city Park. The maximally allowed rate of cannibalism or, in other words, the allowed size of overlaps between catchment areas of a same facility type, was determined between

30% and 70%. Usually the numbers are set between 30% and 45% for neighborhood facilities and set as high as 70% for city-level facilities. This is to compensate for the lower penetration rates in the neighborhood facilities which entail a relatively small numbers of visitors.

Table 2: Sample characteristics.

Sample characteristics	Group section	Percent
Gender	Males	45
	Females	55
Religion	Jewish	86
	Non-Jewish	14
Age	14-21	20.7
	22-35	25.1
	36-50	26.4
	51-64	14.9
	65-90	12.9
Marital status	Single	28
	Married	62
	Widowed, divorced, separated	10
Family size	1 person	7
	2-6 persons	79
	7-15 persons	14
Education	Up to 8 years of study	24
	9-12 years of study	38
	Acad. diploma	16
	13 and more/ no acad. diploma	22
Employment	Full time	46
	Part time	14
	Unemployed	40
Religiousity	Religious	13
	Traditional	35
	Non-religious	35
	No indication	17

Calculated in this way, the proposed (and implemented) facility size is the best estimation of the demand that a new facility will attract. However, this estimated demand is based on limited information about the behavior of the individuals, for example, the penetration rates, and action radius. Other parameters of the method are only proxies of actual behavior that determines the generation of activities and allocation of activities across locations. The actual behavior is governed by a different set of rules which is the activity-based model, using the locational configuration of facilities as an input. The consequences are that only after some time of exploiting the facility, the actual size of demand attracted will be known. Periodically, the suppliers consider re-sizing facilities and possibly even closing facilities based on the actual size of the attracted demand, whereby the estimated facility is replaced by its realized counterpart. This stage is implemented based on people's activity patterns that are constructed using a modified version of the Albatross software (Arentze and Timmermans, 2000).

Table 3: Facility suppliers-parameters for opening outlets.

Parameter	Explanation
Penetration rates	The percentage of population present in a cell that will be attracted to the facility
Radius of catchment areas	The radius of the area from which the facility will attract visitors
Maximum rate of cannibalism	The extent of allowed overlaps in the primary catchment area between facilities of the same type
Center bonus/penalty	Extra demand attracted (positive or negative) due to being in a certain distance from center
Road bonus/penalty	Extra demand attracted due to being in a certain distance from a main road
Space needed per 100 visitors	Floor space size required for each 100 visitors a day
Minimum size of floor space required	Minimum outlet size for a viable facility

The activity patterns of the adult population in the system determine which activities are conducted where, for how long, when, and, if travel is involved, the transport mode. The combination of origin's location, maximal travel time and transport mode determine the locations that are within reach. Concerning children's activities, given the day of the week and age of the child considered, the model predicts whether or not a school activity is to be included in the schedule and, if the answer is positive, determines the attributes of the activity.

Final City Maps

The whole process of creating the city land use and facility maps is now completed and three city-scenarios for 150,000 people are the outcome.

The *Basic City* scenario shows that facilities are spread all over the city. More specifically, neighborhood daily shopping units are dispersed throughout the city, whereas city level shops tend to gravitate towards the central district. The non-daily shopping facilities demonstrate a less efficient distribution, as most shops are developed in the inner part of the city, thereby limiting the number of shops in the outer fingers of development. Schools of all levels, sports facilities and parks are scattered throughout the city, implying convenient access to facilities. Expectedly, leisure and service facilities are developed in all city areas but are densest in the center.

The results for the *Corridor City* as in the *Basic City* scenario show a generally good dispersion. However, the shopping facilities and schools are not evenly distributed and tend to be concentrated in the dense part of the city, hampering their development in the outward-pointing "fingers". Medical, leisure, sports and park facilities, on the other hand, are well dispersed over the city areas, suggesting a very efficient spatial distribution. The leisure facilities show a fairly good distribution.

The results for the *Connected City* show that for this pattern of development, the spatial distribution of facilities is more spread out. Education facilities, medical facilities, leisure, service, sport facilities and parks are placed all over the city. However. leisure and services facilities are denser in the center, as expected. The shopping facilities (daily and non-daily) also show a wide spreading, however not reaching the edges of the city.

KEY PERFORMANCE INDICATORS

The results presented above focus primarily on the spatial distribution patterns of land use and facilities. The performance of each pattern, however, is measured and inter-compared here in terms of a set of three indicators: (i) accessibility; (ii) mobility, and (iii) viability. These indicators reflect different aspects of sustainability, namely the ease with which individuals can reach locations for their activities (accessibility), the total traffic induced by the system and associated negative externalities of traffic (mobility) and the economic performance of the facilities (viability). As a set, the indicators cover the objectives of the different parties involved in planning: individuals and households (accessibility), facility providers (viability) and the community as a whole (mobility). Equity issues are covered by not just reporting measures of central tendency (e.g., average) but also the dispersion (e.g., standard deviation) of each indicator across locations.

For example it is commonly assumed that better accessibility is a positive indication of sustainable development. Figure 6 portrays the results of the total accessibility analysis to the first and second nearest facility. The overall results show that the *Connected City* creates the most accessible form. In addition, the overall total mobility generated in the system across activities shows, in Figure 7, that in the *Connected City* the number of tours and the total travel distance is the lowest. Thus, these results strengthen the previous ones indicating that the *Connected City* is the most efficient one regarding the mobility aspects. The viability indicator, which relates to the economic performance of facilities, shows that concerning the *number of outlets,* the *Connected City* has the largest facility network (*Basic city* (228), *Corridor City* (234), and *Connected City* (240)). In addition, concerning the *mean cluster size* the results are as follows: *Basic City*: 2.89, *Corridor City*: 2.89, and *Connected City*: 2.71. This indicates that both the *Basic City* and *Corridors City* are advantageous in spatial agglomeration and efficient use of space.

Figure 6: Total accessibility – 1st and 2nd nearest facility.

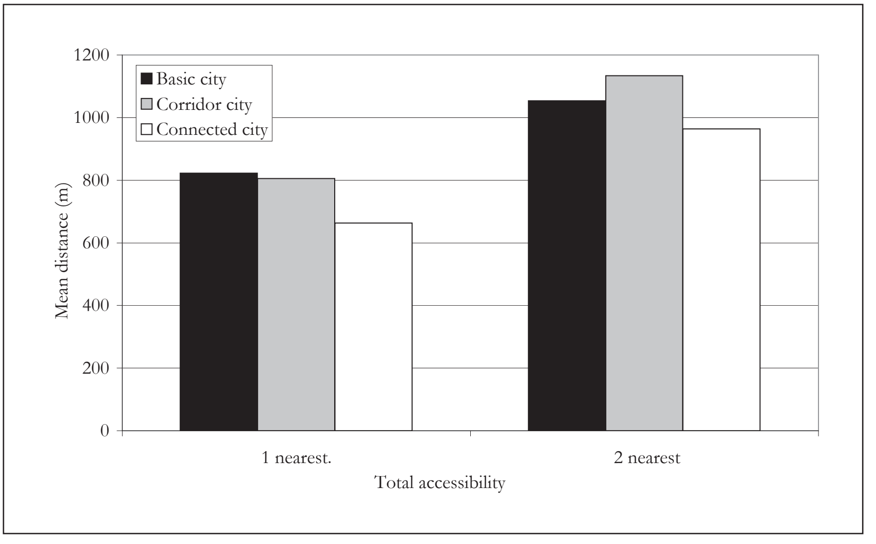
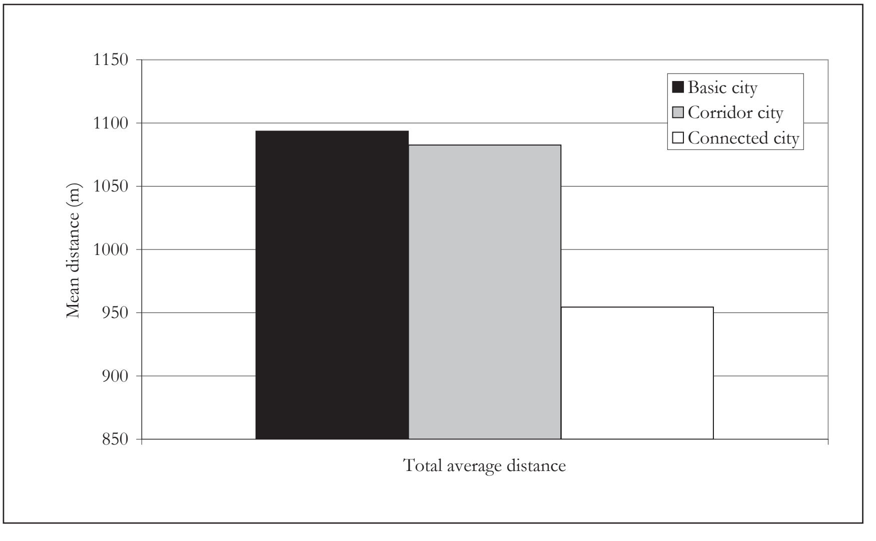


Figure 7: Total average distance.



DISCUSSION AND CONCLUDING REMARKS

In contrast with common planning processes and existing planning models, the described multi-agent system described here is designed in such a way that it creates an outline plan based on parameters of a *specific population*. In each of its planning stages, relevant "live" data is included. The first stage, the creation of the land use map is based on the collected information concerning people's preferences for their built environment. In this study the inputs were deduced from a conjoint study (in addition to the planner's knowledge). The second stage, the development of facilities, is dominated by the people activities in the built environment. These activity patterns in our study were based on time-use data survey. From the outcome of these two stages, different city scenarios were developed. Now the system can be used to evaluate the performance of various emergent city scenarios, and choose the optimized plan based on the pre-defined interests. Moreover, the collected data, which covers several kinds of information, enable the planners to sense and isolate the relevant and focused public interest of that group out of the general public interest.

We argue that this very fundamental nature of the system is a key component for the development of a plan that is targeted at the specific population needs. Hence, the multi-agent planning system is a relevant tool for solving the dilemma defined in the first part of the paper which deals with how to identify public interest, especially the interest of those distinctive groups and how to asses its maintenance.

In this described study three city-scenarios were developed. These city versions are all based on the same data (conjoint questionnaire results and time use data survey) and on the Israeli norms. One can contend that the data for this study is based on the general Israeli population and hence describe an average behavior (taking into account heterogeneity) and therefore cannot indicate any specific needs or create an exclusive plan. Also a claim can be made that these three forms do not cover all the planning options or are not the best alternatives. However, the specific data included in the model or the various city forms are not the core issue. This (general) data enables us to examine the possibility of moving from the traditional planning procedure where information concerning the target population is very limited (with no data concerning activities or preferences used in a systematic way), to a different planning system where the planning is based on the relevant population, their preferences, and activities. That is, after highlighting the capability of the overall method in using a specific population data and city forms, all these inputs can be changed and adapted to a target population that will be addressed.

The separate function of the system concerning the scenario evaluation, which can be used to evaluate alternatives developed by the system or planning options which are made external to the system, is a significant feature of the system for assessing that public interest is guarantied. In this case the system is used only as an evaluating tool. The currently employed indicators or other ones which will be relevant and suitable for the specific interest of the population can be defined so that the outcome plan maintains the particular interests.

To summarize, in this paper we demonstrated that the multi-agent system developed here, which proved its ability to create a tailor-made plan for a target population and to asses different externalities, is an applicable tool for planners to support the creation of a unique and relevant plan, safeguarding public interest.

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