Community Regeneration toward All-Age Friendliness: A Multi-Objective Simulation Approach to Time-Sharing Utilization of Community Spaces

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Abstract

This study investigates community regeneration through the time-sharing use of public space. It identifies public spaces with potential for optimization and spaces in which different user groups interfere with one another, and then formulates computational objectives for maximizing overall spatial-use benefits. The differentiated needs underlying conflicts among age groups are translated into a scenario-based process of multi-objective optimization and decision-making. Tongji New Village in Shanghai is used to demonstrate how the proposed model supports regeneration planning and option selection. Unlike conventional approaches that seek a single optimum, the study develops a planning model based on multi-objective optimization and decision-making, providing a methodological contribution to all-age-friendly community regeneration under the people-centered city agenda.

Keywords: all-age friendliness; community micro-regeneration; time-sharing use of space; multi-objective decision-making; Shanghai

1 Spatial Conflicts in All-Age-Friendly Communities and a Time-Sharing Renewal Approach

According to China's seventh national population census, the demographic structure of major cities is rapidly shifting toward population aging and low fertility. The population aged sixty and above is expected to exceed 400 million by around 2035, when China will enter a stage of advanced aging.[1] Urban communities will remain the principal spatial setting for aging in place. At the same time, declining fertility has made it increasingly important to respond to the childcare practices of younger generations and to create environments supportive of children's development.[2] Building communities that are friendly to older adults, children, and all age groups is therefore an important component of the people-centered city.[2-4]

All-age-friendly community development occurs in two broad settings. New residential developments often have sufficient public space and can respond to age-specific needs through higher development standards. By contrast, many young households in large cities choose older inner-city neighborhoods because they are close to employment and relatively affordable, even though these neighborhoods often have deeply aging original populations. High density and limited public space create recurrent conflicts: older and younger residents compete for exercise space; parent-child activities conflict with pet use; parking occupies green space; and temporary parking obstructs emergency access.

Where the amount of public space cannot readily be expanded, improving its utilization efficiency and shared use becomes a central planning issue. Community public space must simultaneously address accessibility and inclusion, appearance and safety, convenience and comfort, and the provision of facilities and open-space services.[5] Regeneration planning therefore needs to match heterogeneous needs more precisely and to exploit the potential of scarce space through temporal and spatial reallocation. This requires an understanding of time-sharing behavior and a planning method tailored to stock renewal.

Advances in digital technology and spatial modeling provide a useful analytical basis. This study examines differentiated spatial demand among key groups and uses a genetic algorithm and related modeling methods to explore multi-scenario, multi-objective time-sharing of community public space. Its aim is to provide a new planning approach for all-age-friendly regeneration.

2 Potential Demand for Digital Methods in All-Age-Friendly Community Planning

All-age friendliness can be traced to the concept of Lifetime Homes developed in the early twenty-first century by the Joseph Rowntree Foundation, the Habinteg Housing Association, and related researchers. The concept emphasizes inclusive, high-quality environments that accommodate changing needs and do not discriminate as residents age or experience declining physical or cognitive capacity.[8]

In 2007, the World Health Organization proposed a framework for age-friendly cities and communities, seeking to support safe, healthy living and active community participation across the life course, particularly among older adults and children. Chinese research has subsequently examined policies and facility standards for age- and child-friendly cities at the urban scale; land-use structure, facility allocation, and mobility within fifteen-minute community life circles at the intermediate scale; and detailed age- and child-friendly interventions at the project scale.[9-12] Nevertheless, existing studies rarely provide multi-scenario quantitative analysis closely matched to how different age groups actually use public space. Consequently, planners often cannot anticipate conflicts or evaluate the likely effects of proposed regeneration schemes.

Scenario simulation can clarify how different variables affect possible outcomes.[13-15] To reduce subjectivity, scenarios should incorporate observed constraints and behavioral evidence. Previous work has used scenario analysis to identify common priority areas in bicycle-network planning[16] and genetic algorithms to calculate appropriate plot ratios under defined objectives and constraints.[17] Yet scenario results remain dependent on parameters, data quality, and model design. Modeling must therefore be grounded in detailed fieldwork and followed by iterative adjustment.[18]

All-age-friendly regeneration is inherently a multi-objective problem. Improving one group's access may reduce another group's opportunity, and optimizing one function may undermine another. The purpose of multi-objective optimization is not to collapse these conflicts into a single weighted score, but to calculate a set of nondominated alternatives and make their trade-offs explicit. Pareto-optimal solutions make it possible to identify options in which no objective can be improved without worsening at least one other objective. This is more consistent with the negotiated character of community planning than a single mechanically weighted optimum.

3 Research Method for Time-Sharing Use and Optimization of Community Public Space

3.1 Optimization Oriented toward Public-Space Use

Community is both a geographical unit and a social network.[19] Its public space supports everyday interaction, service access, recreation, mobility, and collective identity. In dense established neighborhoods, regenerative interventions should not simply maximize a single spatial indicator. They should improve the overall benefit of public-space use while recognizing different groups, time periods, and spatial constraints.

The study therefore treats community-space optimization as the allocation of limited spatial resources among competing uses. The model identifies spaces that are underused, occupied inefficiently, or subject to behavioral conflict, and evaluates whether time-sharing can release additional capacity without fundamentally changing residents' established daily rhythms. Planning objectives are then defined for specific scenarios, such as maximizing parking supply, securing activity space for older adults and children, reducing congestion, and protecting emergency access.

3.2 Multi-Objective Research Framework and Modeling Logic

The research framework cross-analyzes the physical characteristics of community public space and patterns of resident use. It identifies spaces with optimization potential and spaces in which activities interfere with one another; screens problems that can be addressed through time-sharing; defines optimization objectives; constructs a multi-objective model; and uses a multi-objective genetic algorithm to generate alternative quantitative schemes.[2]

The model employs an evolutionary algorithm, specifically NSGA-II, to calculate multiple possible optima rather than a single solution.[3] Candidate schemes are ranked by nondominance and iteratively selected and evolved. The output is a Pareto solution set representing different balances among planning objectives. Planners can examine the upper and lower bounds of spatial-utilization indicators and select solutions appropriate to the demographic structure, behavior patterns, and policy priorities of the community.

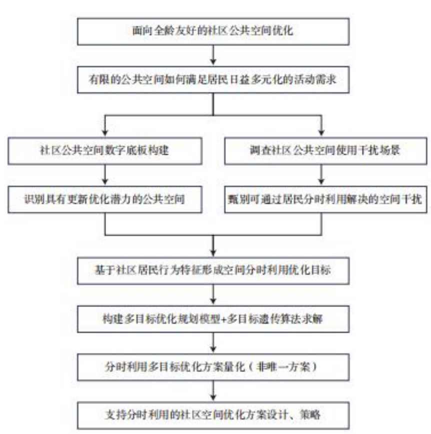

Figure 1. Research framework for multi-objective optimization of time-sharing community public space.

3.3 Implementation Procedure for Spatial Optimization Simulation

The method applies primarily to outdoor spaces closely related to daily life, including community green space, activity grounds, internal roads, and parking areas.

First, field investigation establishes the spatial and temporal activity characteristics of older adults, children, commuters, and other groups. Concentrated periods of use are identified to provide the behavioral basis for scenario analysis.

Second, potentially shareable spaces are identified. Field surveys map currently used spaces and land that could be converted or temporarily reassigned, recording location, area, ownership or management conditions, and accessibility. These data form a digital spatial base.

Third, the use potential of different activities is quantified. Conflicts such as those between vehicle parking and human activity are translated into scenario-specific objectives and constraints. A heuristic algorithm is appropriate because the problem is complex and an exact mathematical solution may be impractical; the aim is to obtain sufficiently near-optimal solutions within reasonable computing time.[4]

4 Time-Sharing of Public Space in Tongji New Village Supported by Multi-Objective Optimization

4.1 Survey and Synthesis of Spatial Conflicts

Tongji New Village, located southeast of Siping Road in Shanghai, was first developed in the early 1950s and underwent successive phases of construction, demolition, and replacement until the 1990s.[28] It covers approximately 18 ha, with a floor area of about 194,600 m² and a floor-area ratio of 1.22. The neighborhood contains 3,819 households and approximately 8,923 residents; about 65% of residents are aged sixty or above.[29] Housing tenure includes owner occupation, private rental, and work-unit-supported rental.

Public spaces consist mainly of green areas, outdoor activity grounds, and vehicle and bicycle parking. Three larger green spaces are combined with outdoor activity facilities and are intensively used. Because the neighborhood was built early, planned parking supply is limited. Cars now occupy main roads, group roads, spaces between buildings, green areas, and pedestrian routes. Peak-hour congestion and blockage of fire and ambulance access are persistent risks. Bicycles and electric bicycles are also parked informally in front of buildings and on green space.

Figure 2. Existing spatial conflicts in Tongji New Village, including occupation of public green space and traffic passages by motor vehicles and non-motorized vehicles.

At the same time, several bicycle sheds are underused or used inefficiently. Some are suitable for daytime conversion into activity space while continuing to provide storage or parking at other times. The most salient conflict is temporal: commuters require parking primarily after work and overnight, whereas older adults and children have stronger daytime and early-evening needs for safe activity space. This creates a realistic basis for time-sharing.

Existing standards imply demand for approximately 3,819 motor-vehicle spaces. Indoor bicycle sheds total about 1,130 m², while the applicable standard suggests demand of approximately 2,850 m², indicating that bicycle parking also requires further spatial optimization.[5]

4.2 Digital Base and Simulation Logic

The regeneration proposal seeks to optimize underused space and improve time-sharing without reducing existing green space or established activity areas.

First, spaces with optimization potential are mapped. The digital base identifies low-use land, existing and informal parking, locations where parked vehicles obstruct sight lines, green-space encroachment, and road segments affecting safety.

Second, potential spaces are assigned time-dependent uses. Some local spaces can function as activity areas during the day and as parking spaces at night. Likewise, spaces occupied by work-related vehicles during the day may be released to residents after working hours. This approach does not assume that all spaces are permanently multifunctional; it specifies permissible uses for defined periods and calculates their combined capacity.

（a）现状　　（b）改造后的白天公共空间利用　　（c）改造后夜间空间利用

Figure 3. Conceptual design for time-sharing use of selected public spaces.

Third, the model establishes decision variables and constraints for two scenarios. In Scenario 1, the decision variables are the numbers of resident vehicles and external vehicles. Available parking area, prohibited parking zones, and time-period restrictions define the feasible solution space. In Scenario 2, the decision variables are the numbers of parked vehicles and users of activity space, with standard spatial requirements assigned to each.

4.3 Simulation and Evaluation of Alternative Planning Scenarios

Scenario 1: Time-Sharing with Parking Optimization as the Primary Value Objective

The day is divided into three periods: t1, 07:00-17:00; t2, 17:00-21:00; and t3, 21:00-07:00 the following day. During t1, external vehicles may use part of the available parking supply. From 17:00, external parking is restricted as residents return home; after 21:00, overnight parking is reserved for residents.

Let x1 denote the number of resident vehicles and x2 the number of external vehicles. M1 is the total area practically available for parking, including planned spaces and locations already used informally; M2 is the area remaining after excluding principal access routes and other locations where parking is prohibited. With a standard area r assigned to each vehicle, the model seeks to maximize overall parking-space use in every period, retain limited external short-stay capacity in t1, minimize external parking in t2, and protect activity space and sight lines during the evening. Total parked area cannot exceed M1; external parking in t1 cannot exceed half of M2; external parking in t2 cannot exceed one-third of M1; and all decision variables must be nonnegative.[6]

For the simulation, M1 was set at 8,452 m² and M2 at 6,912 m². NSGA-II was run with a population of 200, producing 200 nondominated solutions. The solution set makes visible the trade-off among daytime external parking, evening resident parking, and overnight resident capacity. Rather than prescribing one answer, the model allows planners to choose a scheme according to policy priorities and management feasibility.

Table 1. Illustrative nondominated solutions for Scenario 1

Option	Daytime external parking area (m²)	Evening parking area (m²)	Overnight parking area (m²)
1	8	5,028	8,448
2	260	5,100	8,196
3	596	5,328	7,944
4	1,076	5,196	7,464
5	1,520	5,352	7,008

Scenario 2: Balancing Parking with Activity Needs of Older Adults and Children

Scenario 2 addresses the direct conflict between parking and activity. It seeks to secure daytime activity space, maintain acceptable density and comfort in the early evening, and provide adequate overnight parking. Let x1 denote vehicles and x2 denote individual users. The standard area is set at 12 m² per vehicle and 3 m² per person. The open space subject to optimization is M = 2,826 m².[7-8]

The objective functions maximize the effective use of open space, reduce combined vehicle-and-person density during the active evening period t2, and minimize the amount of activity space retained during the overnight rest period t3 so that parking can increase. Constraints ensure that the total space occupied by vehicles and people does not exceed M, that parking in t1 remains below two-thirds of M, and that parking in t2 remains below one-half of M.

The algorithm again generated 200 nondominated solutions. The first twenty solutions in the original table show substantial variation: some maximize daytime and evening activity capacity; others preserve a larger overnight parking supply. A planner can therefore select an alternative according to the relative weight assigned through participatory deliberation rather than embedding that weight invisibly in the model.

Table 2. Selected nondominated solutions for Scenario 2

Remaining usable open space in t3 (m²)	Density indicator in t2	Vehicles in t1	Persons in t1	Vehicles in t2	Persons in t2	Vehicles in t3	Persons in t3
2,673	0.87	0	113	438	31	230	0
1,077	0.47	3	114	486	72	232	1
870	0.39	30	116	447	103	227	10
276	0.29	54	119	482	82	231	14
1,338	0.53	69	119	465	52	228	23

The two simulations demonstrate that multi-objective modeling can generate alternative time-sharing configurations, compare their effects, and provide a quantitative basis for more precise planning decisions. The result is not an automated design, but a transparent decision space within which planners, residents, and managers can negotiate.

5 Conclusion

Meeting diverse needs with limited public space is a central challenge in all-age-friendly community regeneration. Based on differences in the spatial demands and behavior of residents of different ages, this paper proposes a time-sharing approach and develops a multi-objective planning method to support precise renewal decisions.

The method begins with a survey of existing public space, constructs a digital base representing time-sharing potential, cross-matches behavioral and spatial demand to define multiple objectives, and uses a multi-objective genetic algorithm to calculate alternative combinations. Application in Tongji New Village shows that quantitative modeling, multi-objective optimization, and multi-scenario simulation can make the likely effects of regeneration schemes more visible. The process may also improve resident participation and recognition by showing explicitly how different interests are balanced, thereby supporting the principle that a people's city is built by its people.

Community-space conflicts are more complex than any single model can represent. This case focuses on one common tension: parking demand among working-age residents and activity-space demand among older adults and children. Future research should extend the approach to other behavioral patterns, regional contexts, and forms of spatial conflict.

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Notes

1. Beijing's “9064” and Shanghai's “9073” elderly-care models both emphasize aging at home: approximately 90% of older adults receive home-based care, 6%-7% use community-supported home-care services, and 3%-4% use institutional care.[12]
2. The modeling logic begins with time-sharing utilization, identifies conflicts through field investigation and cross-analysis of behavior and space, screens problems that can be addressed temporally, and translates them into objective functions with comparable quantitative measures.
3. NSGA-II is a widely used algorithm for rapidly solving optimization problems with multiple and mutually conflicting objective functions. Its nondominated sorting process iteratively produces a set of alternatives rather than one optimum.
4. A heuristic algorithm seeks a sufficiently near-optimal solution to a complex problem within reasonable computing time.
5. Under current residential parking standards, housing below 90 m² requires one space per household, implying approximately 3,819 car spaces in Tongji New Village. Bicycle-shed standards imply a need for approximately 2,850 m², compared with the existing 1,130 m².
6. In Scenario 1, Equations (1)-(3) are objective functions and Equations (4)-(7) are constraints. They maximize parking-space use, regulate external parking by period, protect evening activity space, cap total occupied area, and require nonnegative solutions.

7. In Scenario 2, Equations (1)-(3) maximize open-space efficiency, optimize comfort during the active period, and release space for overnight parking; Equations (4)-(7) constrain total occupancy and parking shares by period.

8. A vehicle is assigned 12 m² and an individual user 3 m². Scenario 1 uses M1 = 8,452 m² and M2 = 6,912 m²; Scenario 2 uses M = 2,826 m². Each run generated 200 Pareto solutions.

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