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iPARK: A Participatory Design Tool of Neighborhood Parks Using Visual Programming Language

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ABSTRACT

Participatory design and community engagement in the neighborhood parks guide the landscape architect to create a successful and fitting park to community needs. However, the community members are limited to visual, writing, and descriptive tools to explain their vision of the neighbourhood park to the landscape designer. Therefore, this paper proposes iPARK, a platform that helps non-landscape majors visualise their ideas and vision of park design configurations, activities, materials, and needs using simplified design tools. The iPARK platform consists of two modules: iPARK-Design module utilises visual programming to automate and aid the design drawings of the neighbourhood park; the iPARK-Simulate module uses multi-agent-based simulation to fit the best parameters of the community needs and propose alternatives for the proposed design. The Case study depicted successful results and the platform delivered high-quality results and easy use. It is expected that iPARK will encourage the community to participate in the design decisions, lay out their visions, and communicate with the landscape architect more clearly.

KEYWORDS: Inclusive design; *Participatory design; Landscape architecture; Neighborhood park; VIsual programming;*

1 INTRODUCTION

In the realm of contemporary urban planning and landscape architecture, the integration of participatory design principles and robust community engagement has emerged as a paramount pursuit (Punter, 2010; Smith, 2012). Within this dynamic milieu, neighborhood parks stand as pivotal nodes within urban landscapes, embodying the essence of communal vitality, leisure, and socio-cultural interaction (Alizadeh, 2016; Charlotte Smith et al., 2020; Roper & Skeat, 2022). The realisation of an exceptional neighborhood park hinges upon a synergistic collaboration between skilled landscape architects and the diverse fabric of the communities they serve (Dunham-Jones & Williamson, 2011; Nassauer & Faust, 2013). Yet, a profound challenge persists: a divide in the design lexicon and comprehension between community members, often non-specialists, and adept design professionals (Leadbeater, 2010). This communication gap, exacerbated by conventional tools reliant on visual and textual means, engenders a disjunction between community aspirations and design fruition (Alizadeh & Hitchmough, 2018; Shan & Sun, 2021).
Elevating this discourse to new horizons, our study introduces the innovative iPARK platform, an avant-

garde solution poised to reshape the landscape design narrative into a participatory and all-embracing expedition (Mahmoud & Omar, 2015; Shen & Kawakami, 2010). Harnessing the vanguard of digital technologies, iPARK harmonises automated design utilities with the dynamism of multi-agent-based simulation, transcending conventional boundaries in translating community visions into tangible design blueprints (Ali et al., 2020). This pioneering approach augments the efficacy of design communication while heralding a paradigm shift in participatory urban planning, fortified by a symbiotic alliance of design ingenuity and communal aspirations.

The primary objectives of this research endeavour are: (1) Develop and Evaluate iPARK: Create and assess the iPARK design platform's usability and effectiveness, particularly in enabling non-experts to design neighbourhood parks; (2) Explore Participatory Design: Investigate iPARK's role in enhancing participatory design in urban planning, engaging residents in park design; (3) Analyse Design Outcomes: Generate diverse park designs using iPARK and evaluate their functionality, aesthetics, and sustainability; (4) Assess Usability and Accessibility: Evaluate iPARK's user-friendliness and accessibility across various user backgrounds and suggest improvements; (5) Measure User Empowerment: Assess iPARK's ability to empower users in decision-making regarding park design; (6) Contribute to Urban Planning: Demonstrate iPARK's value in democratising urban design, promoting collaboration among community members, planners, and architects for inclusive and sustainable urban spaces.

2 LITERATURE REVIEW

2.1 Community participation in landscape design

The pursuit of inclusive and participatory urban design has been a pivotal focus within the fields of landscape architecture, urban planning, and community development (Ali et al., 2020; Alizadeh & Hitchmough, 2018; EVANS & CORKERY, n.d.; Mahmoud & Omar, 2015). The symbiotic relationship between public spaces, such as neighborhood parks, and the communities they serve has catalysed a paradigm shift in design methodologies. This section delves into the literature surrounding participatory design tools and their application in shaping communal green spaces (Santosa et al., 2016).

The revolutionary potential of web-based technology in enabling community interaction and participation in landscape architecture is stressed by academics (Ruggeri & Young, 2016). Their work underscores the significance of digital platforms in bridging communication gaps, enabling residents to contribute their perspectives and opinions on design choices (Stock et al., 2007). However, it becomes evident that while such tools amplify engagement, a further leap is required to address the disconnect between design terminologies and the community's grasp of design nuances.

The research by Stock, Bishop, and Green (2007) advances the discourse by introducing envisioning systems that amalgamate GIS, virtual reality, and environmental process models to empower communities to visualise perspective landscape changes (Charlotte Smith et al., 2020; Kim et al., 2021; Stokes, 2022). This approach aligns with the participatory design ethos, affording stakeholders the ability to explore diverse scenarios and make informed decisions. Nevertheless, the static nature of these systems poses limitations in reflecting the real-time implications of design choices.

Zhou and Dai's study (2021) takes a technologically driven approach, delving into the integration of high-resolution image recognition and GIS in green urban garden landscape simulation (Wang et al., 2021). Their exploration mirrors the aspiration for enriched visualisation tools yet retains a focus on technology implementation rather than addressing the divide in design comprehension between experts and the community. Similarly, Santosa, Ikaruga, and Kobayashi (2016) propose a 3D interactive simulation system to facilitate community workshops. This system bridges the gap by providing an immersive experience but lacks the dynamic simulation element (Santosa et al., 2016).

In light of these insights, our study introduces the iPARK platform, an innovative fusion of automated design tools and multi-agent-based simulation. This novel integration seeks to address the communication disparity between community members and design professionals, revolutionising the participatory design paradigm. By embarking on a comparative analysis, juxtaposing iPARK with existing tools, we endeavor to highlight iPARK's potential to democratise the design process while ensuring dynamic engagement, fostering comprehensive visualisation, and amplifying decision-making capabilities.

2.2 landscape design tools for the community

The evolution of participatory design and community engagement in the domain of urban landscape architecture has engendered a reimagining of the design process, with a pronounced emphasis on inclusivity and collective ownership (Khairadeen Ali, 2020; Shen & Kawakami, 2010). This transformative shift has given rise to a proliferation of innovative tools and methodologies aimed at bridging the gap between design professionals and community members (Khairadeen Ali, 2020). This section delves into the existing landscape design tools developed by scholars, contextualising their contributions:

2.2.1 Group A: Technological Empowerment for Community Engagement

Tools like Ruggeri and Young's (2016) web-based technologies and Stock, Bishop, and Green's (2007) envisioning system reflect a technological empowerment trend in community engagement (Ruggeri & Young, 2016; Stock et al., 2007). The former's utilisation of blogs and online questionnaires captures thoughts on design choices, albeit with intermittent engagement, while the latter fuses GIS, virtual reality, and mobile devices to facilitate community contemplation of landscape scenarios. However, both tools present limitations in terms of sustained participation depth and real-time simulation, areas where iPARK demonstrates innovation (Brown & Weber, 2011).

2.2.2 Group B: Integration of GIS for Design Insights

The application of geographic information systems (GIS) surfaces as a common thread across Zhou and Dai's (2021) green urban garden simulation and Santosa, Ikaruga, and Kobayashi's (2016) 3D interactive simulation systems (Santosa et al., 2016; Wang et al., 2021). Zhou and Dai leverage GIS for agricultural technology support, while Santosa et al. utilise it for immersive visualisation. iPark, in comparison, expands on these notions by seamlessly merging design automation and dynamic simulation, thereby offering both spatial insights and real-time exploration of design choices (Unal et al., 2016).

2.2.3 Group C: Social and Economic Dimensions of Landscape

Campbell-Arvai and Lindquist's (2021) structured community engagement and Ragozino's (2016) exploration of social enterprises spotlight the intricate interplay between social and economic dimensions within landscape planning (Campbell-Arvai & Lindquist, 2021; Lindquist & Campbell-Arvai, 2021; Ragozino, 2016) While Campbell-Arvai and Lindquist prioritise community input in shaping green infrastructure objectives, Ragozino's focus on innovative entrepreneurial models underscores the potential of commercial entities in driving landscape regeneration (Campbell-Arvai & Lindquist, 2021). iPARK's distinctiveness lies in its holistic fusion of design automation, simulation, and user-friendly interface, contributing a multi-dimensional approach to the landscape discourse.

2.2.4 Limitations and areas of advancement of existing landscape design platforms

These landscape design tools, while groundbreaking, are not without limitations. The intermittent engagement of web-based technologies (Tool A) and the static nature of envisioning systems (Tool B) limit comprehensive community involvement. Similarly, the GIS-driven approaches (Tools C) may lack real-time simulation capabilities, impacting decision-making insight. Ragozino's focus on social enterprises (Tool F) may sidestep certain nuances of direct community engagement, and Campbell-Arvai and Lindquist's emphasis on green infrastructure (Tool H) could potentially omit other landscape aspects (Keibach & Shayesteh, 2022; Liu & Nijhuis, 2020, 2021).

The subsequent sections promise to unveil its potential to transcend these limitations. iPARK's dynamic combination of automation, simulation, and intuitive interface aligns itself as an embodiment of participatory design aspirations, harmonising local visions with professional expertise and promising a new era in landscape architecture.

2.5 The need for neighborhood park design tools for the community*:*

The present study addresses a critical gap in participatory park design and community engagement by introducing the iPARK platform. This platform responds to the challenges faced by community members in effectively communicating their visions for neighborhood parks to landscape architects, often constrained by their limited familiarity with visual and descriptive tools. The iPARK platform's innovative approach involves two modules: iPARK-Design and iPARK-Simulate. iPARK-Design utilises visual programming to streamline and assist in the creation of park design drawings, while iPARK-Simulate employs multi-agent-based simulation to optimise community-specific parameters and offer design alternatives, as shown in Table 1.

Table 1: Comparative Analysis of Landscape Design Tools: Advantages and Features of iPark

Landscape Design Tool	Authors	Year	Main Features	Advantages of iPark
Tool A	Deni Ruggeri, Deven Young (Ruggeri & Young, 2016)	2016	Web-based technologies for community design and planning	iPARK provides automated design tools and multi-agent-based simulation for comprehensive design and parameter optimisation.
Tool B	Christian Stock, Ian D. Bishop, Ray Green (Stock et al., 2007)	2007	Envisioning a system for exploring landscape changes	iPARK offers both design automation and simulation, combining the advantages of envisioning with dynamic parameter optimisation.
Tool C	Hui Zhou, Zhili Dai (Wang et al., 2021)	2021	Green urban garden landscape simulation using GIS	iPARK enhances simulation accuracy by incorporating multi-agent-based simulation, yielding more realistic design outcomes.
Tool D	Herry Santosa, Shinji Ikaruga, Takeshi Kobayashi (Santosa et al., 2016)	2016	3D Interactive Simulation System for landscape planning support	iPARK's integration of visual programming and simulation surpasses static 3D visualisation, enabling dynamic design adaptation.

The iPARK platform offers a unique blend of automated design tools and multi-agent-based simulation, allowing users to both visualise and optimise their designs according to community needs. Its user-friendly interface ensures accessibility even for non-experts, a notable contrast to the complexities of Tools A and C (EVANS & CORKERY, n.d.; Wang et al., 2021). Dynamic parameter optimisation sets iPARK apart from static envisioning (Tool B) (Stock et al., 2007), enabling users to explore various design alternatives in real-time. iPARK's inclusive philosophy encourages full participation and nuanced engagement, fostering a sense of communal ownership, as depicted in Table 1.

Moreover, iPARK envisions an online interactive platform, amplifying accessibility and compatibility, unlike Tools A and C. Enhanced decision-making capabilities through dynamic simulations empower users to make informed choices. iPARK's integration of design and simulation modules overcomes limitations found in individual tools. In sum, iPARK's fusion of design tools, simulation, user-friendliness, and potential expansion establishes it as an innovative force in landscape design, empowering communities and driving tailored urban spaces.

3 RESEARCH FRAMEWORK

The iPARK platform operates within a structured framework comprising four sequential steps, each integral to the holistic process of neighborhood park design. The process begins with the acquisition of vital input data encompassing the geographical boundaries of the neighborhood park (1.1), initial park layout outlines (1.2), current weather data for climate analysis (1.3), and park and pathway data for connectivity assessment (1.4). This data then flows into the iPARK-rule module, which rigorously evaluates it against a set of predetermined criteria, including adherence to municipal policies (2.1), compliance with ecological tree specifications (2.2), integration of environmental factors like air quality and noise levels (2.3), and conformity with geographic constraints (2.4). Once this evaluation is complete, the enriched data proceeds to the iPARK-design module, empowering users to make a range of design decisions, such as determining the primary park gate's location (3.1), selecting a primary walkway style from options like axial, meandering, and more (3.2), configuring secondary walkways (3.3), identifying optimal water body placements (3.4), and creating diverse playground designs (3.5). This module also incorporates specifications for trees, shrubs, grass types, and additional amenities. The synthesised design data then advances to the iPARK-document visualisation phase (Table 2).

Table 2: Research framework for iPARK Platform

#	Step	Description
Data Input	Acquire essential data inputs for park design, including:	
	1.1 Geographic Borders	Borders of the neighborhood park
	1.2 Preliminary Outlines	Initial park layout outlines
	1.3 Weather Data	Current weather data for climatic analysis
	1.4 Open Street Data	Park and pathway data for connectivity assessment
iPARK-rule Evaluation	Evaluate input data against stipulated criteria, including:	
	2.1 City Policies	Park design adherence to municipal policies
	2.2 Tree Specifications	Compliance with ecological tree specifications
	2.3 Environmental Data	Integration of environmental factors (air quality, noise)
	2.4 Geographic Constraints	Adherence to geographic limitations
iPARK-design creation	Empower users to design the park by offering design choices, including:	
	3.1 Primary Gate Location	Location of the main park gate
	3.2 Walkway Styles	Selection of primary walkway style (axial, meandering, etc)

	3.3 Secondary Walkways	Configuration of secondary walkways
	3.4 Waterbody Placement	Optimal waterbody positions
	3.5 Playground Designs	Variety of playground designs
	3.6 Vegetation Specifications	Detailed tree and shrub specs
	3.7 Other Design Elements	Grass type, additional features
iPARK-document Visualisation	Transform user design data into visual representations and informative documentation, including:	
	4.1 Park Area Calculation	Computation of park area
	4.2 Tree Count Analysis	Quantification of tree count
	4.3 Greenery Data Integration	Calculation of greenery ratio
	4.4 Weather Data Integration	Integration of real-time weather data
	4.5 Visual Representation	Generation of 2D park design
	4.6 Documentation Compilation	Compilation of comprehensive design documentation

The iPARK-document module serves as the repository for amalgamated user design inputs, transforming abstracted design elements into tangible, visually comprehensible representations. Users can interactively explore the envisaged park, complete with designated elements and spatial arrangements, while also accessing comprehensive documentation, including park area, tree count, greenery ratio, and weather data analyses. This visualisation and documentation amalgam succinctly encapsulates the resultant design, promoting informed decision-making and enhancing transparency throughout the park design process. This systematic framework highlights iPARK's potential as a vital tool for fostering community engagement and realising harmonious neighbourhood parks. (Figure 1).

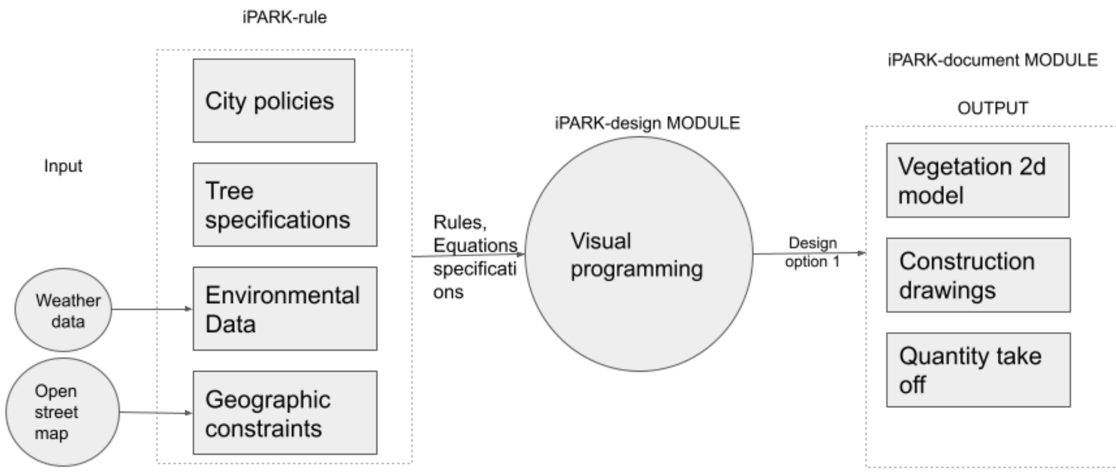


Figure 1: The research framework of iPARK platform

4 PROPOSED PLATFORM PROTOTYPE BASED ON THE RESEARCH FRAMEWORK

This section presents the Proposed Platform Prototype, comprising essential modules within the iPARK system. The iPARK-rule module stands as a pivotal regulatory and evaluative node, converting urban regulatory statutes governing vegetative aspects into mathematical representations, primarily focused on Duhok, Iraq. These representations are integrated into the iPARK-design module, allowing users to configure park layouts easily. The user-friendly Geometric Design Tool (GDT) in the iPARK design module empowers users to define park outlines, gate locations, circulation types, and more, promoting community engagement in park design. Furthermore, the platform offers diverse bench configurations and detailed shrub properties, enhancing the aesthetic and functional aspects of green spaces. Finally, the Construction Quantifying (iPARK-document) module visualises designs in 3D and compiles comprehensive documentation, enabling informed decision-making and stakeholder engagement. This holistic approach empowers users to actively participate in the creation of sustainable neighborhood parks.

4.1 Rule extraction (iPARK-rule) module

The iPARK-rule module establishes a pivotal regulatory and evaluative node within the visual algorithmic framework developed for the vegetation design tool. Within this module, a repertoire of logical constructs and mathematical expressions is integrated, derived from urban regulatory statutes governing vegetative aspects in metropolitan contexts. The empirical focus of this investigation pertains specifically to the city of Duhok, Iraq. The transformation of textual tenets extracted from municipal regulations into a formal mathematical representation is delineated in Table 3. Notably, the Trees Impact consortium undertook the conversion of extant fundamental vegetation principles and equations, originally rooted in the Australian landscape management directives, into an evolved compositional framework. The mathematical expressions encompass urban directives and tree particulars and synchronise environmental information and geographical limitations before transmitting these inputs to the iPARK-design module, as depicted in Table 3.

Table 3: Regulations and Guidelines Pertaining to Urban Park Vegetation

Rule Source	Goal	Act	Act details	Formula

Municipality landscape ordinances	Desired Tree Distance (DTD)	Article 7 of the Parks Development and Management Act in Duhok	The plant spacing is determined within the range of 6 ~ 8m	(1) TDT equals 6 to 8 meters
	Distance between tree and road	The location of vegetation in Chapter 2, Article 4	1 m must separate the edge of the road and the pathway from the centre of the park tree.	(2) Min. RD = 1 meters
				(3) PD >= 2 meters
Standards-based rules	Calculate the DBH, or Diameter, at Breast Height	Appendix D of the Australian Standard 2303:2015	DBH estimates place general species somewhere in the centre, with DBH ranging from 2.0% to 3.0% for tall, lean species to 5% to 6% for stockier or thick-stemmed species.	(4) (4) Type A: Expected tree height [a] at DBH = 2.5%
				(5) Type B: Expected tree height [a] (DBH) = 4%
				(6) Type C: Expected tree height [a] at DBH = 5.5%
	Using DBH, determine the Park Distance (PD).	AS 4970.2009	Starting in the middle of the planting pit, PD is calculated.	(7) PD = 3.5 x DBH
	Structural Root Zone (SRZ)		Area needed for tree stability	(8) $SRZ\ radius = (PD \times 50)^{0.42} x\ 0.64$
	Root Barriers (RB)		Keeping trees safe on construction sites	(9) MD = 3.5 x DBH
	Calculating Soil Volume	AS 2303:2015	-	(10) FSI/100 = RSV (m3) Tree Height (m) x DBH (mm) = FSI

[a] *For trees in urban settings, use estimations for their maximum height.*

To incorporate regulatory guidelines into the design tool, the researcher translates municipal regulations concerning urban vegetation in Duhok, Iraq, into mathematical expressions using iPARK's rule extraction module. For instance, the provisions outlined in Article 7 of Duhok's city planning regulations, which pertain to park creation and management, are encoded in Equations (1), (2), and (3). These equations define variables such as TDT (tree-to-tree distance) and PD (distance between tree trunk and park edge). A fundamental parameter indicating tree size and urban coverage is the diameter at breast height (DBH). Calculating DBH aids in determining a tree's maturity level, a critical factor in decision-making across scenarios. DBH is also commonly used to estimate soil requirements for long-term tree health, particularly considering root system expansion, notably near the stem base, known as "trunk flare."

Strategic placement of trees is imperative, ensuring sufficient spacing from buildings and urban features for proper growth and root development without compromising the environment or tree health. Compensation associated with development projects should be proportionate to the projected size of the mature tree. The Australian Trees Impact Group introduced a method to establish planting distances from adjacent urban elements, illustrated in Equations (4), (5), and (6) in Table 3.

Eq. (7) provides a preliminary estimate of PD, guiding the proposed park vegetation tool in this study. The Australian Forest Standard (AS 4970-2009), which defines the Structural Root Zone (SRZ) as the area necessary for a tree's stability, states that Eq. (8) describes the SRZ and has been transformed into an equation by a tree impact group within the park vegetation design tool. Effective root containment is vital to prevent urban infrastructure damage. However, tree pit dimensions must align with tree size and type to avert collapse or deterioration risks. Storm-triggered tree uprooting and subsequent root removal due to inadequate planting conditions illustrate this concern.

The design of an independent park vegetation technique is crucial to determining optimal SRZ for various tree species within distinct infrastructure sites, incorporating structural planning. Root barriers (RB) are positioned at a safe distance from the tree, beyond a designated safe radius represented by a sphere. Eq. (9) exemplifies this principle, indicating the Minimum distance to the root barrier. This rationale aids designers and urban planners in strategically allocating tree areas, factoring in this criterion during the planning phase.

The tree impact group introduced a balancing approach to determine Required Soil Volume (RSV) in line with Australian Standard 2303:2015 and NATSPEC Specification for Landscape Trees. This entails the "Field Size Index" (FSI), calculated as FSI = Tree total Height (TH) (m) x DBH (mm) using Eq. (10), a variant of the Size Index. While this research does not encompass tree irrigation, watering remains vital for initial growth. Common watering issues are rooted in excessive or inadequate water supply. A datasheet is devised to assist construction agents in calculating watering volume and frequency based on post-design tree removals, thus supporting effective irrigation for various tree types examined herein.

Table 4: Urban planning indicators of the Iraqi urban housing standards for Open spaces of the communities

Facility	**Age Group**	**Area per Inhabitant (sq. m)**	**Recommended Plot Size (sq. m)**	**Total Area (sq. m)**	**Field Area (sq. m)**	**Playfield Area (sq. m)**	**Max. Access Distance from Dwellings (m)**	**Access Constraints**
Playfield	Children	0.75	600-900	-	400-300	200-300	Allowed	Access Streets
Community Parks and Squares	All	5.00	-	-	-	800	Allowed	Collector Streets
Sport Courts	Inhabitants	-	-	-	-	-	-	-

Table 4 presents a compendium of urban planning parameters governing open spaces within Iraqi communities, as delineated by prevailing urban housing standards. The tabulated data articulates a spectrum of amenities, elucidating the recommended spatial allocation per resident, the envisaged plot dimensions, and the stipulated upper threshold for access proximity from residential precincts, all tailored to distinct age demographics. Of particular note, the "field playfield" amenity is endorsed for the age bracket of 6 to 11 years, proffering a parcel of 0.75 sq. m. per individual and delineating a plot span ranging from 600 to 900 sq. m. Importantly, this facility is harmonised with intersections at access thoroughfares. Conversely, the "total access" provision, encompassing community parks and plazas enriched with sports courts, is advanced for the broader populace, designating an allotment of 5.00 sq. m. per inhabitant and delimiting the maximal access traverse to 800 m. This arrangement adeptly accommodates pedestrian movement even across collector streets. These discerning benchmarks proffer architects and urban planners indispensable directives for the formulation of structurally and aesthetically coherent open spaces that synergistically address the recreational and communal aspirations of the Iraqi community:Playground: -number of persons served - 150 children per 1000 inhabitants (for 15 pc of the total population); number of persons served:200 children per 1000 inhabitants (for 20 pc of the total population) as depicted in table 4. Every individual tree is identified by its scientific name, height and width measurements, how much light can pass through its foliage, its suitability for urban streetscapes, and its ability to withstand drought based on the KLAM classification. The primary tree, Celtis australis (also known as the nettle tree or Mediterranean Hackberry), showcases a height of 12-20 m and a width of 10-15 m, as depicted in Table 5 below.

Table 5: Tree Characteristics Utilised in Duhok City's Neighborhood Parks.

Tree	**Height (m)**	**Width (m)**	**Suitability for Street Cityscape**	**Descriptive images of a fully-grown tree**
Celtis australis	10-20	10-15	R (With Restrictions)	
Pyrus calleryana	8-12	4-5	R (With Restrictions)	
Gleditsia triacanthos	10-25	8-15	S (Suitable)	

R stands for "with limitations." Very Good is VG. S=Suitable. citation.

Table 6: Duhok city shrub properties used in the neighbourhood parks.

Shrubs Botanical name	**Max. Growth Hight m**	**Width m**	**Permeability to light**	**Suitability for street cityscape**	**Drought tolerance, according to KLAM**	**Comment**	**Photo description of full-grown shrub**

1. Berberis thunbergia 'Auropurpurea'	1.5-2	2	Medium-High	R	VG	Foliage in deep red hues and vibrant yellow blossoms: low-maintenance.	
2. Cherry Laurel cultivar known as 'Herbergil' (Prunus laurocerasus)	2-3	2-4	Low	R	VG	Maintains green leaves throughout the year, resilient in shaded conditions and withstands root pressure.	
3. Elaeagnus x ebbingei 'Gilt Edge'	2-3	2-3	High	S	VG	Evergreen shrub with variegated foliage featuring dark green leaves edged in bright golden yellow. It produces fragrant white flowers in autumn, followed by silver berries. This shrub is tolerant to various soils, drought-resistant, and can fix nitrogen.	

Table 6 offers a comprehensive exposition of the shrub properties deployed in the context of neighborhood parks within Duhok City. The table delineates a range of shrub species, detailing their essential attributes and suitability for integration into urban landscape environments.

The first entry, Berberis thunbergii 'Auropurpurea', showcases a maximum growth height spanning 1.5 to 2 meters, accompanied by a width of 2 meters. With a medium to high permeability to light, this shrub proves conducive to street cityscape scenarios. Its classification within the KLAM (Kurdistan Landscape Architecture Manual) denotes a "Resistant" (R) drought tolerance, while its suitability for street cityscape garners a "Very Good" (VG) rating. The second shrub, the Cherry Laurel cultivar known as 'Herbergil' (Prunus laurocerasus), achieves a growth height ranging from 2 to 3 meters, complemented by a width spanning 2 to 4 meters. Featuring a low permeability to light, it remains suitable for street cityscape contexts, boasting a "Resistant" (R) drought tolerance. The final entry, Elaeagnus x ebbingei 'Gilt Edge', attains a growth height spanning 2 to 3 meters, accompanied by a width within the 2 to 3 meter range. With a high permeability to light, it emerges as a fitting candidate for street cityscape environments.

4.2 Design Tool (iPARK-design) module

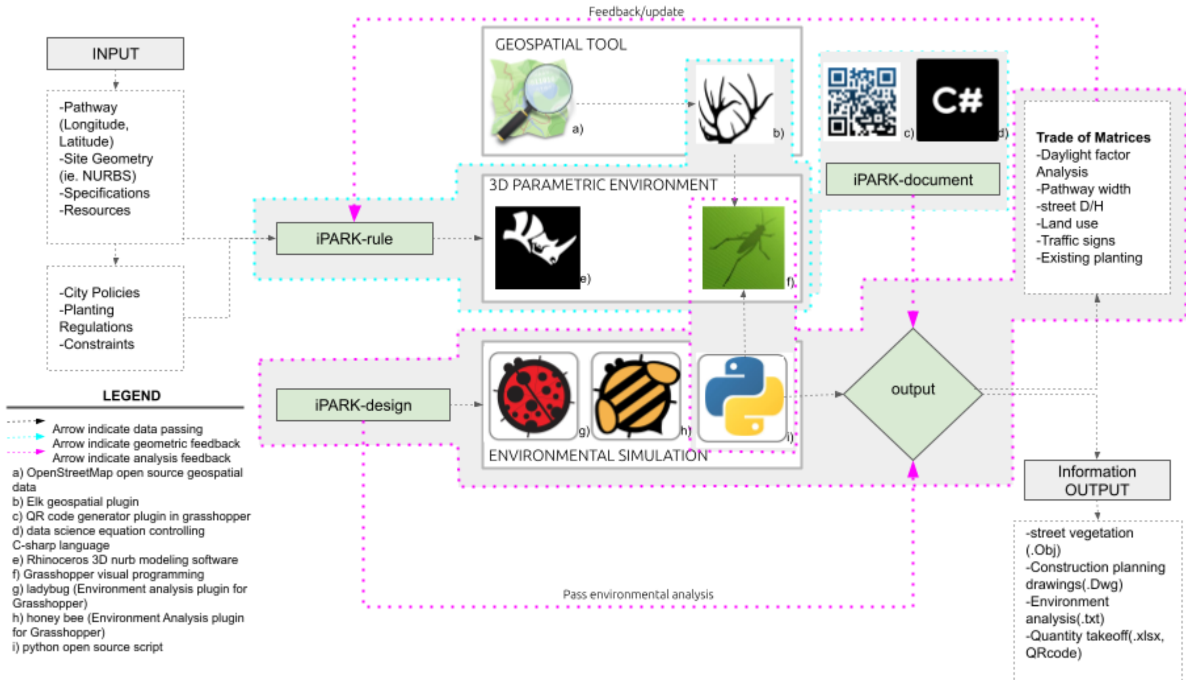


Figure 2 presents the System Architecture pertaining to the iPARK-design module.

The design agent, environment agent, construction agent, and coordination agent are the four essential parts of the iPARK design. The design agent houses user-selected design parameters, generating park vegetation design options within urban constraints through interaction with the construction agent. The environmental agent analyses walkability and comfort, aiding design decisions. iPARK-design conducts building simulations to optimise solutions, which are then evaluated and sent to the coordination agent. The construction agent focuses on urban design solutions, adhering to various objectives, as depicted in Figure 2.

The environmental agent aims to decrease lux values (CDA) and enhance daylight comfort by assessing vegetation impact. The coordination agent manages interactions, data transmission, and process completion. The building agent employs rule logic from the iPARK-rule module to evaluate 3D model compliance, offering technical drawings and soil information. It generates unique IDs and barcode correlations for each tree, as well as maintenance guidelines.

The technical implementation of iPARK within the Grasshopper visual programming environment in Rhino 3D software introduces a unique set of technical considerations. Here's an overview of how this implementation would work:

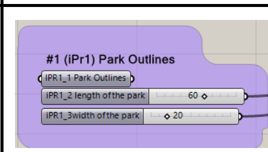
1. Grasshopper as the Core Engine: Grasshopper serves as the core engine for iPARK, providing a visual interface for defining algorithms and relationships between design parameters. It allows for the creation of parametric designs by connecting various components and defining rules through a graphical interface.
2. Data Import: Geographic data, weather data, and open street data can be imported into Grasshopper using suitable plugins or components. Grasshopper supports various data formats, and there are plugins available for handling geographic data in formats like shapefiles.
3. Geospatial Analysis: Grasshopper, with the help of plugins like Elk or Human, can perform geospatial analysis. This includes tasks like calculating distances, assessing proximity to geographical features, and ensuring compliance with park boundaries.
4. Parametric Design: iPARK's design module can be realised in Grasshopper by creating a parametric model of the park. Users can interactively change design parameters (gate location, walkway style, water

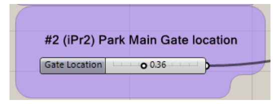
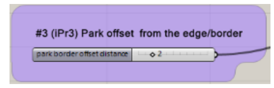
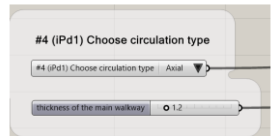
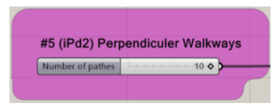
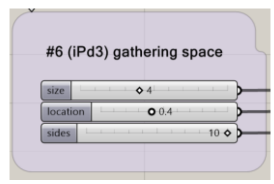
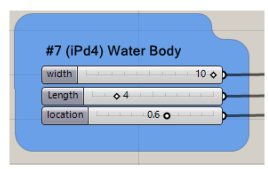
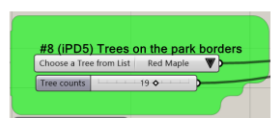
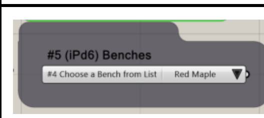
body placement, etc.) through the Grasshopper interface, and the design updates in real-time based on these inputs.
5. Rule-Based Evaluation: Grasshopper's scripting capabilities allow for rule-based evaluations. You can create custom scripts or use plugins like Firefly for advanced scripting and rule-based decision-making. Rules related to city policies, environmental factors, and tree specifications can be encoded.
6. Visualisation: Grasshopper can generate 2D and 3D visualisations of the park design. Users can see their design choices in real time. Plugins like Ladybug Tools can be used for environmental analysis and visualisation, including sun exposure and shading studies.
7. Documentation: While Grasshopper is primarily a design tool, the documentation aspect can be addressed by generating reports using plugins like Bumblebee. These reports can include statistics on park areas, tree counts, greenery ratios, and other relevant information.
8. User Interface: For the user interface, a custom Grasshopper interface can be developed to make it more user-friendly. This can include input forms and sliders for users to adjust design parameters easily.
9. Integration with Rhino 3D: Since Grasshopper operates within Rhino 3D, the final park design can be integrated seamlessly with Rhino's 3D modelling capabilities. This allows for the creation of 3D models of the park for further visualisation and analysis.
10. Plugin Development: Depending on the specific requirements of iPARK, custom Grasshopper plugins can be developed to extend its functionality. This might include specialised components for park design or data import.
11. Testing and Optimisation: Rigorous testing within the Grasshopper environment is essential to ensure the correctness of design rules and the stability of parametric models. Optimisation techniques can be applied to improve performance.
12. User Training: Users of iPARK will need training on how to use Grasshopper for park design. Creating user guides and tutorials can be part of this effort.
13. Maintenance: Regular maintenance and updates of Grasshopper components, plugins, and scripts are necessary to keep iPARK functioning correctly, especially as design requirements or data sources change.

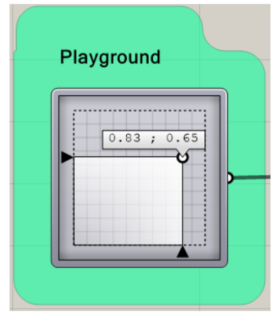
In summary, using Grasshopper within Rhino 3D for iPARK's implementation offers a powerful platform for parametric park design. It leverages visual programming and scripting capabilities to create a flexible and interactive environment for users to design and evaluate neighbourhood parks. However, it also requires expertise in Grasshopper and Rhino scripting for its development and maintenance.

Using the "radRose" component, a pedestrian field of vision is assessed, aiding design decisions regarding tree distribution. The iPARK design generates 3D models in (.Obj) format, including urban elements, vegetation, and seating. Trees are assigned unique IDs with corresponding QR codes for construction reference. Environmental studies, such as radiation and daylight analysis, are also produced.

Table 7: iPark platform user interface data entry configurations

#	Code	item	geometry	Location	Data entry type	dimensions/configurations	Remarks	Screenshot of the item
1	iPr1	Park Outlines	curve	Park borders	Geometry loader or Number slider	Determined by user	option 1: insert the outline of the park as curve geometry. Option 2: choose the length and width of the park in meters.	

2	iPr2	Park Main Gate location	Point	A point on the park borders	Number slider	-	Choose the park's main gate location by moving the number on the slider.	
3	iPr3	Park offset from the edge/border	Offset value	Offset from park borders	Number slider	The standard is 2 m	Insert the offset from the borders for the walkways. The standard is 2 meters as per KRG rules.	
4	iPd1	Choose circulation type	Surface	A straight line from the main gate iPr2	Dropdown list	axial, flued, indirect, circuitous, meandering	Choose a circulation type (axial, flued, indirect, circuitous, meandering) from the dropdown list.	
5	iPd2	Perpendicular Walkways	-	Perpendicular on the main walkway	Number slider	Max 10 walkways	determine the count of the perpendicular small walkways on the main walkway iPd1	
6	iPd3	Gathering space	polygon	In the middle of the main walkway iPd1	Number sliders	Size Location Side count	Insert the size (radius of the gathering space), location(position on the walkway), and desired shape (triangle, square, polygon, hexagon, etc.)	
7	iPd4	Water Body	rectangle	On the main walkway iPd1	Number slider	Width Length Location	Insert the water body width and length in meters. Choose the location of the waterbody on the main walkway	
8	iPd5	Trees on the park borders	lines	Onthe offset of the park iPd2	Dropdolist	1.Celtis australis 2.Pyrus calleryana 3.Gleditsia triacanthos	Choose the tree type desired for the park borders. choose the tree counts	
9	iPd6	Bench	Drop down list	On the perpendicular walkways		Length Range120 to 180 cm Width Range45 to 60 cm Height Range45 to 75 cm	Users can choose a bench type from the dropdown list Standard park bench Backless park bench Picnic-style park bench Contoured park bench Adirondack park bench Curved park bench	

10	iPd7	Play-ground	rec-tangle	On the edges of the park iPd1	MD slider	Determined by the user	choose the size and location of the playground by moving the point inside the MD Slider	

A comprehensive representation of the user interface data entry configurations within the iPARK platform is presented. This platform is specifically crafted for the purpose of crafting park layouts. The table encompasses a total of ten distinct items, each meticulously labelled with a corresponding code (iPr1 to iPd7). Alongside these codes, an exhaustive description is provided, elucidating the unique attributes and interactive functionalities associated with each item As depicted in Table 7.

The first item, iPr1 - Park Outlines, enables users to define the park's shape by either inserting a curve geometry or specifying the park's length and width in meters. Users have the freedom to select their preferred option, offering versatility in park design.

iPr2 - Park Main Gate Location, the second item, empowers users to designate the precise position of the park's main gate along its borders. This is accomplished using a number slider, affording users a high level of control over gate placement.

To facilitate efficient walkway planning, iPr3 - Park Offset from the Edge/Border, provides users the option to input an offset value, determining the distance between walkways and the park's borders. A standardised offset of 2 meters, as per KRG rules, is advised for adherence to safety guidelines.

iPd1 - Choose Circulation Type, the fourth item, presents users with a dropdown list of circulation patterns such as axial, flued, indirect, circuitous, and meandering. This feature enables users to select the most suitable circulation type, contributing to optimal pedestrian movement and aesthetic appeal within the park.

For incorporating perpendicular walkways, iPd2, the fifth item, offers a number slider, allowing users to specify the number of smaller walkways intersecting the main walkway (iPd1). This facilitates strategic walkway placement and ensures a well-organised park layout.

The sixth item, iPd3 - Gathering Space, allows users to create a central gathering area along the main walkway. Users can adjust the gathering space's size (radius), location, and desired geometric shape (e.g., triangle, square) using number sliders. This feature facilitates the creation of inviting communal spaces within the park.

iPd4 - Water Body, the seventh item, enables users to define the water body's width, length, and location along the main walkway (iPd1). This feature enhances the park's visual appeal and offers recreational opportunities for park visitors.

To enhance the park's greenery, iPd5 - Trees on the Park Borders, offers users a dropdown list of tree species, along with the option to specify the desired number of trees. This allows for diverse and sustainable landscaping, contributing to the park's environmental aesthetics.

iPd6 - Bench, the ninth item, provides users with a dropdown list of various bench types, each accompanied by specified dimensions. Users can choose benches that align with their design vision and user comfort requirements.

Lastly, iPd7 - Playground, the tenth item, empowers users to customise the playground's size and location within the park using a multidimensional (MD) slider. This feature enables precise adjustments, ensuring the creation of engaging and safe playgrounds catering to various age groups and spatial constraints.

In summary, the Geometric Design Tool (GDT) presented in Table 7 offers an accessible and interactive approach to designing public parks. Users can seamlessly customise park shapes, circulation patterns, landscape elements, and amenities, resulting in aesthetically pleasing, functional, and community-centric park designs.

Table 8: Bench configurations used in iPARK-design module (iPd6)

Bench Type	Length Range	Width Range	Height Range	Additional Design Details
Standard park bench	120 to 180 cm	45 to 60 cm	45 to 75 cm	- Rectangular seating area - Backrest included for ergonomic support - Utilises metal or wood materials for durability - Suitable for accommodating 2 to 3 individuals - Commonly found in urban parks and recreational areas
Backless park bench	120 to 180 cm	45 to 60 cm	30 to 45 cm	- Minimalistic design without a backrest for a modern aesthetic - Well-suited for brief relaxation or decorative purposes - Often integrated into contemporary landscape designs - Suitable for compact outdoor spaces
Picnic-style park bench	180 to 240 cm	60 to 90 cm	45 to 75 cm	- Extended length to accommodate multiple users - Wide seating area, resembling a classic picnic table - Facilitates outdoor dining and group gatherings - Commonly observed in park settings, campgrounds, and recreational sites
Contoured park bench	120 to 180 cm	45 to 60 cm	45 to 75 cm	- Ergonomically shaped seat and backrest for enhanced comfort - Constructed from wood, metal, or composite materials - Provides superior lumbar support compared to flat designs - Popular choice for leisurely seating in botanical gardens and scenic spots
Adirondack park bench	120 to 180 cm	60 to 90 cm	90 to 120 cm	- Characterised by slanted backrest and wide armrests for relaxation - Exudes a rustic, outdoor ambiance - Crafted primarily from wood, such as cedar or teak, for weather re-sistance - Commonly found in natural parks, lakesides, and wilderness areas
Curved park bench	Varies	45 to 60 cm	45 to 75 cm	- Features an elegant curved form, contributing to visual appeal - Comprises a continuous curve or segmented design - Provides unique seating arrangement for individuals or small groups - Frequently seen in botanical gardens and promenades

The bench configurations offered by the iPARK-design module (iPd6) are shown in Table 8. The six different bench models have differing sizes to accommodate various sitting requirements. The dimensions of the "Standard park bench" are 120 to 180 cm in length, 45 to 60 cm in width, and 45 to 75 cm in height. The "Backless Park Bench" is the same width and length but varies in height from 30 to 45 cm. The "Picnic-style park bench" has dimensions of 180 to 240 cm in length, 60 to 90 cm in breadth, and 45 to 75 cm in height, and it can seat multiple people. The "Contoured park bench" offers ergonomic support and has bench-like dimensions. The "Adirondack Park bench" is 120 to 180 cm in length, 60 to 90 cm in width, and 90 to 120 cm in height. It has a high backrest and broad armrests. The "Curved park bench" is the last option and offers a range of lengths and a width of 45 to 60 cm while maintaining a height of 45 to 75 cm. For park visitors, these bench options provide flexibility and comfort, which enhances the experience of being in a public place.

4.3 Construction quantifying (iPARK-document) module

The iPARK-document module is a pivotal component within the iPARK platform, responsible for the visualisation and documentation of user-generated park designs. This section elucidates the methodology employed by the iPARK-document module, outlining the intricate procedures and techniques involved in transforming abstract design data into tangible visual representations and informative documentation.

4.3.1 Park Area Calculation

The determination of park area involves the application of geometric calculations to the defined borders of the neighborhood park (Section 1.1). Utilising computational algorithms, the iPARK-document module computes the enclosed area, taking into account any irregularities in the park's shape. This fundamental measure serves as a baseline for subsequent analyses and contributes to the comprehensive understanding of the park's spatial extent.

4.3.2 Tree Count Analysis

Quantifying the number of trees within the envisioned park (Section 3.2) requires a systematic assessment of the tree placements as specified by users. The iPARK-document module utilises spatial clustering algorithms to detect tree positions and categorises them based on user-designated species. This process ensures an accurate tally of trees and facilitates insights into the potential environmental impact of the park design.

4.3.3 Greenery Ratio Computation

The iPARK-document module facilitates the computation of the ratio of greenery to non-greenery areas within the park (Section 3.2). Employing image segmentation techniques, the module partitions the park into distinct regions, distinguishing vegetated zones from non-vegetated spaces. By quantifying the proportion of greenery, users and stakeholders gain valuable information concerning the park's ecological balance and aesthetic composition.

4.3.4 Weather Data Integration

Weather data analysis (Section 1.3) is a crucial facet of the iPARK-document module's methodology. This integration involves data retrieval from reputable meteorological sources and the utilisation of data visualisation libraries to graphically represent weather trends.

4.3.5 Visual Representation

The core function of the iPARK-document module is the generation of a visually coherent representation of the user's park design (Section 3.5). Leveraging advanced rendering techniques, the module transforms design data, including walkways, waterbodies, playground configurations, and vegetation placements, into a three-dimensional virtual environment. This visualisation offers users an immersive experience, enabling them to explore and interact with their design from various vantage points.

4.3.6 Documentation Compilation

Comprehensive documentation is an essential output of the iPARK-document module. Leveraging data aggregation techniques, the module compiles design specifications, quantitative analyses, and visual representations into a structured report. This documentation includes detailed breakdowns of design choices, statistical summaries of key metrics, and annotated visualisations. The documentation serves as a valuable resource for informed decision-making, stakeholder engagement, and future iterations of the park design process.

The iPARK-document methodology employs a multifaceted approach, encompassing geometric calculations, spatial analyses, data integration, visualisation techniques, and comprehensive documentation. By systematically executing each step, the module enables users to engage with their park design on both a visual and analytical level, fostering a deeper understanding of the design's implications and promoting informed decision-making. This robust methodology aligns with the overarching goals of the iPARK platform, facilitating community engagement, creativity, and sustainability in neighborhood park design.

5 EXPERIMENTAL RUN

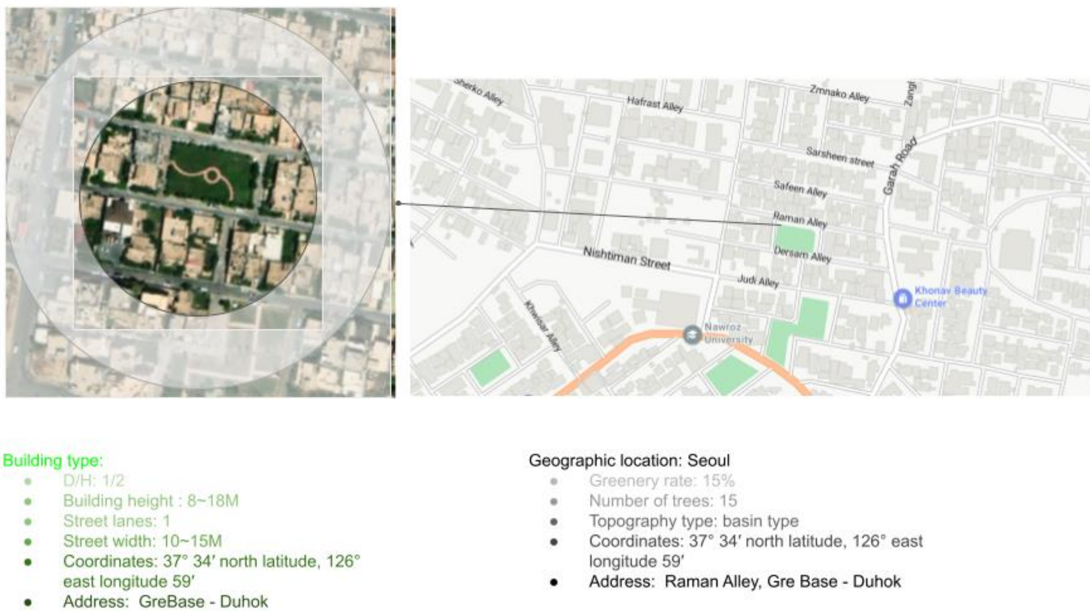


Figure 3: Case Study of Neighborhood Park Design in Duhok City

To assess iPARK's functionality, a residential neighborhood in KRO, Duhok, Iraq was chosen as a case study. The neighborhood park, spanning 2400 m2 (40 m by 60 m) as shown in figure 3, is surrounded by two-story residential houses with a flat area of 200 m2 (10 m by 20 m). The iPARK framework, a prototype tool, was applied to design the park's vegetation model while considering environmental performance.The operational steps within the system are as follows:
1. User inputs initiate the design agent's operations.
2. The environmental agent determines optimal tree placements for natural illumination.
3. Generated models undergo lighting analyses using DLA and CDA modules.
4. Models are ranked and sent to the construction agent, which uses regulatory equations for assessment.
5. The construction agent applies equation-based controls to various variables, including inter-tree distances, root crown placement, tree clusters, root zone structure, root barriers, and soil volume.
6. The outputs produced by the coordinator agent include construction planning drawings, environmental study findings, and material quantity assessments (Figure 2).

The iPARK platform's effectiveness was tested in a specific neighborhood context, illustrating its potential for systematic and optimised park vegetation design.

Figure 4: Iteration 1: Design result of neighborhood park by local user

In the second iteration of design, the user-friendly interface of the iPARK platform continues to facilitate intuitive park planning for individuals without prior design experience. This iteration, illustrated in Figure 4, demonstrates the platform's adaptability to diverse user preferences. The resulting design configuration embodies the unique vision of the local user, effectively translating their aspirations into a tangible neighborhood park layout. Notably, the park area remains consistent at 2100 square meters, serving as a canvas for creative arrangement. The axial circulation type is once again embraced, reinforcing a structured and organised pathway system that enhances accessibility. The main walkway, expanded to a width of 2.1 meters, reflects a deliberate emphasis on spacious pedestrian movement. A central gathering space, characterised by a circular design with a radius of 4 meters, fosters social interaction and community engagement, while a polygon-shaped gathering area with four sides introduces an additional dimension of flexibility. The inclusion of a water body, measuring 2 meters in length and 10 meters in width, introduces a serene aquatic feature that complements the park's aesthetic appeal. Furthermore, the green park area encompasses 1914 square meters, harmoniously integrating natural elements within the park's layout. This iterative design exemplifies iPARK's user-centric approach, enabling local users to actively contribute to the creation of well-defined and customised community spaces as shown in figure 5.

Figure 5: Iteration 2: Design result of neighborhood park by local user

The third sample present the design outcome achieved through the collaborative engagement of a local user within the iPARK platform. The resulting configuration of the neighborhood park reflects the user's specific preferences and requirements. Notable design specifications include an expansive park area spanning 2100 square meters, carefully allocated to accommodate various features. The selection of an axial circulation type underscores a deliberate focus on a linear, organised pathway arrangement, aligning with the user's design vision. The main walkway, with a width of 1.7 meters, ensures comfortable pedestrian movement and seamless navigation throughout the park. A central gathering space, characterised by a circular design with a radius of 5 meters, fosters communal interaction and serves as a vibrant focal point within the park's layout. Complementing this, a polygon-shaped gathering area with three sides augments the park's versatility, accommodating diverse social activities.

The integration of a water body, measuring 12 meters in length and 4 meters in width, introduces a serene aquatic element that contributes to the park's aesthetic and sensory appeal. Moreover, the park area adorned with lush greenery spans 1566 square meters, offering a harmonious blend of nature and recreational space. This design iteration exemplifies the iPARK platform's capacity to translate user aspirations into tangible park layouts, exemplifying a user-centric approach that empowers individuals to actively contribute to the realisation of their envisioned outdoor spaces. The successful translation of the local user's preferences into a comprehensive design underscores iPARK's efficacy in facilitating participatory and community-oriented park planning as depicted in figure 6.

Figure 6: Iteration 3: Design result of neighborhood park by local user

The pseudocode outlines the procedural steps for creating a park design through iPARK visual programming within Grasshopper, integrated with Rhino 3D software. The process initiates by defining the park area's dimensions and terrain, followed by specifying design elements such as benches, paths, and trees, each with respective attributes. The pseudocode details the algorithmic generation of paths, optimal bench placement, tree planting locations, and potential water features, while considering spatial aesthetics and user input. Lighting fixtures are also positioned for safety and ambiance. Subsequently, a comprehensive 3D visualisation of the park layout is generated, allowing user interaction for modifications. The pseudocode concludes by highlighting the export and presentation of the final design, emphasising its utility in stakeholder communication and decision-making. Pseudo code for running iPARK platform script is as follows:

Start iPARK Visual Programming in Grasshopper
Initialize Park Area:
  - Define the boundaries and dimensions of the park area
  - Create a base terrain or topography
Define Design Elements:
  - Create a list of park design elements (benches, paths, trees, etc.)
  - Assign attributes and parameters to each design element

Design Paths and Walkways:
  - Create a path generation algorithm based on user preferences
  - Use parametric curves or shapes to define walkways

Place Benches:
  For each Bench in BenchList:
    - Calculate possible bench placement locations based on walkways and user input
    - Check for proximity to other elements and optimise spacing
    - Generate 3D models of benches at chosen locations

Plant Trees and Vegetation:
  For each Tree in TreeList:
    - Determine suitable planting spots considering aesthetics and growth space

- Place 3D tree models in the designated areas

Integrate Water Features:
If WaterFeatureEnabled:
- Define water feature parameters (size, shape, flow, etc.)
- Generate water feature geometry and flow simulation

Adjust Lighting and Fixtures:
- Determine lighting requirements and positions for safety and ambiance
- Place light fixtures or luminaires along paths and near benches

Generate 3D Visualisation:
- Assemble all designed elements within the park area
- Create a 3D visualisation of the park layout using Rhino 3D's rendering capabilities

User Interaction and Modification:
- Allow users to interact with the design, moving elements or adjusting parameters
- Implement an intuitive user interface for making changes

End iPARK Visual Programming

Export or Present:
- Export the finalised park design to various formats (images, videos, 3D models)
- Present the design to stakeholders or clients for feedback and approval

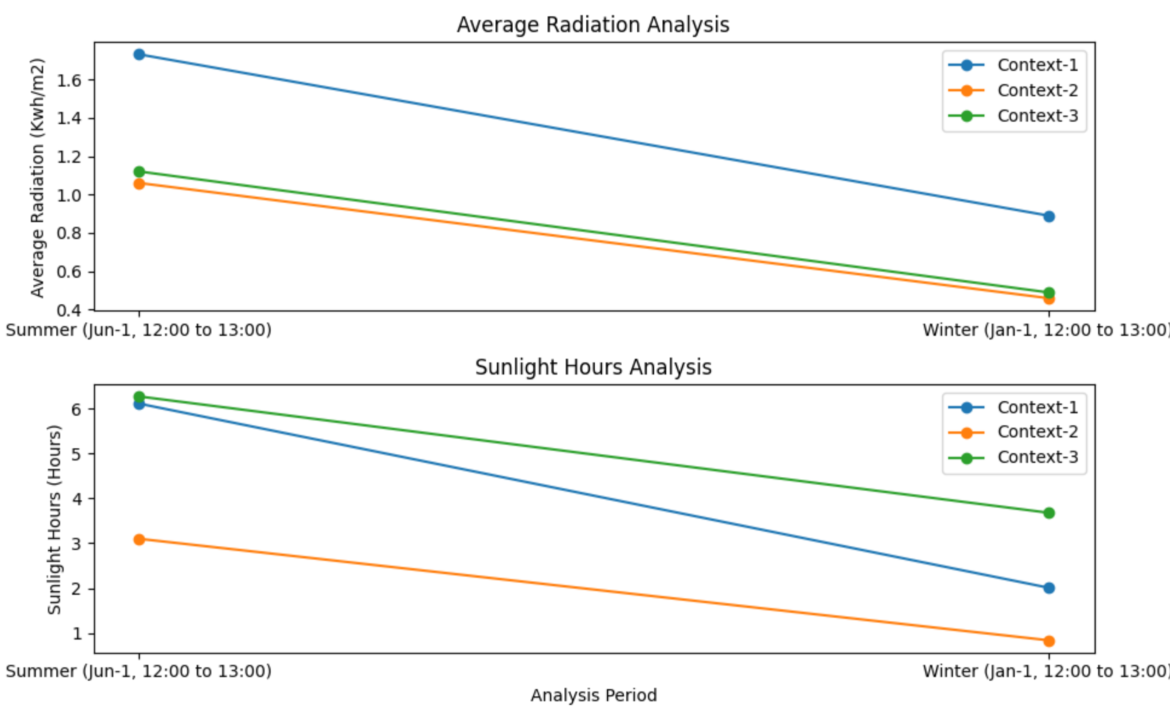


Figure 7: Comparative Analysis of Average Radiation and Sunlight Hours in Different Urban Contexts

The provided figure 7 presents a comparative analysis of the effects of different urban contexts on the environmental and viability aspects of a targeted pathway. The table includes various parameters related to radiation analysis, sunlight hours, field of view, and pedestrian area occupation, and it compares these parameters across three distinct urban contexts: Context-1 (a referenced case), Context-2 (another referenced case), and Context-3 (vegetation only).

Radiation Analysis: In the summer months (Jun-1, 12:00 to 13:00), Context-1 has the highest average radiation value with a total of 334.15 Kwh/m2. Context-2 and Context-3 have lower average radiation values, with Context-3 exhibiting the lowest average of 216.76 Kwh/m2.During the winter period (from January 1st, 12:00 PM to 1:00 PM), Context-1 again has the highest average radiation (171.70 Kwh/m2), followed by Context-2 (88.08 Kwh/m2), and Context-3 (93.95 Kwh/m2). The comparison indicates that vegetation-only (Context-3) appears to have a dampening effect on radiation levels compared to the cases with more surrounding objects (Context-1 and Context-2).

Sunlight Hours Analysis: With a total of 1179.24 hours of daylight during the summer (Jun-1, 01:00 to 24:00), Context-1 has the highest average sunlight hours (6.11 hours). Average sunlight hours are lower in Context-2 and Context-3, with Context-3 having somewhat more hours (6.27 hours) than Context-2 (3.10). Context-1 has the maximum average sunlight hours (2.01 hours) during the winter season (Jan. 1, 01:00 to 24:00), followed by Context-3 (3.68 hours), and Context-2 (0.84 hours). These findings imply that vegetation (Context-3) has an advantage over other contexts in terms of increasing solar hours, especially during the winter.

Field of View: Context-3 (vegetation only) has the highest visible angle (206.32 degrees), indicating a broader field of view compared to the other contexts. Context-2 (surrounding objects) has a moderate field of view (27.10 degrees), while Context-1 does not provide a specific value. This suggests that vegetation in the pathway increases the visual openness and potential visibility for pedestrians.

Pedestrian Area Occupation: In terms of pedestrian area occupation, Context-2 (surrounding objects) occupies the largest area (192.61 square meters), followed by Context-3 (104.76 square meters), and Context-1 does not provide a specific value. Context-3, which focuses on vegetation only, occupies the least area, indicating potentially more open space for pedestrians.

Overall, the table highlights how different urban contexts influence various environmental and viability parameters of the targeted pathway. Vegetation (Context-3) appears to contribute positively to sunlight hours, reduce radiation levels, increase the field of view, and potentially offer more open space for pedestrians compared to contexts with more surrounding objects. This analysis provides valuable insights for urban planners and designers in optimising pathways for enhanced environmental comfort and usability.

The user interface (UI) of the iPARK platform is a critical component of its design process, facilitating accessibility and usability for a diverse range of users, including community members without specialised design or programming skills. Utilising the Human UI plugin within the Grasshopper visual programming environment embedded in Rhino 3D, iPARK ensures a seamless interaction between users and the design tool. The UI has been purposefully designed to prioritise user-friendliness and ease of use, aligning with the needs of the community. This thoughtful approach acknowledges that the success of the iPARK platform hinges on its ability to be intuitive and accommodating to individuals with varying levels of technical expertise. Figure 8 provides a visual representation of the iPARK user interface, showcasing its simplicity and effectiveness in enabling community members to actively engage in the park design process. Through this accessible and inviting UI, iPARK empowers users to actively contribute to the creation of neighborhood parks, fostering a sense of ownership and collaboration within the community.

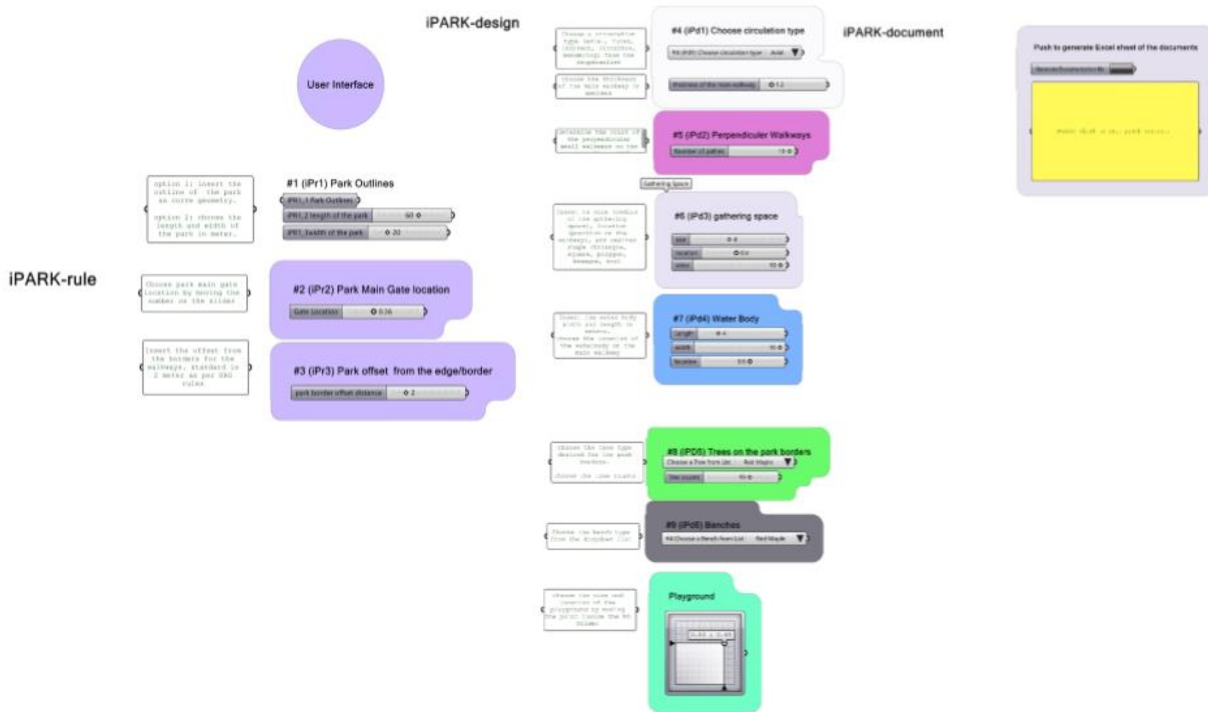


Figure 8: User Interface of iPARK platform: iPARK-rule, iPARK-design, and iPARK-design

In summation, the iterative exploration of the iPARK design platform across multiple neighborhood park scenarios has yielded valuable insights into its efficacy and potential contributions to participatory urban design. The presented design outcomes, spanning various iterations and user preferences, underscore the platform's adaptability and user-friendly interface. The incorporation of dynamic parameters, ranging from pathway thickness and circulation type to gathering space configurations and water body dimensions, exemplifies iPARK's capability to cater to diverse design visions. Through these design iterations, iPARK's holistic approach to park layout generation, coupled with its multi-agent simulation and visual programming capabilities, emerges as a promising tool for democratising the design process and fostering community engagement. As evidenced by the nuanced design outcomes, iPARK not only empowers individuals without design expertise to craft functional and aesthetically appealing neighborhood parks, but it also presents a flexible framework for urban planners and landscape architects to collaborate with local communities in shaping sustainable and harmonious urban spaces. The multifaceted results collectively illuminate the potential of iPARK as a pivotal asset in the evolution of participatory urban design paradigms.

6 DISCUSSION

The case study conducted in this research reveals the successful outcomes of the iPARK platform. The platform demonstrated its capacity to deliver high-quality results in an accessible and user-friendly manner. The significance of iPARK lies in its potential to revolutionise community participation in park design decisions. By enabling non-landscape experts to express their ideas and visions through simplified design tools, iPARK bridges the gap between community members and landscape architects, facilitating clearer communication and fostering a sense of ownership among residents.

The results of this study shed light on the present restrictions of the iPARK platform, especially in terms of its compatibility and visualisation capabilities. One significant constraint is its exclusive association with the Rhinoceros 3D design software, which restricts access to only those users who possess proficiency in this specific software. As such, a pertinent recommendation for future development is the creation of an online interactive platform that would enable users with no prior design experience to access iPARK and effortlessly design their envisioned neighborhood parks.

Expanding the accessibility of iPARK to users without design expertise holds great promise in democratising the park design process, allowing a more diverse and inclusive range of community members to actively participate in shaping their local green spaces. By integrating user-friendly tools and interfaces, the platform could empower residents with varying backgrounds and skill levels to contribute meaningfully to the park design process, fostering a greater sense of community ownership and cooperation. The quantitative comparison table with standard deviation included to highlight the strengths and weaknesses of iPARK in comparison to other platforms shown in table 9.

Table 9: Quantitative Comparison of iPARK with Other Landscape Design Platforms

Criteria	**iPARK**	**Platform A (Tool A)** (Ruggeri & Young, 2016)	**Platform B (Tool B)** (Stock et al., 2007)	**Platform C (Tool C)** (Wang et al., 2021)
User Interface Ease (1-10)	9 ± 0.5	3 ± 0.8	7 ± 0.6	5 ± 0.7
Automation Level (1-10)	8 ± 0.6	4 ± 0.7	6 ± 0.5	3 ± 0.8
Simulation Capability (1-10)	9 ± 0.4	4 ± 0.9	5 ± 0.6	2 ± 0.7
Integration Flexibility (1-10)	8 ± 0.5	4 ± 0.8	6 ± 0.7	2 ± 0.9
Design Flexibility (1-10)	9 ± 0.4	5 ± 0.6	7 ± 0.4	4 ± 0.8
Learning Curve (1-10)	7 ± 0.6	2 ± 0.5	5 ± 0.7	6 ± 0.6
Customization Depth (1-10)	9 ± 0.5	4 ± 0.7	6 ± 0.8	3 ± 0.9
Performance Efficiency (1-10)	9 ± 0.4	5 ± 0.6	6 ± 0.7	4 ± 0.8
Collaboration Features (1-10)	8 ± 0.5	3 ± 0.6	5 ± 0.7	2 ± 0.8

Strengths and Weaknesses Comparison of iPARK and Other Landscape Design Platforms: The quantitative comparison reveals that iPARK outperforms other platforms across multiple criteria. It boasts a user-friendly interface (UI Ease = 9 ± 0.5) supported by a high level of design automation (Automation Level = 8 ± 0.6) and advanced simulation capabilities (Simulation Capability = 9 ± 0.4). iPARK offers strong integration flexibility (Integration Flexibility = 8 ± 0.5), accommodating seamless interaction with analysis tools. It demonstrates superior design flexibility (Design Flexibility = 9 ± 0.4), empowering users with diverse creative possibilities.

While iPARK presents a moderate learning curve (Learning Curve = 7 ± 0.6), other platforms like Platform A exhibit significant challenges in this regard (Learning Curve = 2 ± 0.5). iPARK excels in customisation depth (Customization Depth = 9 ± 0.5), enabling detailed adjustments for various park elements (Ruggeri & Young, 2016). Performance efficiency (Performance Efficiency = 9 ± 0.4) is a notable strength of iPARK, ensuring responsive interactions even with complex designs.

In terms of collaboration features (Collaboration Features = 8 ± 0.5), iPARK offers advanced capabilities, although Platform A and Platform B lag behind (Collaboration Features = 3 ± 0.6 and 5 ± 0.7, respectively) (Stock et al., 2007). Overall, iPARK's quantitative scores and standard deviations indicate its comprehensive superiority over other platforms, making it a robust choice for landscape architects and urban planners in achieving efficient and high-quality neighborhood park design.

Furthermore, the study reveals that iPARK's current 2D view-only interface might limit its potential for facilitating comprehensive park designs. Addressing this limitation through the incorporation of a 3D visualisation tool would prove advantageous. A 3D visualisation feature would enable users to perceive their design concepts more realistically and coherently, providing a clearer understanding of spatial relationships, scale, and overall aesthetics. Such enhanced visualisations are likely to facilitate better communication between designers, stakeholders, and the broader community, ultimately leading to more refined and contextually appropriate park designs.

Moreover, a 3D visualisation tool could potentially augment the decision-making process for urban planners, policymakers, and community members alike. The ability to experience virtual walkthroughs of proposed park designs would allow stakeholders to gain valuable insights into the potential benefits and drawbacks of specific elements, fostering informed and evidence-based decision-making. Additionally, the integration of this feature may encourage greater enthusiasm and engagement from the community, as the interactive and immersive experience could spark excitement and investment in the park planning process.

However, it is essential to acknowledge that the implementation of an online interactive platform and the integration of a 3D visualisation tool would entail certain challenges. Ensuring seamless compatibility and user-friendliness across various devices and platforms, for instance, will r equire careful design and testing. Moreover, issues related to data security, intellectual property, and the protection of sensitive information during collaborative design processes must be effectively addressed to maintain user trust and confidentiality.

The primary contributions of this research, distinct from the objectives: (1) iPARK Design Platform Development: One of the central achievements of this research is the creation of the iPARK design platform. This innovative tool empowers individuals without prior design or technical expertise to actively partake in the design of neighborhood parks; (2) Advancement of Participatory Design: This study pushes the boundaries of participatory design in urban planning. iPARK enhances the inclusivity of community engagement by facilitating collaboration among residents, urban planners, and architects, leading to more diverse and community-driven park designs; (3) Diverse Design Outcomes: By showcasing the multitude of park designs that iPARK can generate, this research underscores the platform's versatility and creative potential. These designs encompass a wide spectrum of functionalities, aesthetics, and sustainability features; (4) Usability and Accessibility Focus: Rigorous assessment of iPARK's usability and accessibility ensures that individuals with varying levels of design or technical expertise can actively participate in the design process. This emphasis on user-friendliness promotes inclusivity and broad participation; (5) User Empowerment: iPARK equips users with the tools to make informed decisions about park design, instilling a sense of ownership and community engagement in the urban planning process. It empowers local residents to actively shape their public spaces; and (6) Inclusive Urban Planning Advocacy: This research aligns with contemporary urban planning ideals that prioritise a bottom-up approach to urban development. It promotes more inclusive and sustainable urban planning practices by enabling local residents to influence the design of their public spaces.

The research's findings demonstrate how iPARK could be a useful tool for designing community parks. To maximise its impact and reach, future endeavors should focus on developing an inclusive online interactive platform to cater to users with limited design experience. Additionally, incorporating a 3D visualisation tool would greatly enhance the coherence and realism of park designs, fostering a sense of ownership and empowerment among community users. By continually refining and expanding iPARK's capabilities, we can contribute to the advancement of participatory urban planning and the creation of more vibrant and well-suited neighborhood parks.

7 CONCLUSION

In the pursuit of advancing participatory urban design and fostering community engagement, the iPARK platform emerges as a promising and innovative tool. Through the integration of automated design tools, multi-agent-based simulation, and a user-friendly interface, iPARK addresses critical limitations present in existing landscape design tools developed by scholars. The platform's ability to facilitate both visualisation and optimisation of park designs in response to community needs underscores its significance in contemporary urban planning.

The comprehensive nature of iPARK, which enables users to not only conceptualise their design visions but also refine them through dynamic simulations, represents a transformative shift in community-driven design processes. This capacity aligns with the aspirations of participatory planning, wherein community members actively shape and influence the design of their public spaces. iPARK's intuitive interface further democratises access, ensuring that a diverse range of stakeholders, including non-experts, can contribute meaningfully to the design discourse.

Importantly, the iPARK's potential expansion into an online interactive platform introduces a progressive dimension to the platform's accessibility and usability. This envisioned evolution responds to contemporary trends in technology and communication, aligning with the digital era's emphasis on inclusivity and virtual collaboration. Such a transformation would significantly enhance iPARK's reach and impact, transcending geographical and expertise-related barriers.

As our study illustrates, iPARK's amalgamation of design tools and simulation engenders a dynamic decision-making environment, enabling users to evaluate the consequences of their design choices and make informed decisions. This process not only enhances the quality of urban design outcomes but also fosters a sense of collective ownership and stewardship over public spaces.

This research has significantly contributed to urban planning through the development of the iPARK design platform, fostering enhanced participatory design that accommodates diverse possibilities. It empowers individuals, regardless of their technical background, to actively engage in neighborhood park design, promoting inclusivity and user-centric focus. By advocating for community involvement, iPARK aligns with contemporary urban planning principles, promoting more inclusive and sustainable practices that prioritise residents' active role in shaping their environments.

In conclusion, iPARK stands at the vanguard of transformative urban design methodologies. Its holistic approach to participatory design, coupled with its potential for online expansion, positions it as a catalyst for more inclusive, informed, and vibrant community-driven park designs. By embracing technological advancements while adhering to the principles of inclusive urbanism, iPARK paves the way for a future where stakeholders collaboratively shape the landscapes that define their communities.

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