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공간의사결정보조체계를 이용한 다단계 및 다목적 도시 공원 배분에 관한 연구

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MULTI-STAGE AND MULTI-OBJECTIVE ALLOCATION PROCEDURES OF URBAN PARKS USING LOCATION DECISION SUPPORT SYSTEMS

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요 약

본 연구의 목적은 공간의사결정보조체계를 도시 시설중의 하나인 공원배분계획에 이용하여 현재 이용되고 있는 공원배분계획의 결점을 보완하는 데 있다. 두 가지 요소 즉 이용자 행태 및 효율성과 형평성을 고려한 정책이 공원배분계획에 주요한 역할을 하는 데 본 연구에서는 효율성과 형평성을 중심으로 공원배분계획을 살펴 보고자 한다. 이를 위해서 지리정보체계(GIS: Geographic Information System)를 이용한 공간의사결정보조체계가 이용되었는데, 이는 많은 양의 데이터나 계산은 물론 가중치, 계획 기준 등 변수를 변화시켜 봄으로서 여러 가지 대안을 쉽게 평가할 수 있어 공원배분계획에 도움을 주기 때문이다.

도시 공원을 위한 GIS응용 공간의사결정보조체계(GIS oriented Urban Park Location Decision Support System: UPLDSS)의 유용성은 원형(archetypes)연구를 통해 살펴 보았다. 원형은 여러 가지 유형중 도시 근린공원을 이용하여 도시 지역을 모사한 것이다. 원형연구에서 UPLDSS의 모델들이 다단계 및 다목적 계획을 잘 수행할 수 있음을 보여 주었다. 즉, UPLDSS는 계획가가 계획 목적(형평성과 효율성)에 따라 여러 가지 다른 시나리오를 만들어 그에 따른 대안을 구축하고 평가하는 데 도움을 줄 수 있다. 이것은 특히 계획가가 여러 가지 대안 중 어느 대안이 우수한지 쉽게 평가하기 어려울 때 계획가의 의사결정에 도움을 준다. 그리고 본 연구는 다른 위계의 공원 계획에도 이용될 수 있음은 물론 다른 도시 시설물의 배치에도 이용될 수 있다.

INTRODUCTION

Recreation has an important role in human life. Specifically, the open space around residential areas such as playgrounds or neighborhood parks influences people's daily lives implicitly or explicitly. Studies show that having a small neighborhood park close to home is considered the most important of all the components in modern municipal recreation systems (e.g., Gold, 1973). In spite of such contributions, however, the literature directly related to the provision of parks is quite rare. It was not surprising that the National Urban Recreation Study (US. Department of Interior et al., 1978) showed that the existing park and recreation facilities were generally inadequate in the majority of the urban regions. The report further indicated that neighborhood parks are too few in number, and are often located in the wrong places. Spatial distribution of services is directly related to the physical access of users.

Therefore, the main claim of this study is that the incorporation of location-allocation in a Spatial Decision Support System (SDSS) can address the methodological shortcomings of current practice in open space planning, especially urban park allocation, and that location-allocation models alone are insufficient because they do not function well in ill-structured problems. Regarding the location - allocation of parks, two factors - user behavior, and possible policies involving equity and efficiency - are the main concerns. This study focuses on the second factor to address how and where recreational resources should be located.

DESCRIPTION OF URBAN PARK LOCATION DECISION SUPPORT SYSTEM (UPLDSS)

Spatial Decision Support System for Location - Allocation

Park location-allocation problems are also often ill- or semi-structured in their overall planning process, since they require dealing simultaneously with large amounts of data (e.g., population, street network, distances, etc.) and many computational and analytical capabilities to derive good decisions. In turn, park allocation problems demand that planners make appropriate decisions based on a systematic integration of analytical and statistical modeling capabilities (e.g., optimization) and the geographic representation of modeling results (e.g., GIS). In addition, planners should be able to change and select planning issues, weights, and parameters according to site-specific situations, which always vary. This all indicates that park allocation problems can not be fully solved by some mathematical models, but should be supported by a systematically integrated decision support tool.

Spatial Decision Support Systems (SDSS), a field of DSS, specifically focus on using a variety of data types to bring analytical and statistical modeling capabilities to bear on problems, rely on graphic displays for problem solving, and can easily be modified to include new capabilities. Geographic Information Systems (GIS) provide basic procedures of data query and overlay (e.g., arithmetic and geometric analysis, statistical analysis), but do not support the analytical and statistical modeling required by many planners. For those users who are concerned with system processes, there is almost certainly a need for a modeling capability (Clarke, 1990). In the broadest sense, modeling should be an integral part of GIS, but is often treated as though it were a separate process.

In order to overcome these problems, SDSS attempts to integrate GIS and DSS into one effective system. In combination with simulation or optimization models and expert systems tools, SDSS not only adds the spatial analytical capabilities to GIS, but also illustrates the benefits obtained by applying GIS to decision making in urban applications (Fedra and Reitsma, 1990).

Multiple Decision Stages

Following Kaiser et al. (1995)'s argument suggesting three steps of open space provision, the UPLDSS emphasizes the importance of a multiple stage decision process rather than a single stage decision in dealing with urban open space provision. As the first stage decision, the existing open space condition might be easily investigated by examining the service zones of the existing facilities. If reasonably delineated, the service zones of the facilities would clearly indicate where the problem areas (either underserved or overserved) exist. The next decision stage then focuses on location-allocation issues, based upon the results of the first stage.

Delineation and Location-Allocation Models

The two models, the simple linear programming model and gravity model, seem appropriate in delineating service zones of urban parks, whereas the maximal covering model (pursuing spatial equity goal), p-median model and gravity model (pursuing spatial efficiency goal) have dominated the field in allocating facilities. The models can be further defined by their mathematical characteristics (either deterministic characteristics or probabilistic characteristics). The optimization-related models (e.g., the linear programming model, maximal covering model and p-median model) contain deterministic characteristics, while probabilistic characteristics are included in gravity model.

Compared to the optimization models, some technical issues have been raised from gravity model, such as calibration problems and specification problems (Brown, 1992). For this study, the linear programming model in the delineation stage, and maximal covering model and p-median model in the location-allocation stage are applied in this study, being examined in designated archetypes.

Main Issues Related to Urban Park Allocation

Except for a few studies (e.g., McAllister, 1974 and Wright et al., 1976), it seems that the allocation issues specifically related to urban parks have not been extensively studied. There are certain issues, however, that have been investigated in terms of allocating general public services. They are equity, efficiency, socioeconomic status, and adequacy. Table 1 shows the rationale why the issues based on the literature review are selected and attributes to use in UPLDSS (Urban Park Location Decision Support System).

Table 1. Attributes of UPLDSS

Planning issues	Attributes	Rationale
Adequacy	Capacity of parks: *the upper or lower limits of park size per person*	Consider the degree of spatial match between need and provision (acre/person); require facilities to be greater than a minimal size needed for efficient operation (minimum park size)
Accessibility	Walking distance: *WDS*	Allocate public services within appropriately accessible distance
	Walking difficulty: *WDF*	Allocate public services within appropriately low walking difficulty; consider roads themselves (e.g., number of crossings and road width) as barriers to park access
Attendance Efficiency	User *Population*	Public services are provided where the cost of delivering them is lowest or where more people were benefitted in the same delivering cost
Need Equity	Socioeconomic Index : *SEI*	Allocate services so that both socially and economically disadvantaged groups, individuals, or areas receive extra increments of resources
Demand Equity	*Population density*	Allocate resources on the basis of consumption and/or advocacy
Socioeconomic Homogeneity	*Standard Deviation of SEI*	People might use neighborhood parks and playgrounds more frequently with a familiar and comfortable social context

Introduction to Proposed Tools

Figure 1 represents the general framework of the UPLDSS, where the planner's critical decisions are supported by three computer-based SDSS modules. It specifically shows how the modules of UPLDSS can help the planner's decision by providing data management tools, analytical capabilities, and representation tools in sequence. While planners make decisions for park allocation process, the UPLDSS provides the planner three SDSS modules to support those decisions. The three modules are database management module, analytical module, and representation module. Those modules in UPLDSS help try scenarios, generate alternatives under different assumptions, and make visual and statistical representations for spatial distribution.

Database for Urban Park Allocation

Due to the ready availability of data, geographical units such as census tracts have traditionally been used as analytical units. The Census of Population and Housing (Census Bureau, 1990) provides the major source for socioeconomic data in planning applications. The three major levels of aggre-

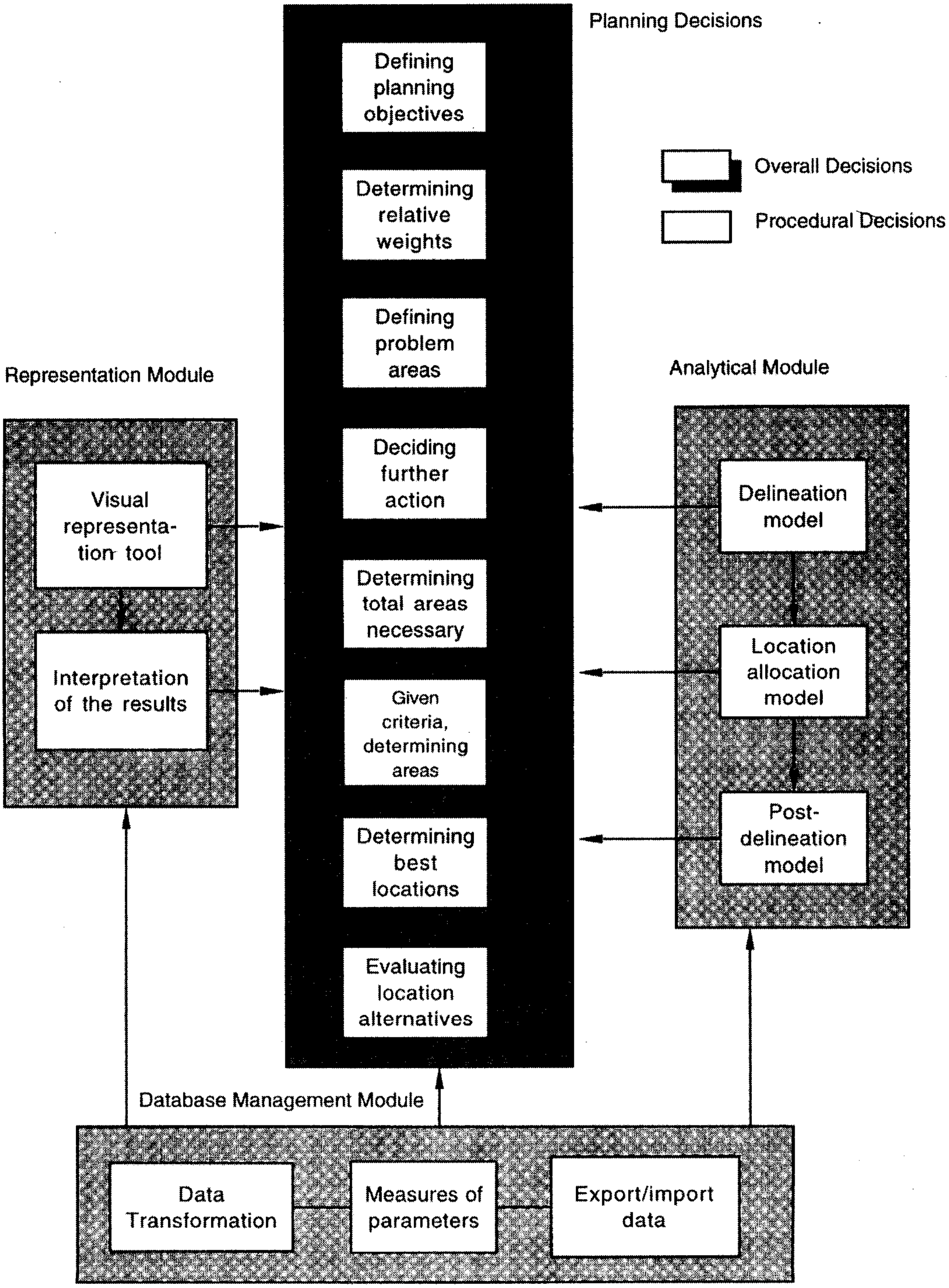

Figure 1. Overall Framework of UPLDSS

gation for geographic reporting for urban areas, block, block group, and tract, form a nested hierarchy. Blocks constitute the lowest level in the geographical hierarchy. Block groups are aggregations of contiguous blocks. Tracts are aggregations of contiguous block groups. Block groups and tracts are modifiable geographical units since their boundaries are arbitrary. A block group is composed of groups of census blocks and average about 1100 people. A tract is an aggregation of block groups and averages about 4000 people.

Blocks are usually small areas bounded on all sides by visible features such as streets, roads, streams, and railroad tracks, and by invisible boundaries such as property lines, legal limits, and short imaginary extensions of streets and roads. For this study, in terms of neighborhood parks, urban parks usually consist of one or more blocks; hence, the block level is appropriate for examining allocation issues.

The US Census Bureau's TIGER files were used to create geographic base maps (e.g., blocks, block groups, and tracts), whereas the Census of Population and Housing data are mainly used in generating the attribute database. TIGER/Line files are digital street network files that have become one of the more commonly used spatial data for geographic information systems. TIGER Files contain topological structures describing how points and lines relate to each other on a map to define geographic areas. TIGER/Line files were converted into a coverage in ARC/INFO.

Mathematical Models for UPLDSS

Two types of procedural models are necessary for UPLDSS; one is the urban park service zone (UPSZ) delineation model for analyzing the spatial distribution of existing park systems. The other is the location-allocation model for allocating new parks in underserved areas (or relocating existing parks as well). Here, the mathematical structures of the linear programming model as used in the UPSZ delineation stage, and maximal covering model and p-median model as used in location-allocation stage are introduced. For this study, it is assumed that the relationships of the aforementioned attributes are linear.

One main argument of this study is that incorporating multi-objectives in the model is certainly more appropriate than optimizing each objective separately. A weighting method was selected in solving multi-objective linear programming models. The weighting method also assumes that each objective function is additive and there is no interaction between objectives. The weighting method is to apply a variation of positive weights in a linear combination of the objectives.

Delineation Model

The example of a mathematical structure for the multi-objective linear programming model utilizing the weighting method is:

$$\text{Minimize} \sum_{j=1}^{n} \sum_{i=1}^{m} (w_1 rP_i + w_2 rSEI_i + w_3 rDensity_i)$$

$$* \; WDS_{ij}(\text{or } WDF_{ij}) * X_{ij} \qquad (1)$$

$$\sum_{i=1}^{m} X_{ij} = a_j/a \qquad (2)$$

$$\sum_{j=1}^{n} X_{ij} <= P_i \qquad (3)$$

where,

X_{ij} = decision variable; the population in block i allocated to park j

WDS_{ij} = the distance from block i to park j

WDF_{ij} = the walking difficulty index from block i to park j

m = the number of blocks

n = the number of neighborhood parks

a = park size (m^2)/person

a_j = the area of park j

rP_i = the reversed population index[1] of block i

$rDensity_i$ = the reversed density index of block i

$rSEI_i$ = the reversed socioeconomic index (SEI) of block i

P_i = the population of block i

The first constraint (2) for the optimization model is to evaluate whether a park provides sufficient area per person with regard to the current park size (according to adequacy objective). The second constraint (3) ensures that the number of people in block i assigned to all parks j can not exceed the total population in block i. Coefficients W_k (k= 1, 2, 3) are the relative weights of each objective.

Location-Allocation Model Structure

Multi-objective maximal covering model. The objectives for location-allocation are to minimize the demand (population, SEI, density) not covered within a given threshold (e.g., WDS < 1200 m) by a specified number of parks. This objective (minimize uncovered blocks by multi-objectives) could be formulated as follows:

$$\text{Minimize} \sum_{i \in I} (w_1 P_i + w_2 rDensity_i + w_3 SEI_i)\, y_i \quad (4)$$

within given WDS or WDF thresholds

s.t.

$$\sum_{j \in J} x_j = p \quad (5)$$

$$\sum_{j \in N_i} x_j + y_i >= 1 \quad \text{for all } i \in I \quad (6)$$

$$x_j = 0,\ 1 \text{ for all } j \in J \quad (7)$$

$$y_i = 0,\ 1 \text{ for all } i \in I \quad (8)$$

where,

I = the set of blocks

J = the set of park sites

$N_i = \{ j \in J \mid d_{ij} \leq S_i \}$, the set of park sites eligible to provide coverage to block i

S_i = distance beyond which block i is considered uncovered

d_{ij} = the shortest distance from block i to park j

$Density_i$ = the density index of block i

SEI_i = the socioeconomic index of block i

y_i = (0,1), 0 if block i is within the threshold distance of a facility, otherwise 1

x_i = (0,1), 1 if park is allocated to site j, otherwise 0

P_i = the population of block i

p = the number of parks to be located

The constraint (6) requires y_i to equal one unless one or more facilities are established at sites in the set N_i; i.e., when there is at least one facility within S units of demand block i. The total number of facilities allocated is restricted to equal p in constraint (5).

Multi-objective p-median model. In this case, the multi-objective function is formulat-

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1) Population index is normalized value of population by the the formulation $Pi = \frac{x - \min(x)}{\max(x) - \min(x)}$ then, the normalized value is subtracted from 1($rP_i = 1 - P_i$) to use in objective function(1). It was used as *population weight* to make the model incorporate blocks in the service zone that have more population with in same distances. It was found that, if this parameter was not used, some blocks of high population (even in near distances) were continuusly excluded. $rSEI_i$ and $rDensity_i$ was obtained the same methods as rP_i.

ed to locate given facilities while minimizing WDS or WDF according to the population (attendance efficiency), density (demand equity), and SEI (need equity). The objective is:

$$\text{Min } z = \sum_{i \in I} (w_1 P_i + w_2 \text{Density}_i + w_3 \text{SEI}_i)$$

$$* \text{ WDS}_{ij} \text{ or } (\text{WDF}_{ij}) * x_{ij} \qquad (9)$$

s.t.

$$\sum_{j=1}^{n} x_{ij} = 1 \text{ for all } i \qquad (10)$$

$$x_{jj} - x_{ij} >= 0 \qquad (11)$$

$$\sum_{i=1}^{m} x_{jj} = p \qquad (12)$$

$$x_{ij} >= 0 \text{ for all } i \qquad (13)$$

$$x_{jj} = (0,1) \text{ for all } j \qquad (14)$$

where,

W_k = the weigh of objective k

P_i = the population of block i

Density_i = the density index of block i

SEI_i = the socioeconomic index of block i

WDS_{ij} = the shortest distance from block i to park j

WDF_{ij} = the walking difficulty index from block i to park j

x_{ij} = 1 if block i is assigned to park j, otherwise 0

x_{jj} = 1 if block j is park, otherwise 0

p = the number of parks to be located

The first constraint (10) ensures that each block i is assigned to a park j. The second constraint (11) ensures that the demand of a block will be assigned only to a block that has been allocated a park. When j has a park, x_{jj} must be one, but x_{ij} may be zero or one. If there is no facility at j then both x_{jj} and x_{ij} will be zero for any i. This constraint therefore prevents x_{jj} from having the value zero when x_{ij} is one. The third constraint (12) restricts the number of facilities in the system to p by making use of the fact that there must be p self assigning nodes in the final solution. GAMS, specifically ZOOM which is one of the GAMS modules, is used for solving the above maximal covering and p-median models. ZOOM solves zero/one mixed-integer programming problems (Brooke et al., 1992).

IMPLEMENTATION OF UPLDSS IN ARCHETYPES

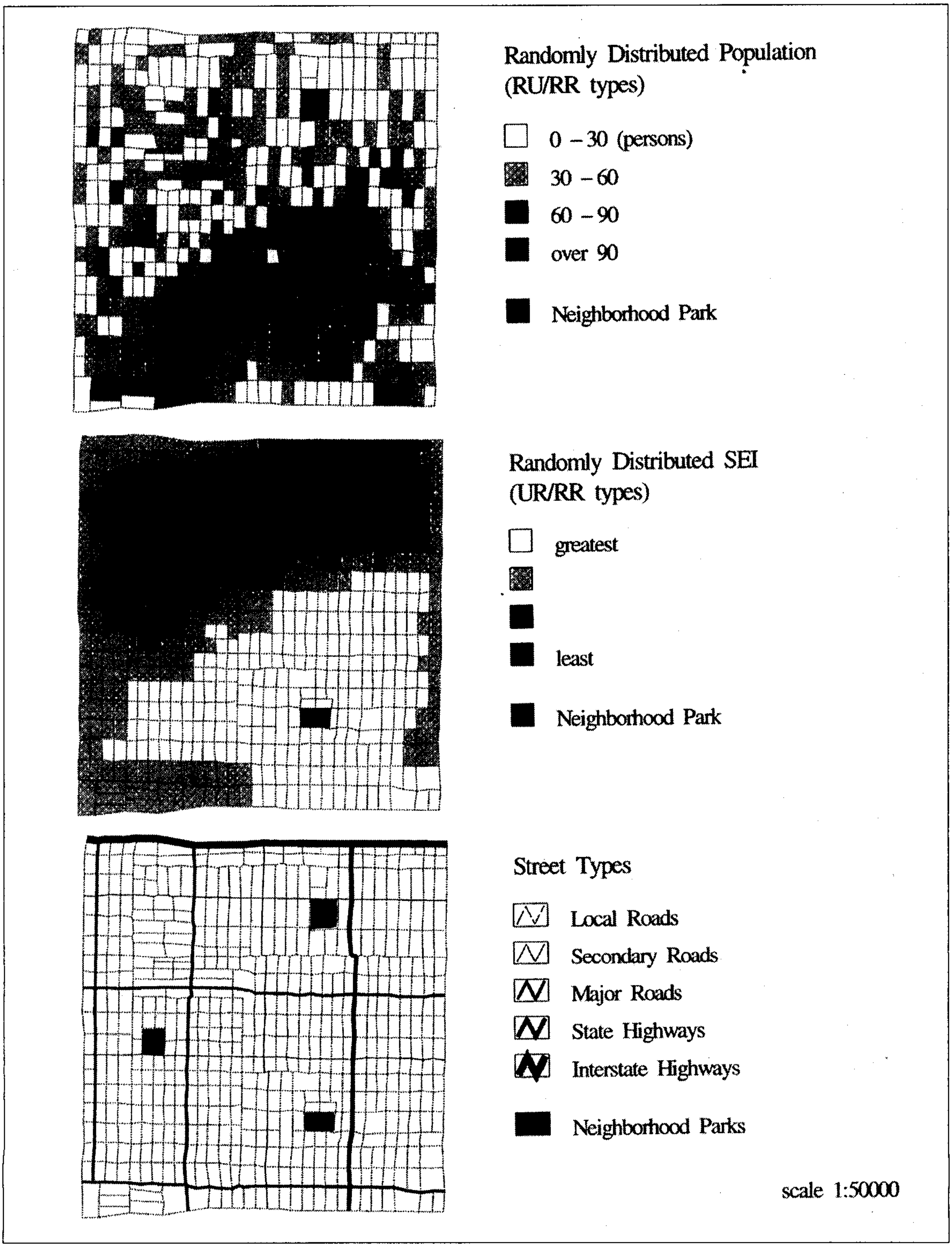
Brief Descriptions of Archetypes

A small set of contrived examples of structured data is developed to demonstrate how the system actually functions, and to examine

Table 2. UU archetype; UR archetype; RU archetype; RR archetype

		Population Distribution	
		Uniformly	Randomly
SEI Distribution	Uniformly	Uniformly Distributed Population and Uniformly Distributed SEI: ***UU*** type	Randomly Distributed Population and Uniformly Distributed SEI: ***RU*** type
	Randomly	Uniformly Distributed Population and Randomly Distributed SEI: ***UR*** type	Randomly Distributed Population and Randomly Distributed SEI: ***RR*** type

Figure 2. GIS-generated Archetype: Population, SEI, and Street Types



various allocation procedures discussed in the previous chapters. By testing the models against the archetype, the behaviors of the models can be easily illustrated. As a design tool, its purpose was also to show how SDSS with a GIS and spatial optimization models can be utilized in the planning process. The structures of archetypes are composed of the combinations of two variables (population and socioeconomic status) and the distribution type (uniform versus random) as shown in Table 2. Here, housing value, one of the six socioeconomic variables of SEI, was used as an index of socioeconomic status for convenience, instead of using all of the variables of SEI.

The area for the archetype was set to be around 1.5 square miles which is small but enough to show the variation. It is assumed that 3 neighborhood parks exist in the present situation. The population of blocks and standard deviation of populations among blocks are taken from the existing city data (Portland, OR). The data of the housing value are also obtained using the same method as in the population. Figure 2 shows the random distribution of population and housing value (UR and RR) in the archetype. Similar to CFCC (Census Feature Class Codes) in TIGER files, the street types are also assigned as shown in Figure 2.

Delineation of Park Service Zone

Efficiency Objective Demonstration: Attendance Efficiency

Figure 3 and Figure 4 show the examples of single objective delineation results, which is maximizing attendance efficiency (e.g., minimizing aggregated WDS with block population), on the archetypes of different population distribution types (uniform versus random). It had been expected that as the distribution of population changes from uniform to random, the optimal service zones change. The figures, Figure 3 and Figure 4, show that the service zones constructed from two different population distribution types were different, responding to population change.

In addition, Figure 5 also illustrates another result of the attendance efficiency objective using WDF instead of WDS (e.g., minimizing aggregated walking difficulty with block population) on the randomly distributed population. This figure shows different geographic results in delineation from those considering walking distance. As state highways are given large weight (9 in 1 to 9 scale), the neighborhood outside the highways is not generally included in park service zones. The significant difference on the delineation between two accessibility measures (walking distance versus walking difficulty) suggests that these two accessibility measures can produce different solutions.

Multi-Objective Demonstration

Figure 6 shows the delineation results of multi-objective linear programming using weighting methods on the RR archetype, where need equity, demand equity and attendance efficiency objectives are considered together. Table 3 also presents the results of the multi-objective model compared with the results of the single objective models. As expected, for each single objective, each solution was superior to others on the target objective, ranking the first; however, for other objectives, the solution was ranked in

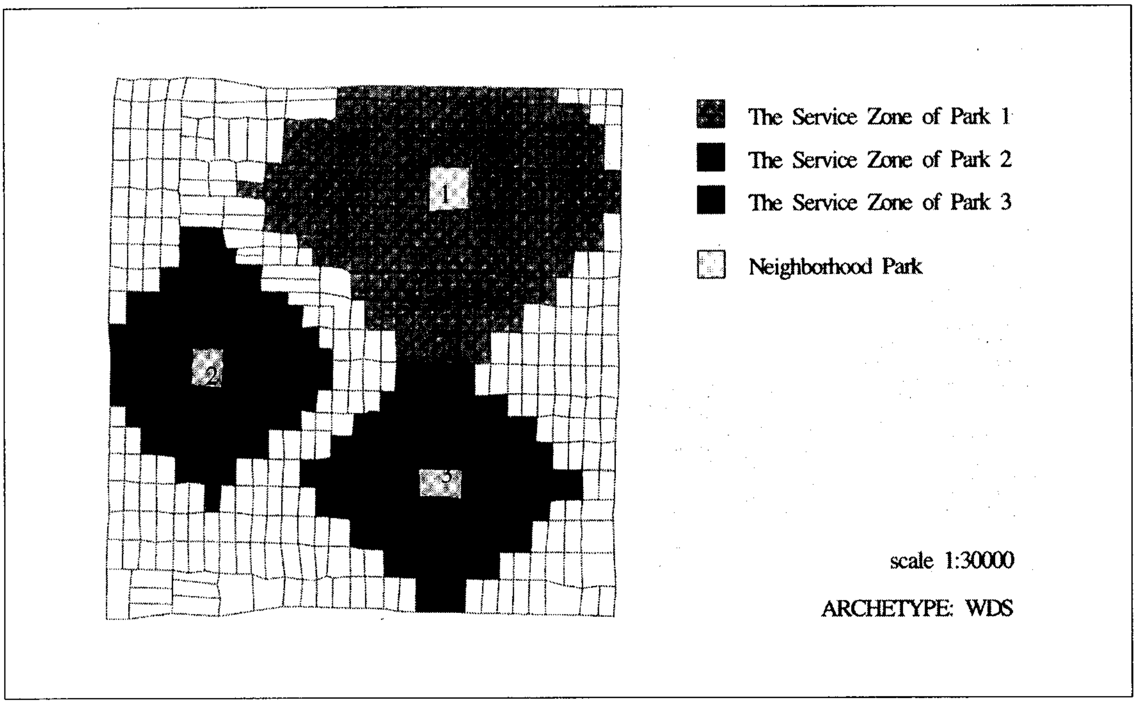


Figure 3. Maximizing Attendance Efficiency (UU/UR types)

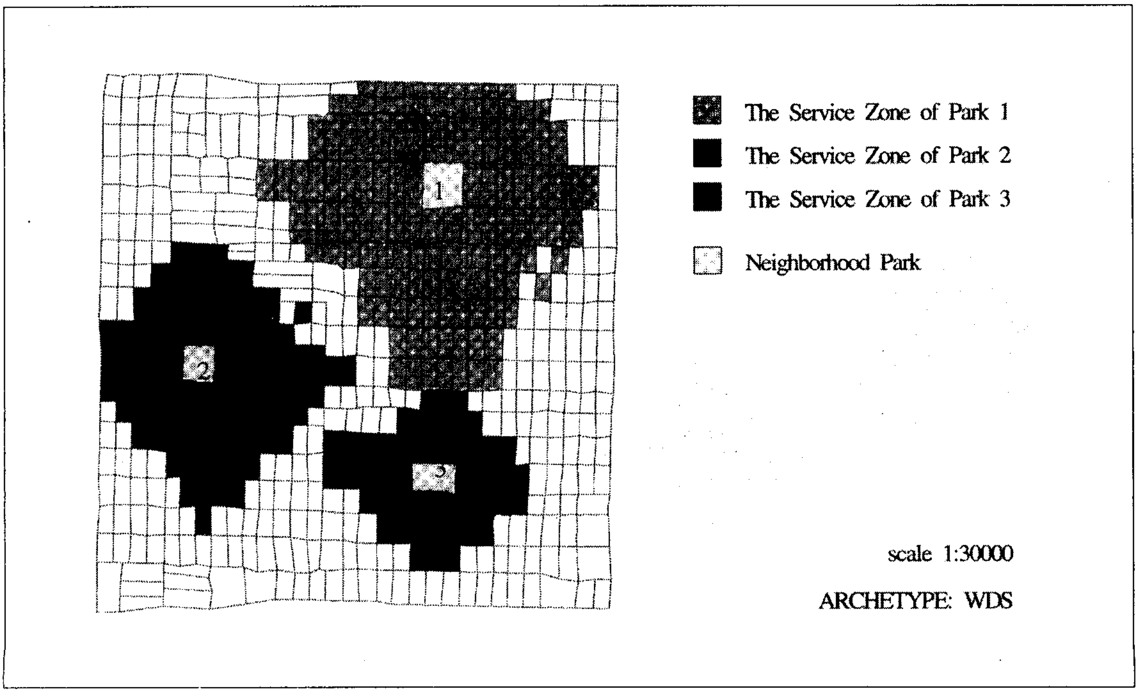


Figure 4. Maximizing Attendance Efficiency (RU/RR types)

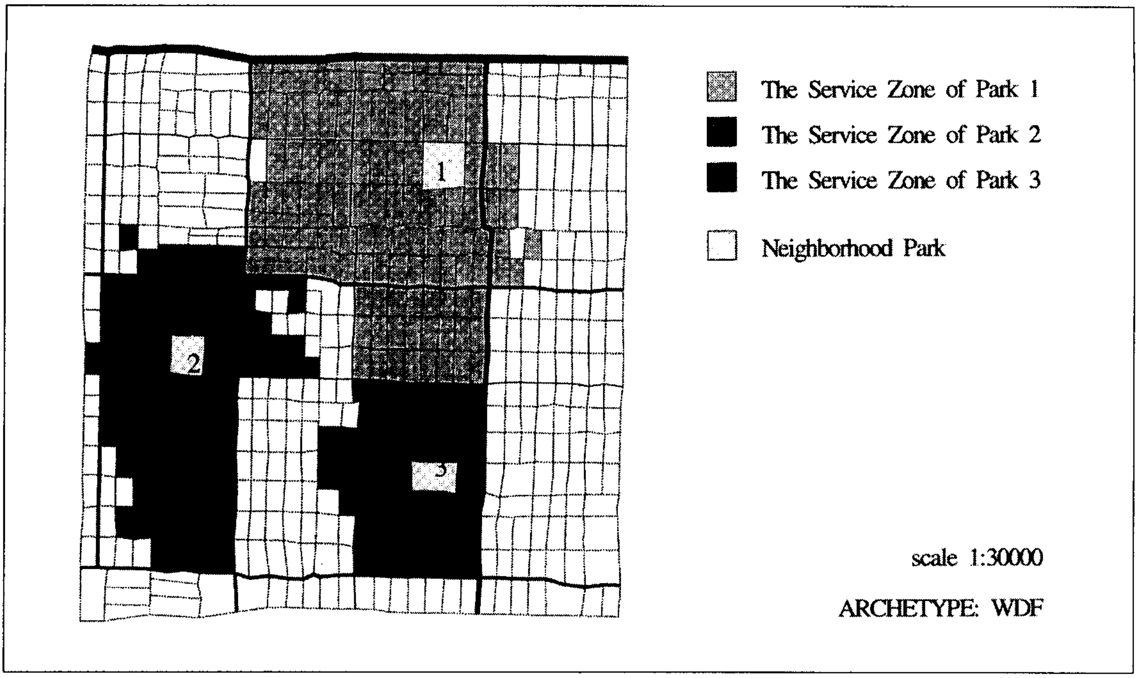


Figure 5. Maximizing Attendance Efficiency (RU/RR types)

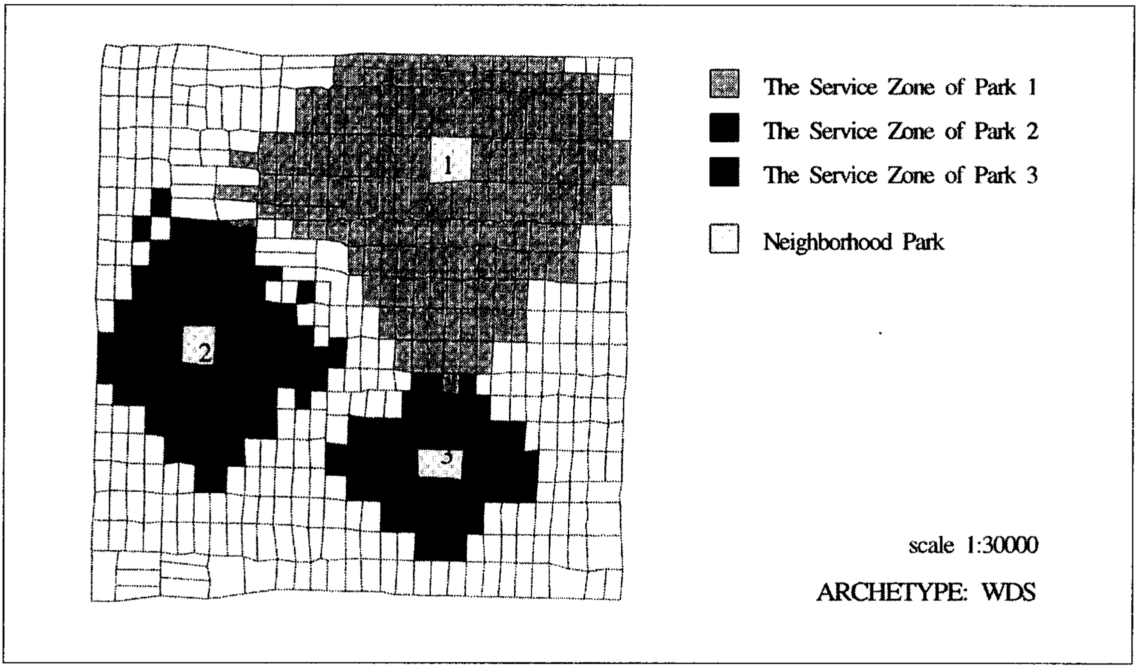


Figure 6. Multi-Objective Delineation (RR type)

Table 3. Comparisons between Single Objectives and Multi-objectives

	Single Objectives			**Multi-objectives**
	Maximizing Need Equity	Maximizing Demand Equity	Maximizing Attendance Efficiency	
Aggregating WDS * Housing Value (Need Equity)	5,694,032 [1]	7,131,706 [4]	7,003,728 [3]	6,004,567 [2]
Aggregating WDS * Population density (Demand Equity)	4,820,071 [4]	4,007,680 [1]	4,325,155 [3]	4,237,353 [2]
Aggregating WDS * Population (Attendance Efficiency)	6,122,305 [4]	5,745,115 [3]	5,457,019 [1]	5,640,555 [2]
Aggregating WDS * Multi-objectives	16,636,409 [2]	16,884,502 [4]	16,785,903 [3]	15,882,475 [1]

Note. The numbers indicate the measure scores of each objective solution. The lower the number is, the better it is in terms of its relevant (target) objective. The number inside of the square brackets,[ ], indicates the ranks among the scores in each row.

not very high positions. For example, the solution of the single objective, 'maximizing demand equity (practically minimizing WDS with population density)' had the lowest score in aggregating walking distance with population density, which was the best solution score, in terms of increasing accessibility to high density block groups. But, it also ranked 4th (need equity measure score), and 3rd (attendance efficiency measure score) in other single objective values. Most of all, it ranked 4th in multi-objective measure scores. The solution of other single objectives yielded similar situations.

Selection of Park Candidate Sites

On the basis of the delineation of park service zone, the candidate sites can be selected. Here, the candidate sites were selected only from underserved areas. Further criteria for selecting candidate sites should be established, since every block (even in underserved blocks) can not be searched. Without screening candidate sites, it would be time consuming and require huge computational work to consider all possible sites. Using GIS representation tools and its database, these criteria were applied to select the sites. This procedure of selecting candidate sites, however, was not utilized in the examination of archetypes, since there were not many candidate sites available in those types.

Location-Allocation of Parks

The location-allocation stage starts with the decision of how many parks are needed. Adequate park area per person and budget should be considered. In this archetype, it is assumed that the standard, 8 m^2 per person suggested by NRPA, is used to calculate total park area necessary. It could be less or more than that if determined by other criteria such

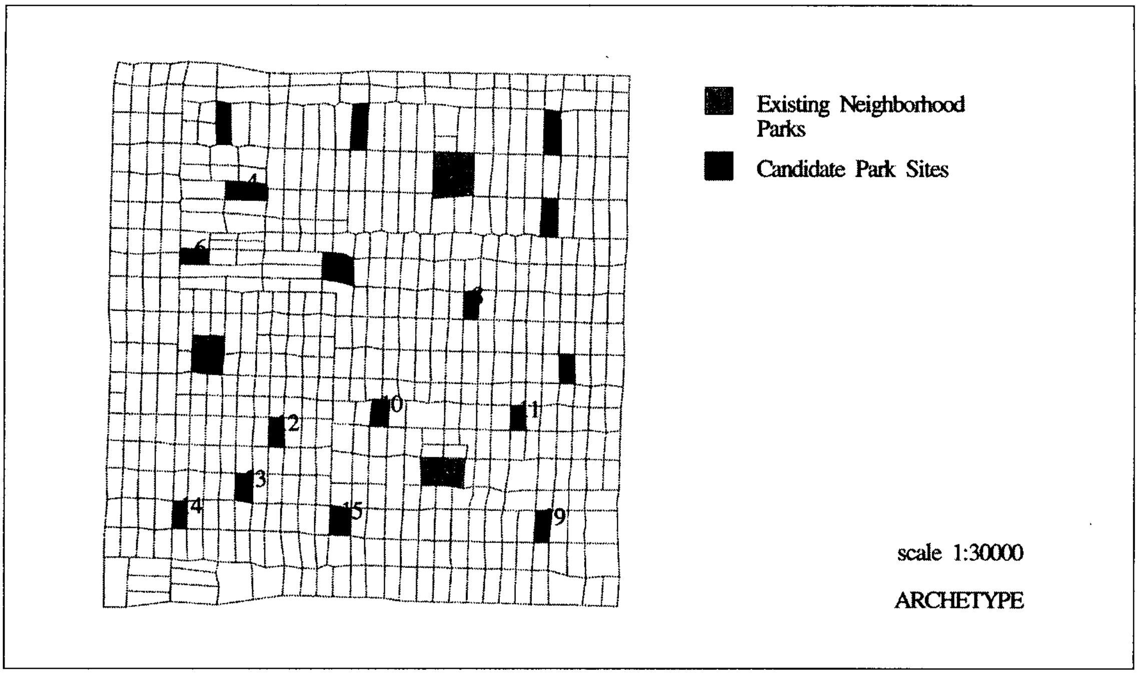


Figure 7. Candidate Sites

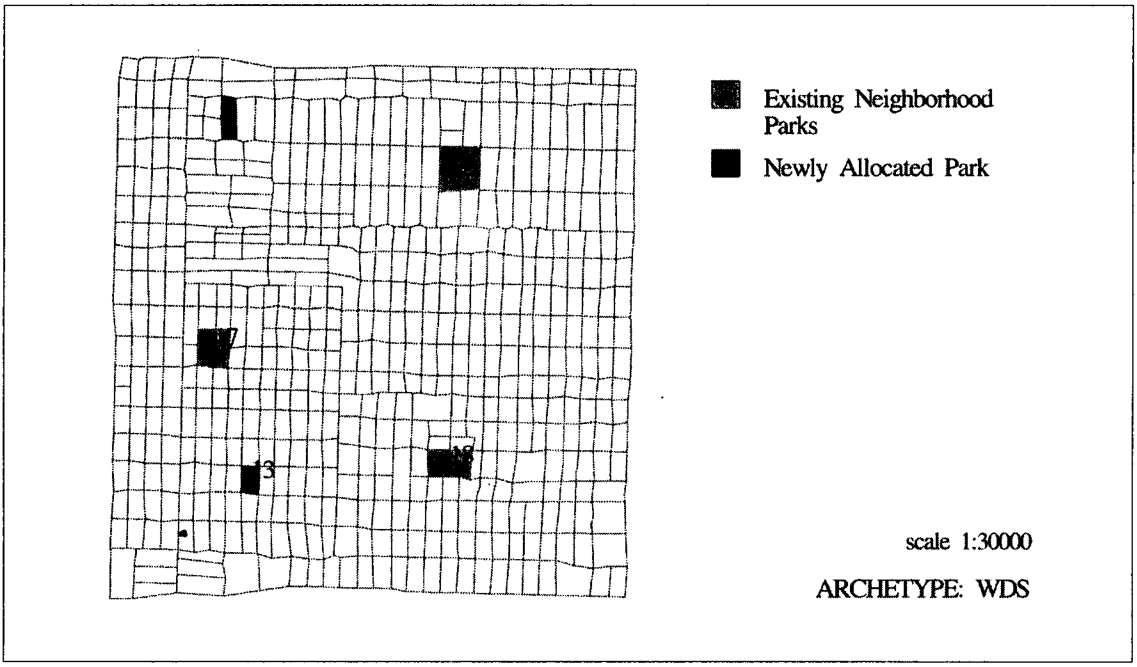


Figure 8. Multi-Objective Allocation Using the Maximal Covering Model (RR type)

as budget. Then, existing park area is subtracted from total park area necessary and divided by the minimum size (e.g., 5 acres = 20,235 m^2) and maximum size (20 acres = 80,940 m^2) of the neighborhood park which are also suggested by NRPA standards. This procedure gives the possible range of the number of new parks which should be added to the existing park system. If the minimum size of the park is increased, the maximum number of parks necessary will be decreased. In this archetype, 178,760 m^2 is the total park area necessary according to the given population (22,345 persons) and 99,101 m^2 is in existing park areas. Thus, this archetype area needs 79,658 m^2 for new parks; hence the allocation of 1 to 4 additional parks is necessary. However, it is believed that in real decision situations, the budget is usually limited, and the allocation of all necessary parks would not be possible. In such situations, the planner should be able to decide the best locations of the available number of parks, which best achieves planning objectives. For the purpose of illustration, it is assumed that only two additional parks are possible within the given budget. With two additional parks, Figure 8 shows the geographical representation of the multi-objective location-allocation solution using the maximal covering model, whereas the solution using p-median is reported in Figure 9.

Location-Allocation without Considering Existing Parks

The further investigation of the allocation procedure was done for the single decision stage which ignores the locations of existing parks and their delineations. Since it also assumes that the existing parks can be moved, five parks including the existing parks were given for the examination of new locations. Figure 10 shows the results of the single decision stage examination with multi-objectives using the maximal covering model. The comparison between single decision and multi-decision stages indirectly shows that the present locations of existing parks are not appropriate in terms of the planning objectives defined if two more parks are added, and overall new locations are desirable.

In this section, several issues of application of the UPLDSS (e.g., multi-objective versus single objective, multi-decision stage versus single decision stage, and maximal covering versus p-median model) were examined in various archetypes. One of the interesting investigations of the archetype was also shown in the comparison between the single decision stage and the multi-decision stage. The results in this study showed that the solutions from ignoring existing locations (e.g., single decision stage) are better than those from keeping existing locations (e.g., multi-decision stage). This indicates that if the budget (or changing cost of the existing locations) is not limited, overall relocation of the parks is more appropriate in terms of pursuing planning objectives, even though this is hardly the case in a real planning situation. It also shows the importance of park location-allocation planning as an integral part of urban development planning rather than as an after-thought. This study further indicates that the UPLDSS of this study might also play a significant role when it is applied to newly developing sites which do not have existing park sites.

In terms of the location-allocation models, the maximal covering and p-median models have been long standard models for resource

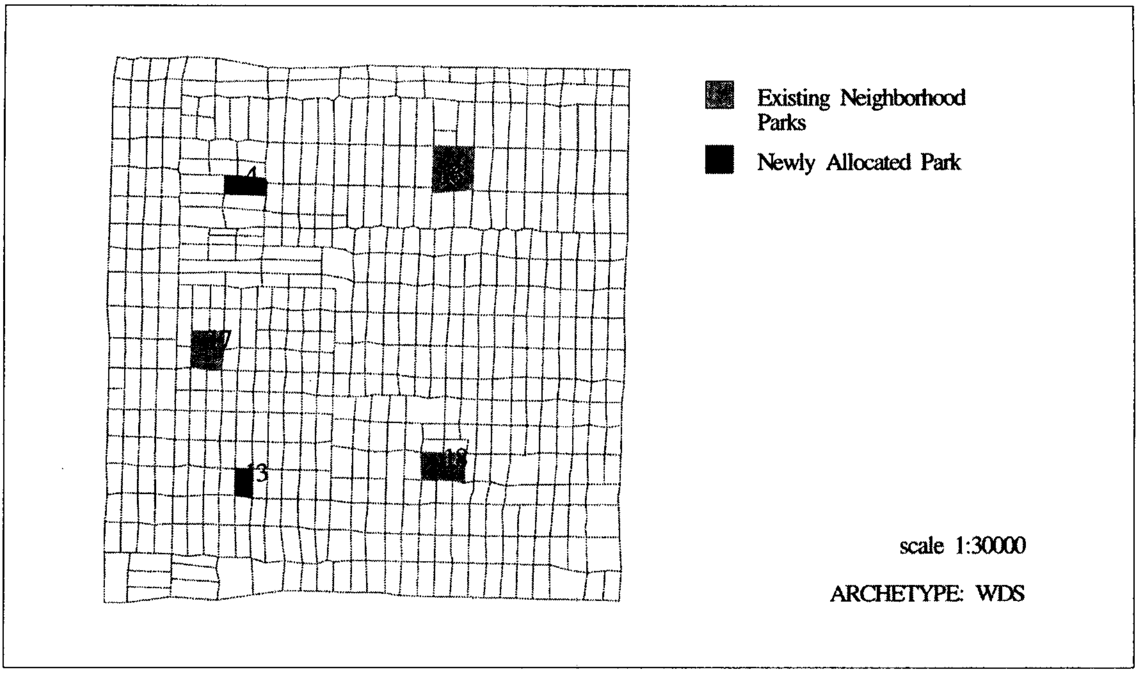


Figure 9. Multi-Objective Allocation Using the P-Median Model (RR type)

Figure 10. Single Decision Stage with Multi-Objectives (the Maximal Covering Model: RR type)

allocation. While it is difficult to compare the two models, one of the implications that might be suggested from these results is that when we focus on the population and demographic characteristics to maximally cover the areas within some threshold, the maximal model would be better than the p-median model. This also further indicates that when the budget is not limited (where we can provide all parks needed in the target area), the maximal covering model might be a better model to apply, because decision makers can allocate parks as many as necessary (with the same threshold) without ignoring any under-served areas. On the contrary, if the budget is limited (where we cannot provide all parks needed), the p-median model might be a better approach to apply, since it searches best service locations without excluding any blocks to be served. However, there are certain trade-offs between the two models. Even though the maximal covering model tries to find the best locations to maximally solve (or cover) objectives *within given thresholds*, it does lose control outside of the thresholds. P-median requires a lot of calculation time, which sometimes makes the calculation itself not possible, but it provides, if possible, overall appropriate solutions for all blocks.

DISCUSSION

This study argued that planning around size standards for park resources, as is current practice, is inadequate because it does not address how the spatial distribution of recreational resources should be performed. This study focused on 'the notion of equity and efficiency' which addresses how and where recreational resources should be located. This study also argued that the creation of a SDSS (UPLDSS) is necessary for the location-allocation of urban parks, because the location-allocation of parks, as an ill-structured problem, needs to handle the large amount of data and requires many computational tasks as well as needs the decision-maker's adequate judgement according to the planning issues (e.g., standards, objectives, weights and other model parameters). These were illustrated through the archetypes. The archetypes were used to demonstrate the behavior of the models under well-structured conditions. Implications of UPLDSS showed that it helps planners to try out different scenarios, construct alternatives, and evaluate them regarding various open space planning objectives (e.g., equity and efficiency) when it is, specially, difficult to anticipate the benefit of pursuing planning polices. The following issues, as well as the implications of the UPLDSS in various planning cases should be further studied.

Accessibility Measures (WDS versus WDF). Spatial distribution of services is directly related to the physical access of users. The importance of accessibility to facilities should be emphasized, since physical access to urban services and facilities is a major component of the quality of life including individual welfare by conferring choice and opportunity. The planning objectives defined in this study were all related to the issue of accessibility. This study utilized two different measures of the accessibility, e.g., walking distance and walking difficulty. While this study examined both measures, additional study is suggested to find out which measure fits best to user behavior in each level of the park system.

Dynamic UPLDSS for Newly Developing Areas. It has been discussed that the allocation procedure of the urban open space for the sites, where there are existing urban parks, may have to start with defining the underserved areas. It should be noted that the UPLDSS of this study can also be applied to the *newly* and *totally* developing areas. As far as we can predict population, landuses, and street networks, we can begin with the location-allocation procedure, employing a single decision stage. After initial location-allocation of parks, the location of parks and demographic characteristics of near population should be monitored continuously. Thus, the location procedure of parks could be considered dynamic rather than static. If a park system is underused (or overused) with respect to the change of demographic characteristics of near population, an additional adjustment should be necessary, and the monitoring and reapplying the UPLDSS should be continued.

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