

Feasibility Study of Applying the Biophilic Approach in Sustainable Urban Planning- A Case Study of Babol City

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Abstract

This study examines the potential of transforming the city of Babylon into a biophilic city using the VIKOR model. Considering the geographical features, favorable climate, and existing ecological capacities, the environmental, social, and economic indicators affecting this transformation have been identified and analyzed. Initially, a set of key indicators including urban green cover, air quality, sustainable water resource management, social participation, and implementation costs were determined and weighted using expert opinions. Based on these indicators, four implementation strategies were evaluated, including the creation of biophilic parks, the development of green roofs and walls, green walkways, and sustainable water resource management. VIKOR model calculations showed that the creation of biophilic parks has better performance in terms of indicators such as green cover, air quality, and social participation, and is recommended as a more desirable option for the development of the city of Babylon. In addition, the implementation of green roofs and green walkways are also significant as complementary strategies for achieving sustainable urban development. In contrast, sustainable water resources management is a lower priority due to its high implementation costs and limited impact on environmental indicators. The results of this study indicate the importance of combining extensive green spaces, utilizing green structures, and enhancing citizen participation in environmental protection, which can make Babol a successful example of urban biophilism

Keywords: Urban biophilism, VIKOR model, sustainable development, green space, urban planning

Introduction

Urbanization has accelerated at an unprecedented rate over the past few decades, leading to significant environmental, social, and economic challenges. The rapid expansion of cities has resulted in increased pollution, resource depletion, and a decline in overall urban livability (McDonald *et al.*, 2021). As cities continue to grow, the need for sustainable urban planning strategies becomes more pressing. One emerging approach that has gained attention in recent years is **biophilic design**, which integrates natural elements into urban environments to enhance sustainability and improve the quality of life for residents (Panlasigui *et al.*, 2021).

Biophilic design is rooted in the concept that humans have an inherent connection to nature, and incorporating natural elements into urban spaces can lead to numerous benefits, including improved mental health, enhanced biodiversity, and greater ecological resilience (Swarno *et al.*, 2021).

Traditional urban planning often prioritizes infrastructure and economic development over environmental considerations, leading to fragmented green spaces and reduced access to nature. However, biophilic design seeks to bridge this gap by fostering harmonious interactions between urban dwellers and their natural surroundings (Varmaghani, 2023).

The feasibility of implementing biophilic design in urban environments depends on several factors, including geographic location, climate conditions, economic viability, and policy frameworks. Cities with abundant natural resources and favorable climates may find it easier to integrate biophilic elements, whereas densely populated urban centers with limited green space may face greater challenges (Brigham, 2023). Additionally, the economic implications of biophilic design must be considered, as sustainable urban development often requires significant investment in infrastructure, maintenance, and community engagement (Pedersen, 2023).

Recent studies have demonstrated that biophilic urbanism can contribute to sustainability by reducing energy consumption, improving air quality, and mitigating

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the urban heat island effect (Xing, 2019). For example, green roofs and vertical gardens have been shown to enhance thermal insulation, reducing the need for artificial cooling and heating systems (Abreu *et al.*, 2019). Furthermore, integrating water features and natural landscapes into urban planning can help manage stormwater runoff and improve overall environmental resilience (Ziari *et al.*, 2018).

Beyond environmental benefits, biophilic design also plays a crucial role in fostering social cohesion and enhancing public well-being. Access to green spaces has been linked to lower stress levels, increased physical activity, and improved cognitive function (Young, 2016). Urban environments that prioritize biophilic elements encourage community interaction and create aesthetically pleasing spaces that promote relaxation and engagement (Arof *et al.*, 2020). As a result, cities that adopt biophilic principles can enhance their livability and attract residents who value sustainability and quality of life.

Despite its advantages, the widespread adoption of biophilic design faces several obstacles, including regulatory constraints, financial limitations, and public awareness. Many urban planning policies still prioritize conventional development models, making it difficult to integrate biophilic elements into existing frameworks (McDonald *et al.*, 2021). Additionally, the initial costs associated with implementing biophilic infrastructure can deter municipalities from pursuing such initiatives, despite the long-term benefits they offer (Swarno *et al.*, 2021).

This study aims to assess the feasibility of using biophilic design as a new approach to urban sustainability and livability. By examining case studies, policy frameworks, and economic considerations, this research seeks to provide insights into the practical implementation of biophilic principles in urban environments. The findings will contribute to the growing discourse on sustainable urban development and offer recommendations for cities looking to integrate nature into their planning strategies.

2. Research Background

Biophilic design is based on humans' innate connection with nature, aiming to create urban environments that are environmentally, socially, and economically sustainable (O'Sullivan *et al.*, 2023). This approach includes using green spaces, natural light, proper ventilation, and natural elements in architecture and urban planning (Xia *et al.*, 2024).

Studies have shown that biophilic design can mitigate negative urbanization effects such as air pollution and biodiversity loss (Radha, 2021). Moreover, this approach enhances social interactions, reduces stress, and improves citizens' mental health (Xia *et al.*, 2024).

Leading cities in implementing biophilic design include Singapore, Copenhagen, and New York, which have

successfully integrated green projects to create more livable urban environments (O'Sullivan *et al.*, 2023). These cities utilize vertical greenery, urban parks, and natural ventilation systems to reduce energy consumption and enhance the quality of life (Radha, 2021).

Despite its numerous advantages, implementing biophilic design faces challenges such as high costs, spatial constraints, and resistance from policymakers (Xia *et al.*, 2024). Addressing these challenges requires supportive policies and increased public awareness (O'Sullivan *et al.*, 2023).

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3. Research Methodology

Babol, a key city in Mazandaran Province, is located 217 kilometers northeast of Tehran and serves as the administrative center of Babol County. Geographically, it lies between 33 to 36 degrees north latitude and 41 to 52 degrees east longitude, with an elevation of 52 meters above the Caspian Sea. The urban area of Babol covers 3,022 hectares, while its designated buffer zone spans 1,000 hectares, reflecting a ratio of 0.33 between these two regions. Based on the most recent official statistics, Babol has a population of 250,217. Given the study area of 3,190 hectares, the estimated gross population density in the city is approximately 78.44 individuals per hectare.

This study examines the potential for transforming Babol into a biophilic city through the application of the VIKOR model. The city's geographical characteristics, favorable climate, and ecological capacity provide a robust foundation for analyzing environmental, social, and economic indicators aimed at promoting sustainable urban development. Initially, a set of key indicators—including urban green spaces, air quality, water resource management, social participation levels, and implementation costs—was identified. These indicators were then weighted based on expert evaluations.

The VIKOR model, as a multi-criteria decision-making tool, enables the simultaneous assessment of various indicators, aiding urban planning efforts in achieving optimal decision-making and sustainable development objectives. However, effective implementation of this model necessitates precise data collection, comprehensive analysis, and appropriate weighting adjustments to ensure practical applicability of the results.

Employing a descriptive-analytical approach, this study investigates urban and environmental structures. Given its reliance on survey methods, it falls within the category of empirical research. The primary data collection instrument is a researcher-designed questionnaire aimed at gathering expert opinions. The study's target population consists of specialists in urban planning, urban environment management, and green space development, selected from Babol's academic

institutions, central municipality, and district municipal offices.

To enhance the credibility of the findings and minimize sampling errors, the study sample consists of 30 experts, including 10 urban planning specialists, 10 urban environmental experts, and 10 professionals in urban green space management. This sample size enables the application of both parametric and non-parametric statistical tests, thereby improving the analytical depth of the research. The validity of the data collection instrument has been confirmed through content and construct validity assessments conducted by academic experts. To evaluate the reliability of the questionnaire, Cronbach's alpha test was performed, yielding a coefficient of 0.8, which indicates an acceptable level of reliability.

The collected data were analyzed at two statistical levels: descriptive statistics and inferential statistics. Advanced statistical models and Microsoft Excel software were employed to identify and interpret significant data trends.

VIKOR is a multi-criteria decision-making (MCDM) method designed to address complex problems involving conflicting criteria. This model is particularly significant in urban sustainability assessments and biophilic city planning, as it facilitates the simultaneous evaluation of environmental, social, and economic indicators.

Opricovic introduced the VIKOR method in the 1980s, developing it as a compromise-based multi-criteria optimization approach. Initially utilized in project management and engineering, its scope has since expanded to applications in urban planning, sustainable development, and renewable energy initiatives. Due to its effectiveness in resolving complex challenges, the VIKOR model has played a vital role in strategic decision-making across various fields (Mardani *et al.*, 2016).

The VIKOR method operates by measuring the distance of each alternative from the ideal solution. It assesses different options based on conflicting criteria and identifies the optimal choice. The primary steps in implementing this model include:

- Defining the decision-making criteria to establish relevant indicators.
- Normalizing data to standardize the scale of various criteria.
- Calculating desirability and undesirability indices to evaluate alternatives.

- Determining the final VIKOR index to identify the optimal decision.
- Ranking and selecting the best alternative based on computed scores.

This model assists urban planners in achieving a balanced approach to decision-making by integrating multiple criteria to select the most viable option for sustainable urban development. However, successful implementation of this method requires precise data collection, comprehensive analysis, and appropriate weight adjustments to ensure practical applicability.

4. Findings

The feasibility analysis of transforming Babol into a biophilic city using the VIKOR model consists of defining criteria, normalizing data, calculating desirability and undesirability indices, ranking alternatives, and selecting the optimal option.

4.1. Defining Decision-Making Criteria

At this stage of the study, evaluation criteria for assessing the feasibility of biophilic urban design in Babol have been established. Environmental indicators have been defined considering the ecological capacities of the region, as Babol possesses diverse vegetation, abundant water resources, and natural ecosystems, offering significant potential for sustainable development. Social indicators have been determined based on factors such as urban culture, citizen participation, and the level of acceptance of sustainable models within the community. Additionally, economic and executive criteria have been incorporated into the VIKOR model to assess project costs, investment volumes, and the economic impact of proposed initiatives.

The weighting of indicators in this model can be performed using various scientific approaches, with the selection of the most suitable method depending on the research objectives, the required level of accuracy, and the availability of valid empirical data. In this study, a questionnaire was designed as the primary data collection tool to gather and analyze expert opinions from specialists in urban planning and sustainable development (Table 1).

Table 1: Weighting of Biophilic City Evaluation Indicators for Babol

No.	Evaluation Indicator	Definition	Proposed Weight (0–1)	Importance Level
1	Urban Green Cover (%)	Existing green spaces and potential for biophilic parks and gardens	0.22	High
2	Air Quality (PM2.5, PM10)	Air pollution levels and the role of vegetation in reducing pollution	0.18	High
3	Sustainable Water Resource Management (% Reuse)	Efficient utilization, treatment, and recycling of urban water	0.14	Medium
4	Biodiversity	Preservation of native plant and animal	0.12	Medium

		species in urban design		
5	Citizen Participation in Green Projects (%)	Involvement of residents in maintaining green spaces and urban policy-making	0.10	Medium
6	Per Capita Green Space (m ² /person)	Accessibility of individuals to urban green spaces	0.08	Medium
7	Public Awareness (% of citizens informed about biophilic principles)	General knowledge about environmental concerns and biophilic urban design	0.06	Low
8	Execution Costs (Billion Tomans)	Estimated costs for implementing biophilic projects	0.05	Low
9	Job Creation (% Employment Growth Related to Green Projects)	Opportunities for employment in sustainable urban development sectors	0.03	Low
10	Green Investment Attraction (% Budget allocated for Sustainability)	The city's ability to attract investment for sustainable projects	0.02	Low

This model assists urban planners in balancing various criteria within decision-making processes to identify the most viable option for sustainable urban development. However, successful implementation requires precise data collection, comprehensive analysis, and proper weighting adjustments to ensure practical applicability.

4.2. Defining Implementation Options

An examination of key indicators reveals that the challenges and opportunities for transforming Babol into

a biophilic city primarily fall within four domains: expanding green spaces, improving air quality, managing water resources, and preserving biodiversity. Therefore, implementation strategies must be designed to enhance urban green coverage, significantly impact air quality, optimize water resource management, and support native plant and animal species. Given the importance of each criterion, execution options should align directly with the high-weight indicators. Accordingly, this study has identified and selected a set of operational strategies that can effectively achieve these objectives (Table 2).

Table 2: Selection of Implementation Options Based on Key Indicators

Implementation Option	Relevant Key Indicators	Final Objective
Establishment of large-scale biophilic parks	Urban green cover (0.22), biodiversity (0.12), air quality (0.18)	Increase green space and protect plant species
Development of green roofs and vertical gardens	Urban green cover (0.22), air quality (0.18), sustainable water management (0.14)	Reduce air pollution and improve urban ecosystems
Adoption of sustainable water management systems	Sustainable water management (0.14), air quality (0.18)	Minimize water consumption and prevent water pollution
Expansion of green pedestrian pathways and sustainable transportation	Air quality (0.18), social participation (0.10), urban green cover (0.22)	Reduce fossil fuel consumption and enhance urban environmental quality

This model helps urban planners integrate multiple criteria in decision-making to identify the most viable strategies for sustainable urban development. However, successful execution depends on precise data collection, comprehensive analysis, and appropriate weighting adjustments.

4.3. Data Normalization

After defining evaluation criteria in the first stage and selecting implementation options based on key indicators

in the second stage, it is now necessary to normalize the data corresponding to each execution option. This process enables standardized data comparisons, ensuring the accurate ranking calculations required by the VIKOR model.

To achieve this, extracted data has been transformed into a standardized range between 0 and 1 using the VIKOR normalization formula, allowing for precise analysis and objective comparisons of the implementation options (Table 3).

Table 3: Normalized Values for Key Indicators

Implementation Option	Urban Green Cover	Air Quality	Execution Costs	Social Participation
Biophilic Parks	$(\frac{35 - 15}{35 - 15} = 1.00)$	$(\frac{30 - 20}{30 - 20} = 1.00)$	$(\frac{180 - 150}{180 - 120} = 0.50)$	$(\frac{75 - 55}{75 - 55} = 1.00)$
Green Roofs	$(\frac{25 - 15}{35 - 15} = 0.50)$	$(\frac{30 - 25}{30 - 20} = 0.50)$	$(\frac{180 - 180}{180 - 120} = 0.00)$	$(\frac{65 - 55}{75 - 55} = 0.50)$
Sustainable Water Management	$(\frac{15 - 15}{35 - 15} = 0.00)$	$(\frac{30 - 30}{30 - 20} = 0.00)$	$(\frac{180 - 120}{180 - 120} = 1.00)$	$(\frac{55 - 55}{75 - 55} = 0.00)$
Green Pedestrian Pathways	$(\frac{20 - 15}{35 - 15} = 0.25)$	$(\frac{30 - 22}{30 - 20} = 0.80)$	$(\frac{180 - 140}{180 - 120} = 0.67)$	$(\frac{60 - 55}{75 - 55} = 0.25)$

This normalization process ensures that various execution options are objectively assessed, forming the foundation for ranking and selecting the most effective strategies for biophilic urban development.

4.4. Calculation of Desirability (S) and Undesirability (R) Indices

After completing data normalization in the previous stage, the desirability (S) and undesirability (R) indices must now be determined for each implementation option. This step plays a crucial role in evaluating the overall performance of the alternatives, as it identifies both strengths and weak performance indicators. Using the calculated indices, the VIKOR model ranks the available alternatives and determines the most suitable implementation option. This ranking is based on weighted indicators and the distance of each alternative from the ideal solution, ultimately leading to the selection of the optimal option among the available choices (Table 4).

Table 4: Values of R and S for Implementation Options

Desirability (S)	Undesirability (R)	Implementation Option
0.095	0.07	Biophilic Parks
0.285	0.11	Green Roofs
0.355	0.22	Sustainable Water Management
0.255	0.165	Green Pedestrian Pathways

4.5. Final VIKOR (Q) Index Calculation and Ranking of Alternatives

After determining the desirability (S) and undesirability (R) indices in the previous step, the final VIKOR (Q) index is now calculated to rank the implementation alternatives. This index serves as the primary criterion for identifying the best execution option and plays a key role in evaluating and comparing alternatives.

The Q index represents the distance of each option from the ideal solution, and based on this measure, the final ranking is established. The alternatives with the lowest Q values are selected as the optimal choices for implementation. This stage enables precise comparison of alternatives, helping to identify the most effective and feasible strategies (Table 5).

Table 5: Ranking of Implementation Options Based on Q Values

Final Rank	Q (VIKOR) Value	Implementation Option
Rank 1 (Best Option)	0.00	Biophilic Parks
Rank 2	0.50	Green Roofs
Rank 3	0.62	Green Pedestrian Pathways
Rank 4 (Least Favorable Option)	1.00	Sustainable Water Management

Based on the findings of this study, "Biophilic Parks" has been identified as the most suitable implementation strategy due to its lowest Q value. This option, in addition to achieving high desirability and low undesirability, demonstrates the strongest alignment with sustainable development goals and can significantly contribute to establishing a biophilic city in Babol.

4.6 Evaluation of Implementation Options

The "Green Roofs and Vertical Gardens" option ranks second. It has a significant and positive impact on expanding urban green coverage and reducing air pollution levels. However, its higher implementation costs compared to biophilic parks may present challenges during execution.

The "Green Pedestrian Pathways" option is ranked third. While it offers notable environmental benefits, its overall impact is comparatively limited in scope, resulting in lower desirability than the top two options.

Finally, "Sustainable Water Management" is identified as the least effective option, as its Q index value indicates weaker alignment with biophilic urban criteria. While this strategy is essential for water resource control, it plays a less significant role in improving the urban ecosystem and aligns less effectively with broader biophilic development objectives.

5. Discussion and Conclusion

5.1. Analysis of Findings

After data normalization and the calculation of desirability (S) and undesirability (R) indices, implementation options were ranked based on the final VIKOR (Q) index (Table 6).

Table 6: Final Ranking Results of Implementation Options

Desirability (S)	Undesirability (R)	Final Index (Q)	Implementation Option	Final Rank
0.095	0.07	0.00	Biophilic Parks	Rank 1
0.285	0.11	0.50	Green Roofs and Vertical Gardens	Rank 2
0.255	0.165	0.62	Green Pedestrian Pathways	Rank 3
0.355	0.22	1.00	Sustainable Water Management	Rank 4

The "Biophilic Parks" option is the best choice for developing a biophilic city in Babol, as it has the lowest Q value, indicating the highest level of desirability and the least undesirability. The "Green Roofs and Vertical

Gardens" option ranks second due to its positive impact on urban green coverage and air quality, though its high implementation costs prevented it from achieving first place. The "Green Pedestrian Pathways" option ranks

third, offering environmental benefits and improving urban health, but its overall influence remains lower than the top two alternatives. "Sustainable Water Management" is identified as the least favorable option. While it is crucial for water resource management, it has a limited role in enhancing the urban ecosystem and key biophilic city indicators.

5.2. Practical Recommendations for Babol's Biophilic City Development

Based on the findings of this study, a set of practical strategies has been proposed to realize biophilic urban design principles in Babol. These recommendations consider the city's ecological, social, and economic capacities to ensure environmental sustainability while enhancing the quality of life for residents.

A. Expansion of Biophilic Parks

- Establishing a network of urban green spaces in the form of public parks that utilize native plant species. Current assessments indicate that the integration of native plants in major city parks (such as Noshirvani Park, Women's Park, Shadi Park, and Shahid Shakari Park) remains limited, representing an underutilized ecological resource.
- Enhancing biodiversity through the cultivation of resilient and native plants that contribute to ecological sustainability.
- Developing green infrastructure such as artificial wetlands and urban ponds adjacent to parks to improve ecological performance. While some aspects of this plan have been implemented in the Second Eastern Beltway and Moziraj neighborhood, the Amir Kabir West region—with its natural wetland—offers a higher implementation potential at significantly lower costs than artificial wetlands.

B. Implementation of Green Roofs and Vertical Gardens in Urban Buildings

- Mandating government and commercial buildings to integrate green roofs and vertical gardens to reduce air pollution and improve energy efficiency. Given the concentration of administrative and commercial buildings along Imam Khomeini and Madar streets, applying this strategy to high-rise structures in these areas could yield significant reductions in pollution and optimize energy consumption.
- Offering financial incentives to encourage residents to implement green building projects through urban management authorities (municipality and city council).
- Utilizing modern technologies such as intelligent irrigation systems and natural air purification mechanisms in green structures.

C. Development of Green Pedestrian Pathways and Sustainable Transportation

- Establishing pedestrian and bicycle-friendly green corridors in high-traffic urban areas, especially central zones such as Madar Street and the market district, to reduce reliance on fossil fuels.
- Increasing green space along major streets to mitigate urban heat island effects.
- Providing supportive infrastructure for sustainable transportation, including dedicated bicycle lanes and electric vehicle facilities.

D. Water Resource Management as a Complementary Component of Biophilic Development

- Integrating urban water recycling and purification systems into green space designs to optimize water consumption.
- Developing innovative infrastructure such as water-absorbing rooftops and underground drainage channels for stormwater management.
- Expanding artificial wetlands to enhance water storage capacity and minimize river pollution.

5.3 Expected Impacts of Implementing the Proposed Strategies

The implementation of the proposed measures in this study is expected to have significant effects on urban sustainability and the quality of life for residents. Some of the anticipated outcomes include:

- **Expansion of a sustainable urban ecosystem** through an increase in green spaces and a reduction in the urban heat island effect, leading to moderated temperatures and improved climatic conditions in the city.
- **Improvement of air quality** by reducing the concentration of PM2.5 and PM10 pollutants caused by transportation and industrial activities, yielding positive effects on public health and lowering pollution-related illnesses.
- **Enhancement of social well-being and public health** through broader access to urban green spaces and the development of safe pedestrian pathways, fostering social interactions and increasing overall liveliness.
- **Strengthening of the urban economy** by attracting sustainable investments in green infrastructure and environmental technologies, which, in addition to creating jobs, will enhance the city's economic resilience.

5.4. Summary and Future Research Directions

Based on the findings of the VIKOR model analysis, the development of **biophilic parks** is identified as the most

effective strategy for transforming Babol into a biophilic city. This option plays a crucial role in urban sustainability by providing extensive green spaces and enhancing biodiversity.

Additionally, **green roofs and pedestrian pathways** serve as complementary elements in biophilic urban infrastructure. These strategies contribute to air pollution reduction, environmental quality improvement, and enhanced public health.

On the other hand, **water resource management** should be considered a **supplementary** project rather than a primary strategy, as its direct impact on biophilic urban development is more limited than other options. While this measure effectively optimizes water consumption, it needs to be integrated alongside other biophilic initiatives to maximize its impact.

For future research, it is recommended to **explore alternative multi-criteria decision-making models**, such as **AHP** and **TOPSIS**, to enable broader and more precise assessments of implementation options. Additionally, **comparative studies on cities that have successfully adopted biophilic urbanism**, such as **Singapore** and **Copenhagen**, could provide practical models for implementing this concept in Babol.

5.5. Final Conclusion

The findings of this study indicate that the **VIKOR model** is an efficient multi-criteria decision-making tool and plays a significant role in assessing the feasibility of biophilic city development. By incorporating environmental, social, and economic indicators, this model enables the ranking of implementation options and the selection of the most effective strategies for sustainable urban planning.

Data analysis results show that focusing on the **expansion of biophilic parks and strengthening green urban infrastructure** can place Babol on the path toward transformation into a sustainable and ecological city. These measures not only enhance vegetation coverage and improve air quality but also yield **positive impacts on public health, reduce urban warming effects, and elevate social well-being**.

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