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Integrating AI into Urban Decision-Making: A Case Study of KFUPM Campus

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ABSTRACT

King Fahd University of Petroleum and Minerals (KFUPM) currently relies on administrative judgment for urban planning, which may introduce human error and overlook environmental and social factors. This study examines the potential of Artificial Intelligence (AI) to enhance urban planning decisions by using Autodesk Forma to analyze solar exposure, wind behavior, and microclimate variations across the proposed building sites. This study utilized an AI-driven site evaluation framework to conduct multifaceted environmental analyses, including highly predictive wind movement simulations. This approach generated quantifiable metrics essential for sustainable urban design optimization, demonstrating their practical value. For example, one design option achieved 0% uncomfortable pedestrian wind conditions, which is a key measure of success unattainable through conventional evaluation methods. The findings highlight the role of AI in improving planning accuracy, reducing reliance on static datasets, and supporting data-driven decision-making. However, human expertise remains essential for interpreting AI-generated outputs, ensuring alignment with institutional goals, and validating the results. Future research should explore the integration of custom datasets for enhanced wind analysis, AI-driven site selection automation, and expert-driven refinement into planning strategies, further advancing a hybrid AI-human decision-making framework.

Keywords: artificial intelligence, urban planning, autodesk forma, campus development, sustainable design, decision-making framework

1. INTRODUCTION

Urban planning is essential for sustainable development and shaping infrastructure, environmental quality, and resource allocation. At King Fahd University of Petroleum and Minerals (KFUPM), planning decisions have traditionally relied on expert judgment and often lack predictive modeling and real-time environmental analysis. Artificial intelligence (AI) has emerged as a transformative tool that enhances efficiency through data-driven forecasting, land use optimization, and scenario simulations. Prior work in this domain has successfully applied AI and machine learning to architectural design and the initial stages of ecosensitive site assessment [1]. Despite the potential of AI, gaps remain in its application in site-specific environmental assessments and campus expansion strategies.

To address this, this study investigates AI-driven urban planning methodologies at KFUPM, focusing on site selection for new architectural buildings. This study determines how effectively AI tools (e.g., Autodesk Forma) assess microclimatic factors to identify optimal construction sites and what quantifiable differences exist in sustainable performance (e.g., wind comfort) between the proposed sites. Predictive modeling was leveraged to develop a robust and sustainable development strategy for KFUPM expansion. Specifically, the aims were to (i) evaluate the efficacy of AI-driven environmental analysis tools for site selection; (ii) quantify the differences in key sustainability metrics between the site options; (iii) provide a data-driven framework to integrate predictive simulation results into the planning process; and (iv) determine the role of human oversight when translating AI-generated metrics into decisions.

2. LITERATURE REVIEW

KFUPM is at a pivotal point in urban planning, where traditional expert-driven approaches lack predictive modeling, real-time environmental assessment, and scenario simulation. With Saudi Arabia's Vision 2030 prioritizing smart city development [2], integrating AI-driven tools presents an opportunity for sustainable data-informed campus growth. This review examines AI-assisted urban planning, focusing on its role in decision making, site analysis, and spatial strategies at KFUPM.

2.1. AI-Assisted Site Analysis with Neural Networks.

AI enhances urban planning by streamlining site analysis, with tools such as Autodesk Forma providing automated evaluations of solar exposure, wind behavior, and terrain conditions to support data-driven decision-making [1]. Although AI improves efficiency, it lacks autonomous functionality and requires expert oversight. Neural networks structure data inputs for interpreta-

Table 1. *Comparative evaluation of AI applications for environmental site analysis*

Existing AI application	Application description	Strength	Weaknesses
Urban FootPrint	A geospatial intelligent tool offering climate, community, and built environment data insights across the U.S.	Supports in decision making	Specified to only USA & above the research budget
TensorFlow	Machine learning framework for building various AI models using Python. It enables developers to create dataflow graphs with computational nodes representing mathematical operations.	widely adopted in the AI community	Requires prior coding knowledge
CityEngine	an advanced 3D modeling software that creates large, realistic interactive urban environments quickly using GIS. AI in CityEngine enhances procedural modeling, boosts efficiency, analyzes urban data, automates tasks, and provides real-time feedback for better design.	Real-time feedback and automation capabilities	No efficient data about the cost of the subscription after the end of the free trial & requires GIS data
UrbanSim	A virtual training application for mission command in counterinsurgency and stability operations.	Game-based learning environment	requires huge amount of CSV data
ENVI-met	A microscale 3D software model for simulating urban environments, incorporating principles of fluid mechanics and thermodynamics.	detailed simulation to environmental interaction, great for sustainable urban planning	requires a substantial amount of data & interface is not very user-friendly.
UrbanForm	AI technology delivering quick zoning information through maps and analysis tools.	efficient in zoning discovery	has zoning regulations for the U.S. only
Big Query	A fully managed data platform for AI-ready data management and analysis, supporting languages like SQL and Python.	Supports machine learning	Requires prior coding knowledge
Autodesk Forma	cloud-based AI software for architects, urban planners, and developers to create 3D massing models, test site proposals, and analyze factors like noise, wind, sun, and microclimate, streamlining early-stage design with intuitive, generative tools.	User-friendly and fits the research aim and objectives	None

tion, while tools such as ChatGPT assist with cultural context assessments, and MidJourney enhances spatial visualization. AI applications in transportation modeling, infrastructure forecasting, and environmental analysis accelerate timeline planning and optimize land use [3]. However, concerns about algorithmic bias, explainability, and ethical transparency remain, emphasizing the need for hybrid AI-human frameworks [4]. AI also supports sustainable urban design and evaluates environmental impacts such as waste, energy use, carbon emissions, and water needs, although human oversight remains essential for cultural, ecological, and accessibility considerations [5].

2.2. AI Applications for Environmental and Site Analysis.

2.2.1. Evaluation of AI tools for site analysis. A comparative evaluation was conducted to identify the most suitable AI platform for environmental analyses on campuses. The criteria included

1. Functionality and Scope: Types of analyses supported
2. Data Accuracy & Output Format: Visual vs. numerical data
3. Ease of Use: Accessibility for non-specialist users
4. Built-in Data Availability: The platform should offer ready-to-use datasets (e.g., terrain, climate, solar exposure) without requiring custom data uploads.
5. Platform Accessibility: Software/hardware requirements
6. Source Reliability: Documentation and developer support

Table 1 shows a comparative evaluation of AI applications. Based on this assessment, Autodesk Forma was selected as the most balanced platform because of its predictive features, real-time environmental modeling, and user-friendly interface. Its built-in datasets eliminate manual data uploads, making it well suited for AI-driven site analysis at KFUPM.

2.2.2. Autodesk Forma in sustainable site design. Autodesk Forma is categorized as an Analytical AI, offering machine-learning-powered tools for terrain analysis, solar exposure modeling, and wind behavior prediction [1]. These capabilities are particularly useful for sustainable infrastructure planning and layout optimization. However, Forma relies heavily on visual (rather than numerical) outputs and requires planners to validate insights using supplementary tools [6].

3. METHODOLOGY

To evaluate potential locations for the new Architecture and City Design Department building, Autodesk Forma was employed to conduct environmental analyses of sun exposure, wind conditions, and microclimate. The resulting data were processed and visualized using Microsoft Excel to support comparative site selection. Figure 1 illustrates a methodology flowchart outlining the sequential steps undertaken in this study.

3.1. Site Selection and Building Parameters. Four locations within the KFUPM campus were analyzed: the current

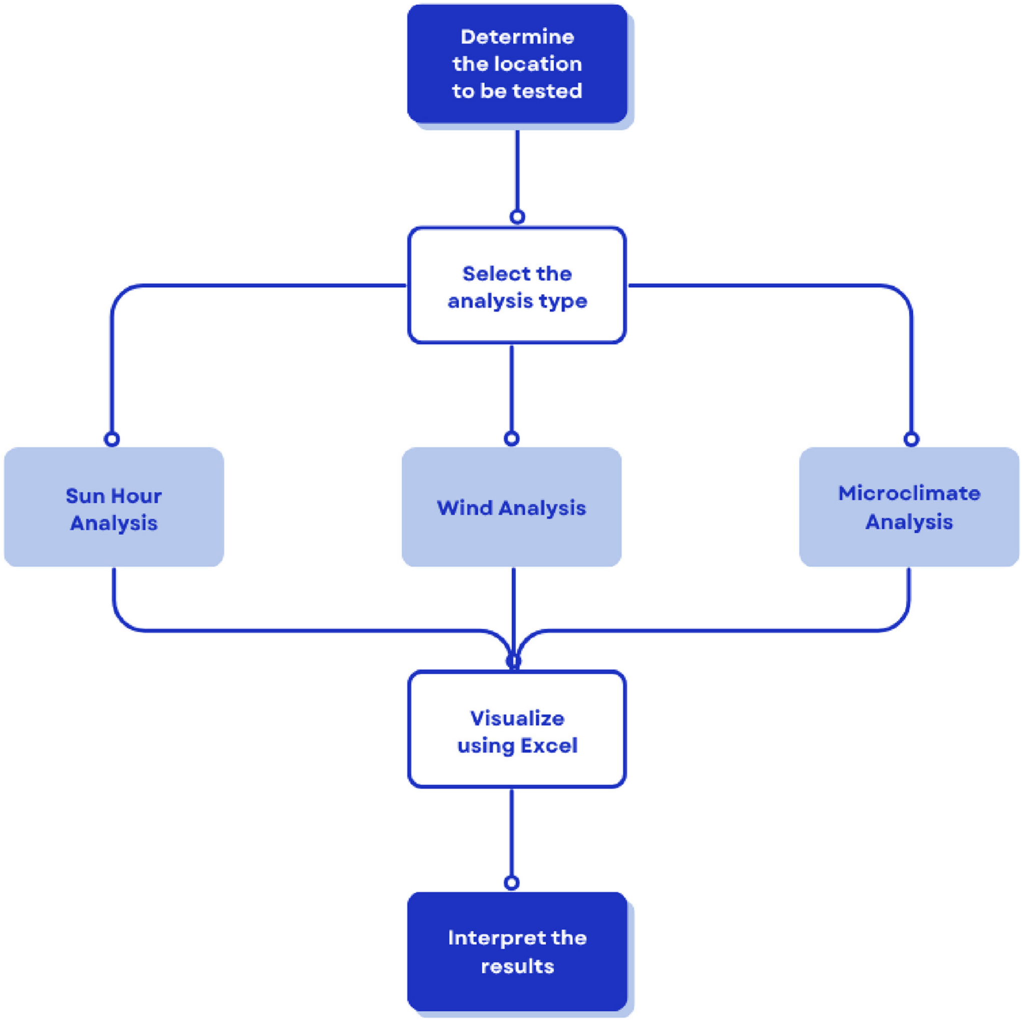

Figure 1. Methodology flowchart

department site, parking lot 19 (proposed for the new building), and parking lot 18 and 11 as alternative sites owing to their proximity. Each site was assessed within a 150-m radius to ensure consistent environmental conditions.

The proposed building design features three aboveground floors (15 m) and an underground parking level (2.5 m), totaling a structural height of 17.5 m. Owing to the absence of specific width and length data, the Bioengineering Department's rectangular footprint was used as a reference to ensure comparability across site analyses.

The AI capabilities of Autodesk Forma facilitate real-time predictive analyses of wind, noise, and operational energy, thereby enhancing the efficiency and accuracy of environmental assessments. By automating complex calculations and providing instant feedback, these tools improve data-driven decision-making for evaluating site suitability[7]. Figure 2 presents the 3D model representations of each site, illustrating the spatial characteristics of Autodesk Forma.

3.2. Analytical Tools and Procedures.

3.2.1. Sun hours analysis. The total annual sun exposure on building rooftops was assessed. Analyses were conducted on the first day of each month in 2023 to capture seasonal variations. This method aligns with the standard practices for evaluating solar exposure over time.

3.2.2. Wind analysis.

1. Pedestrian Wind Comfort: Comfort levels were evaluated using the default Lawson LDDC comfort scale, which categorizes conditions as uncomfortable, strolling/walking, or sitting/standing.
2. Wind Speed Classification: Wind conditions were classified into low, intermediate, and high wind categories.

Wind data were sourced from the Global Wind Atlas 3.0, using a roughness length of 0.1 and a measurement height of 1.75 m above ground level. Owing to software constraints, the analyses were conducted in real time between 6:00 PM and 7:00 PM on the 9th of May 2025.

3.2.3. Microclimate analysis.

1. Temperature exceedance: The rate at which temperatures exceeded 40°C during the hottest months (June, July, and August) at 3:00, 4:00, and 5:00 PM.
2. Air Temperature: Recorded ambient air temperatures during the same periods.

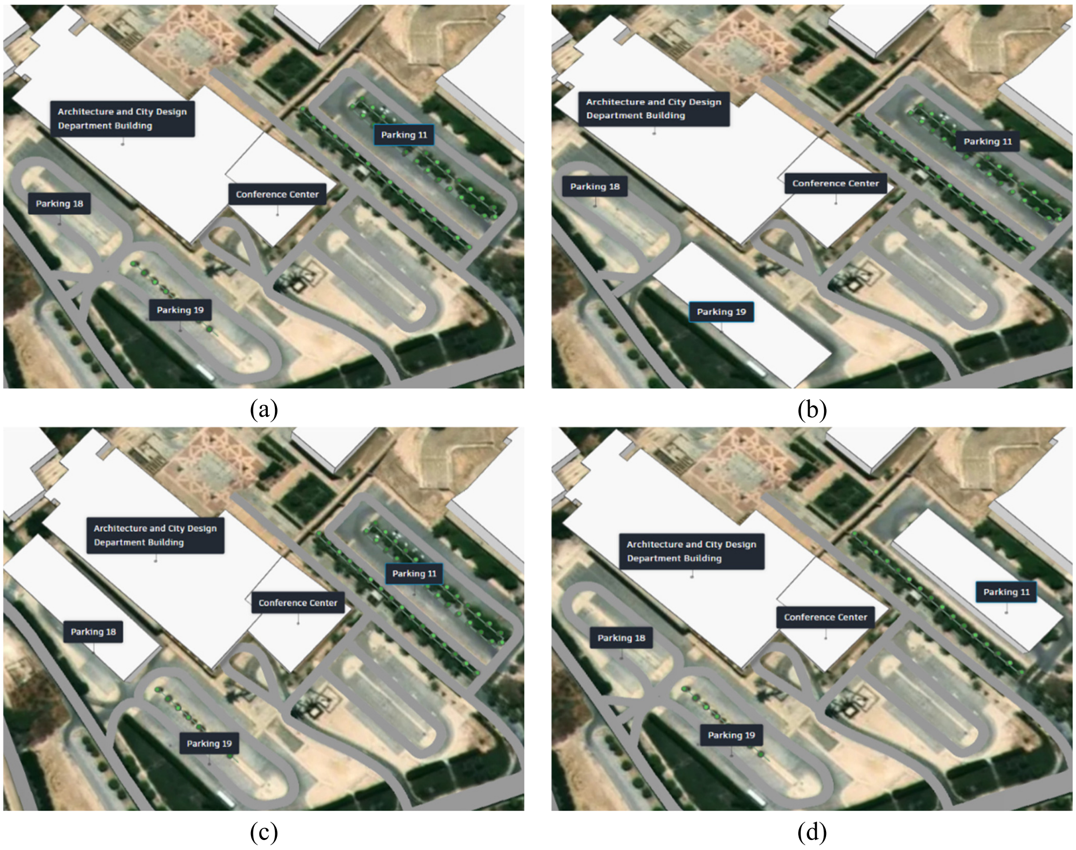

Figure 2. Autodesk Forma 3D models of analyzed sites: (a) model of Current Campus; (b) model of parking 19 (proposed site); (c) model of parking 18; and (d) model of parking 11

Analyses for colder months were not feasible because of software limitations restricting data collection to 8:00 AM–8:00 PM, thereby excluding pre-sunrise periods, when minimum temperatures typically occur.

3.3. Exclusions and Limitations. Several analyses available in Autodesk Forma were excluded from this study:

1. Noise Analysis: All sites were presumed to have minimal noise variation.
2. Daylight potential: All buildings were expected to receive adequate sunlight, rendering the analysis redundant.
3. Solar Energy Analysis: All sites yielded identical results of 2171 kWh/m^2, offering no differentiation.
4. Embodied Carbon Analysis: Technical issues encountered during execution.
5. Shadow Study: Primarily illustrates shadow movement throughout the day without providing additional insights.

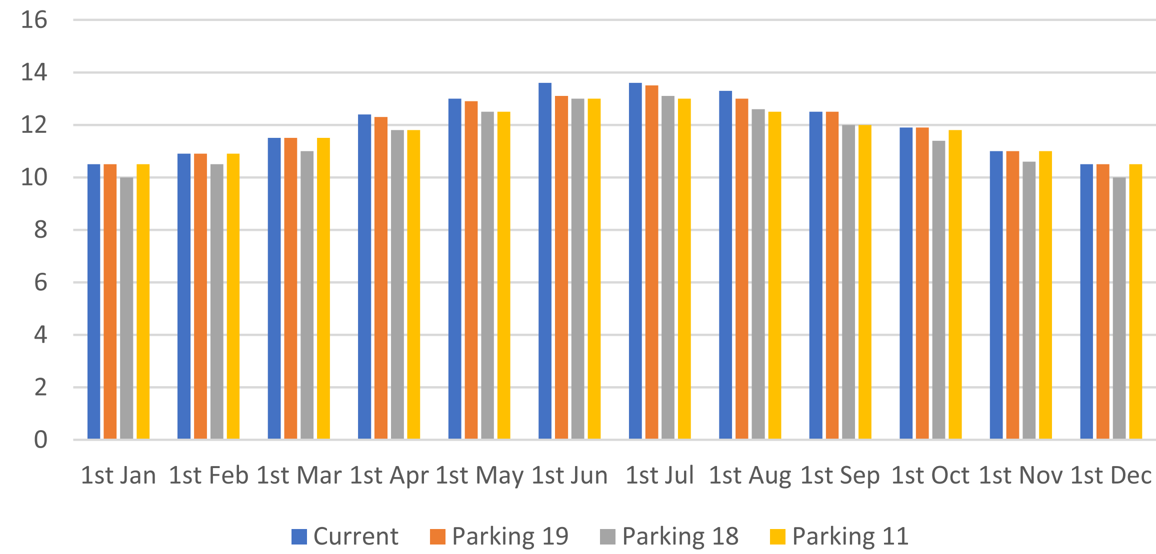

Figure 3. Annual sun exposure comparison across proposed sites

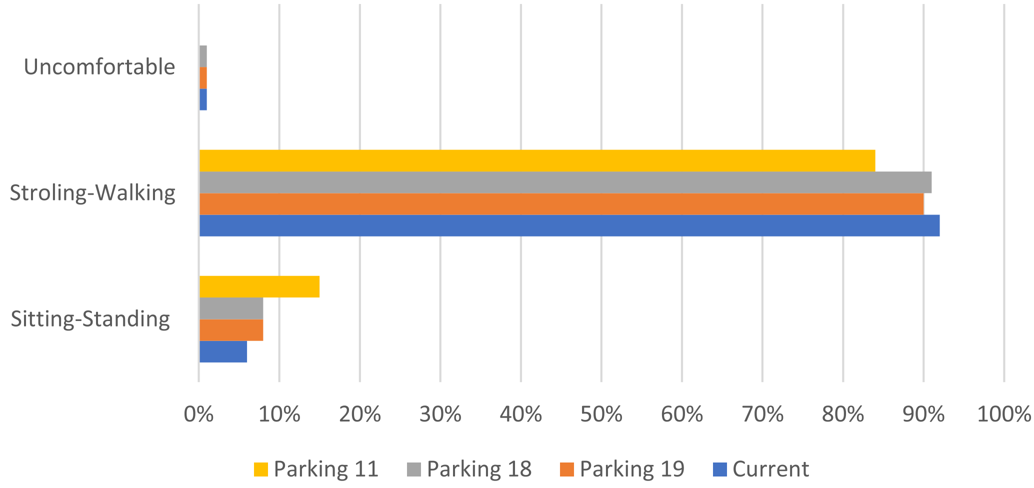

Figure 4. Pedestrian wind comfort levels at each site

4. RESULTS

4.1. Sun Hours Analysis. Figure 3 shows the annual sun exposure data for each site. Parking area 18 consistently exhibited the lowest or equal sun exposure compared with Parking area 11, suggesting that it benefits from the shading provided by the existing Architecture and City Design Department building. This reduced exposure contributes to improved thermal comfort and energy efficiency.

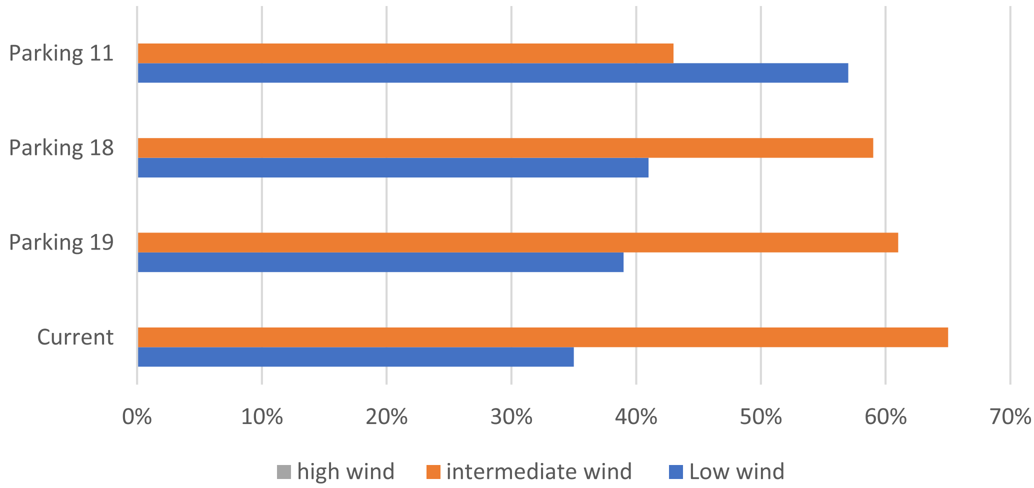

Figure 5. Wind speed classification distribution by location

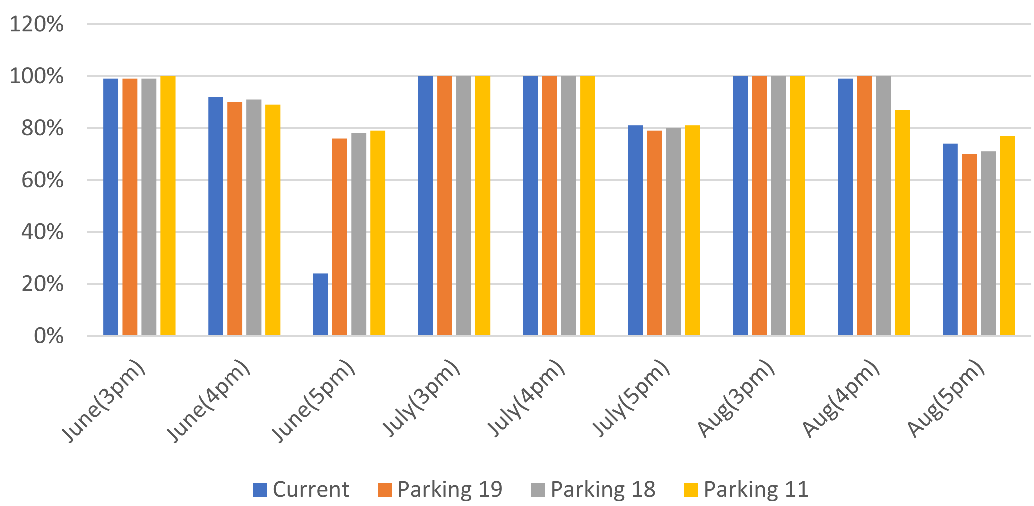

Figure 6. Wind temperature exceedance rates above 40°C in extremely hot weather

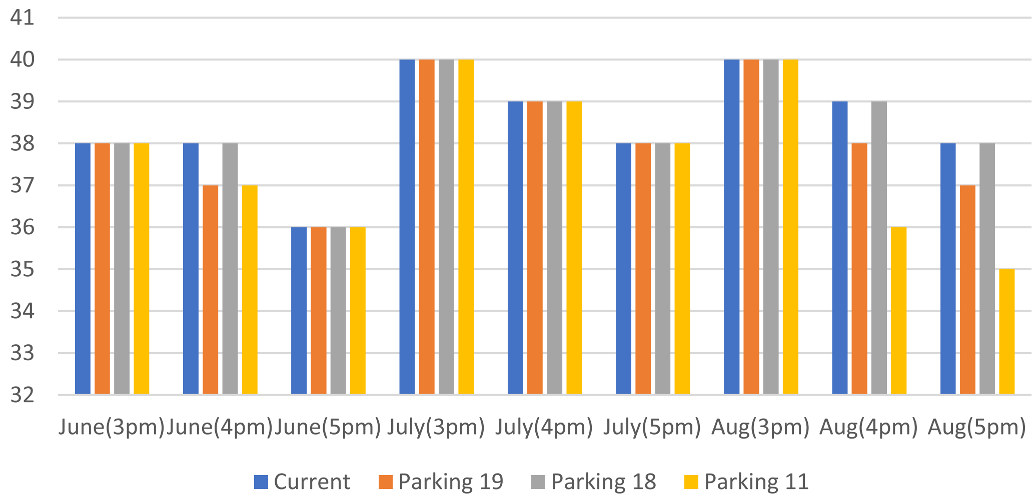

Figure 7. Average air temperature in extreme hot weather across sites

4.2. Wind Analysis.

4.2.1. Pedestrian wind comfort. As shown in Figure 4, parking lot 11 experienced the lowest percentage (0%) of uncomfortable wind conditions. The current campus and parking lot 18 demonstrated the highest percentages of strolling/walking comfort. However, an anomaly was observed across all the location data except parking lot 18, where the total comfort percentages did not sum to 100%. This discrepancy suggests potential data inconsistencies.

4.2.2. Wind speed classification. Figure 5 illustrates that all sites recorded 0% for high wind conditions, which is favorable. The current location had the highest percentage of intermediate wind speeds, followed by parking lot 19. Unlike the comfort analysis, the wind speed classification data for all sites totaled 100%, suggesting more reliable data for this aspect.

Overall, the predominant wind direction was from the north with a consistent extreme wind speed of 4.5 m/s across all sites.

4.3. Microclimate Analysis.

4.3.1. Temperature exceedance. Figure 6 displays the percentage of time that temperatures exceeded 40°C during June, July, and August from 3 PM to 5 PM. In June, the current campus location showed an outlier with a 92% exceedance at 4:00 PM, dropping to 24% at 5 PM, suggesting possible data inconsistencies in Autodesk Forma's real-time temperature modeling. Parking lot 19 had the next lowest exceedance in June and had

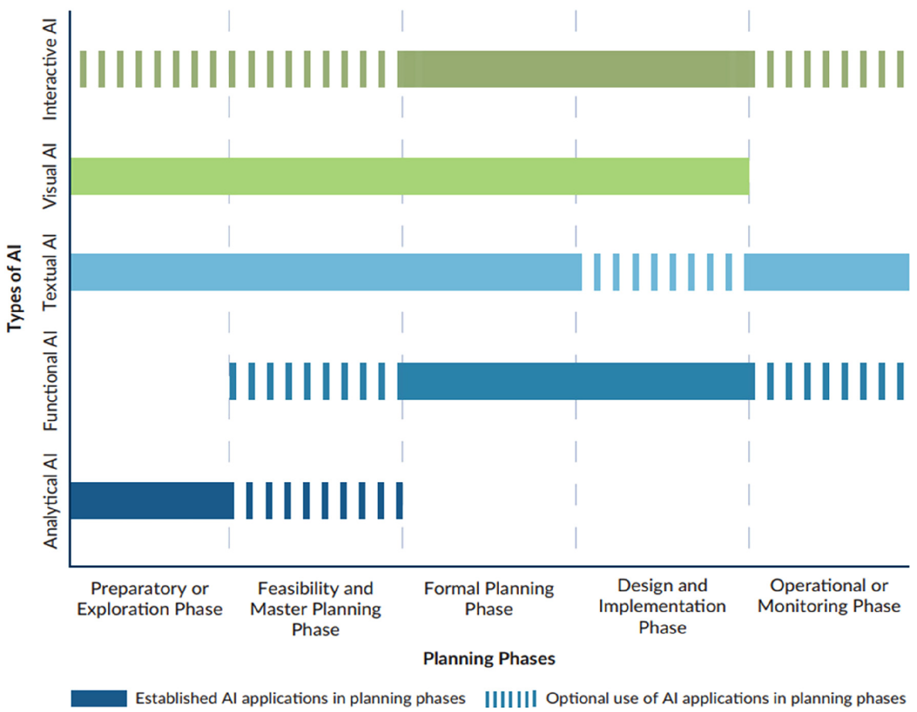

Figure 8. Use of AI tools in different planning phases. A proposal for the use of AI tools related to urban planning in different planning phases. Source: Own illustration based on Diller et al. (2017) and Urban Learning (2024). From Othengrafen et al.[4]

the lowest exceedance in July. In August, parking lot 11 had the lowest exceedance.

4.3.2. Air temperature.

As depicted in Figure 7, the June temperatures were slightly lower at parking lots 19 and 11 compared to the other sites. In July, all sites exhibited similar temperatures. In August, parking lot 11 recorded the lowest air temperature, followed by parking lot 19.

5. DISCUSSION

This study strongly confirms the utility of AI-driven tools, such as Autodesk Forma, in providing quantifiable metrics for optimal site selection, thereby significantly moving beyond traditional expert judgment. The successful generation of comparative environmental metrics across the proposed sites validated the predictive capability of the AI model for complex microclimatic analyses. This successful application aligns directly with the framework proposed in Figure 8 by Othengrafen[4], demonstrating the value of Analytical AI in the early assessment phase. This approach allows KFUPM planning cycles to support the resource-conscious goals of Vision 2030. Furthermore, the efficacy is enhanced by the necessity of importing custom datasets and assigning specific weight thresholds, which allows the tailoring of AI outputs to specific institutional priorities.

Despite its demonstrated utility, the investigation revealed critical constraints that reinforced the need for expert consultation. Autodesk Forma's wind analysis, which is limited to real-time data, restricts its ability to capture long-term trends; therefore, future research must incorporate historical meteorological data. Crucially, observed data inconsistencies, such as wind comfort percentages not totaling 100% and AI's inability to independently select the optimal site, emphasize the necessity of human oversight. Expert interpretation is essential for validating AI outputs, interpreting anomalies, and aligning development initiatives with strategic goals. While AI streamlines processes, the final strategic decision must be made by human experts to ensure that the predictions are balanced with practical knowledge. Future studies should focus on validating simulations using onsite sensor data and enhancing data integration for a truly hybrid planning mode.

6. CONCLUSIONS

This study confirms the potential of AI-driven tools, specifically Autodesk Forma, in enhancing sustainable urban planning at KFUPM by providing real-time, quantifiable environmental insights (solar exposure, wind, and microclimate). AI-powered analysis improved planning accuracy and adaptability, particularly through the use of custom datasets and the ability to assign weight thresholds. However, critical constraints were identified. Autodesk Forma's wind analysis was limited to real-time data, hindering long-term trend capture. In addition, AI currently lacks the capability to suggest optimal locations independently. Ultimately, although AI streamlines processes and optimizes resource allocation, expert interpretation is essential for validating outputs and aligning development initiatives with strategic goals. Future work must focus on enhanced data integration, including historical weather data and expert-driven refinement processes, to further improve the AI-assisted campus planning at KFUPM.

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