A Treatment Wetland Park Assessment Model for Evaluating Urban Ecosystem Stability using Analytical Hierarchy Process (AHP)

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Received: 20/09/2018 Accepted: 05/01/2019 Published: 30/03/2019

Abstract

The increased impervious and built-up urban areas threat ecosystem stability through major environmental problems, such as surface runoff, flooding, and wildlife habitat resource depletion. Hence, urban ecologists and planners are attempting to enhance the capacities of wetlands parks in urban ecosystem stabilization. They need an assessment tool to evaluate and quantify the performance of wetland parks on these issues, hereof this study has developed the Urban Wetland Park (UWP) index assessment model. The research conducted three phases; the requirement study to identify the features of wetland park design, formulating index model using Analytical Hierarchy Process method, and model validation using expert input. The UWP model identified eighteen features clustered into three criteria and fifteen sub-criteria and then determined the weights of features. For model validation, the UWP model was applied in Putrajaya wetland park. The UWP resulted with grade B (Good) for Putrajaya wetland park. It means the Putrajaya wetland park performs well in ecosystem stabilization, although the experts recommended few minor improvements regarding site selection ($W_{C1.1} = 0.588$), multi-cell and multi-stage design ($W_{C1.5} = 0.604$), depth proportion ($W_{C1.6} = 0.652$), and biodiversity ($W_{C2.1} = 0.691$). Study proposed the UWP as a universal decision support tool to help urban authorities, urban planners and ecologists to assess the ecosystem stabilization of wetland parks.

Keywords: Urban Ecology, Treatment Wetland, Wetland Park, Decision Support Tool, Analytical Hierarchy Process

1 Introduction

Rapid population growth and built-up areas have increased demand for residential, commercial, industrial, and agricultural land users [1,2]. The increased impervious and built-up areas can restrict infiltration to the ground, which then results in major issues, such as increased surface runoff volume and speed, untreated channeled water, and flooding [3]. A continuously increasing runoff eventually erodes watercourses (i.e., streams and rivers) and causes flooding if the flow exceeds the maximum capacity of the stormwater collection system [4]. Runoff more often occurs in such developed than undeveloped urban areas. Before urban and land development (e.g., buildings, roads, highways, and other land construction), the runoff may occur in a site which is called ‘pre-development runoff.’ The natural site may expect low ratio runoff if rainfall intercepts and absorbed by the ground and vegetation (Figure 1). The runoff may also occur in a site during urban growth which is called ‘post-development runoff.’ Urban growth essentially converts the green landscape into impervious surfaces with compacted soils (e.g., parking lots, roads, and buildings), and this scenario prevents rainfall absorption by the ground. As a result,
rainfall flows within site quickly. Hence the accumulated high-volume runoff may move in the site very rapidly (Figure 1).

Urban wetland’s functions and ecological processes are various with different services (e.g., habitat, hydrology, and water quality, etc.). Urban wetlands contribute significantly to flood reduction, groundwater recharge, stream bank stabilization, and fish and wildlife habitat resource conservation [6,7]. The urban wetlands typically aid to microclimate control, biodiversity support flood control, and pollutant removal from wastewater, aesthetic and recreation [8]. Regarding the structure and functionality, urban wetlands differ from constructed/natural wetlands [9,10]. Most of the natural urban wetlands are remnants of larger wetlands where have been destroyed or modified through housing development, agricultural infills, drainage or other types of anthropogenic actions [11,12].

The environment and urban planners are practicing the wetland park design where can simultaneously play the wetland and park roles. Such wetland park mimics the city parks and water park. The wetland park has aquatic plants and equipment. Literature shows that the ecological functions of urban wetland parks were often neglected, whereas the social (i.e., recreation and entertainment) function is over-emphasized. These issues convey the essential need for urban wetland parks development where they can emulate the environmental and ecological functions of the natural wetlands.

The public and political knowledge of wetland park values have been increased. However, environmental planners and landscape designers need to enhance their knowledge in the assessment of capabilities and performances of urban wetland parks for ecosystem stabilization. Reviewing the literature shows that there are only few wetland assessment models (e.g., [13-17]) while no model for wetland park assessment. Those wetland assessment models differ in approaches and analytical methods, that are not specifically applicable for wetland parks. For example, Chen et al. [14] developed an ecological wetland risk assessment tool based on the information-based network method for environmental analysis. Cui et al. [18] designed a coastal wetland assessment model to evaluate the impact of coastal wetlands on the rising sea levels by using the spatial assessment method and by adopting the source–pathway–receptor–consequence (SPRC) model. Guo et al. [19] assessed wetland’s ecosystems through empirical geochemical analysis, and Garg [20] applied geospatial technology and landscape ecological metrics for wetland management. Chatterjee et al. [21] have applied the fuzzy Analytical Network Process (ANP) for analyzing the causes of wetland degradation.

In summary, a crucial limitation exists in the development of a scientific assessment model for measuring and evaluating urban wetland park’s performances in ecosystem stabilization. In this regard, this research has developed the Urban Wetland Park (UWP) assessment model. The UWP model has applied the Waterfall Process method. Accordingly, the UWP model has been developed into three phases. Phase one is features identification through a critical literature review on the features of wetland park design. Phase two is a model design which develops the UWP index model and conducts AHP analysis to obtain the weight of each feature. And, phase three is model validation that implements the UWP model in a real case.

2 Materials and Methods
2.1 UWP Model Features
This section presents the features involved in the UWP assessment model. The UWP model as a decision support tool must constitute comprehensive features to evaluate the wetland park cases comprehensively and properly. The features have been investigated through reviewing the wetland park management literature. The features have been identified by the critical literature review applying the combinations of keywords; included, wetland assessment, wetland ecosystem, wetland park, wetland ecology, wetland physical design, wetland environmental design, and ecosystem stability in the available references. The critical literature review is a replicable and scientific method helped us to deal with a manageable number of references that critically studied these topics. Also, the critical literature review helped to identify the features with a minimize bias and errors. The references were extracted from our available sources; included, ScienceDirect, Scopus, Taylor and Francis, Emerald, Google Scholar, and the relevant journals, named, Wetlands, Wetlands ecology and management, Urban Forestry and Urban Greening, Science of the Total Environment, Aquatic Conservation, Journal of environmental management, and Water Science and Technology, in addition to government reports. The features are clustered into three criteria based on physical, ecological and environmental aspects as: Wetland Park Physical Design (C1), Wetland Park Ecological Approaches (C2), and Landscape Environmental Elements to Support the Wetland Park (C3). Each criterion involves a series of sub-criteria, totally fifteen sub-criteria have been
identified as follows;

C1. Wetland Park Physical Design
C1.1. Site Selection: The urban wetland parks depend on the physical attributes of a site to function not only for human but also for wildlife habitat. Land use, access, and topography play key roles in the selection of a suitable site for wetland [22].

C1.2. Wetland Shape Configuration: The shape of a wetland park not only considers aesthetic value but also mimics the image of natural wetlands which can enhance the ecology of wetland parks [23]. Additionally, irregular shorelines should be maximized to enhance water quality by increasing the contact sites for sediments and contaminant removal. Regarding habitat and floating island issues, the allocation of islands for wildlife habitat must be positioned away from the shoreline and separated from permanent water flooding [23].

C1.3. Wetland Zoning and Water Treatment Processes: The integration of different spatial distributions of wetlands can affect stormwater treatment and ecosystem stabilization in different zones of the wetland park. In case of overflow or emergencies, water should be directed to an outlet zone through a bypass or spillway [24].

C1.4. Wetland Surface Flow (SF) and Subsurface Flow (SSF) Systems: Water quality conservation and treatment performance are meaningful in the practice of urban wetland parks (Bao et al., 2007). In wetland park water treatment, the SF and SSF systems can conserve the water area, especially for wildlife habitat [9].

C1.5. Wetland Multi-cell and Multi-stage Design: Urban wetlands can be designed based on the desired plant community and landscape position (linear or basin) [25].

C1.6. Wetland Park Depth Proportion: The different water depths in each wetland cell should have different functionalities. For instance, stormwater retention, contaminant removal, and wildlife habitat are the main planning aspects of depth proportion designs [26,27].

C2. Wetland Park Ecological Approaches
C2.1. Biodiversity: It is defined as the variety of living organisms in the aquatic ecosystems (such as marine and terrestrial, and ecological complexes) [28].

C2.2. Air Pollution Reduction: The landscape planting and vegetation can help reduce CO₂ and other hazardous gases emission in the atmosphere which contributes to climate change [29].

C2.3. Wetland Plant Selection: The plant environment in urban wetland parks must incorporate wetland species, which are classified according to their ecological features and indigenous plants, which play an important role in increasing the wetland biodiversity [30,31].

C2.4. Wetland Wildlife Habitat: The urban wetland design techniques involve the factors to enhance the surrounding wildlife habitat, such as the provision of nesting boxes, identification of depth zones to support plant and animal communities, and provision of buffers planted with buttonbush [32].

C2.5. Wetland Ecological Shoreline Revetment: Shoreline revetment is important for protection against floods, ecological compensation, and water purification [22]. The shoreline environment often becomes areas for wildlife habitat and resting purposes; thus, biodiversity is rich along shorelines [33].

C3. Landscape Environmental Elements to Support the Wetland Park
C3.1. Safety: Safety consideration is critical to good park design, not only from the viewpoint of liability but also because dangerous conditions may distract wildlife habitat [34].

C3.2. Vegetation and Greening: Wetlands have diversity and beauty, and host various vegetation communities (e.g., planting native flowering herbs or shrubs are common in these areas [35]).

C3.3. Route Accessibility: The route for bicycles and walking should be designed as these options can minimize air pollution [34,36].

C3.4. Site Furniture: Site furniture is needed to meet visitors’ comfort, but the natural-made furniture is recommended as they can complement the natural identity of the wetland parks [37,38]. Furniture is normally incorporated to suit the surroundings, and the materials used should be made of natural materials [39].

2.2 Analytic Hierarchy Process (AHP)
The UWP model has applied the analytic hierarchy process (AHP) decision-making method. The AHP conducts a series of pairwise comparisons to determine the weight of features and can prioritize ranking for decision-making situations [40]. The research has executed the following AHP steps to determine the weights of features (i.e., criteria and sub-criteria):

Step 1. Hierarchical decomposition: Any decision-making problem must be interpreted into a hierarchy structure. Accordingly, the hierarchical structure of an urban wetland park design for ecosystem stabilization was formed based on the AHP structure. The top layer is the decision-making goal (i.e., developing an urban treatment wetland), the middle layer involves the urban treatment wetland criteria (i.e., Wetland Park Physical Design (C1), Wetland Park Ecological Approaches (C2), and Landscape Environmental Elements to Support the Wetland Park (C3)), and the bottom layer includes the sub-criteria of each criterion.

Step 2. Pairwise comparison: To develop the UWP model, the research evaluated and rated the features through the AHP algorithm. The features were compared to each other pairwisely. An expert input study was conducted that five experts were involved. The experts have been selected based on the purpose sampling method of GGDM (Grounded Group Decision-making) method [41]. According to Dehdasht et al. [42] and Shafaghat [43] the MCDM techniques, such as AHP, do not need a big sample size while in-depth interviews will be performed with the experts. The experts had approximately ten years of experience in urban ecology, wetland park design, and decision-making from the United States, Malaysia, and Ecuador. We asked the experts to prioritize their judgments (e.g., valid importance) toward each pairwise comparison criterion and sub-criterion. In this research, the n value for the features is 18 (3 criteria and 15 sub-criteria). The experts’ inputs were plotted as a n × n matrix. In x_{ij}^{k}, l is
the influence level of feature \( i \) on feature \( j \). The matrix size for the criteria is \( 3 \times 3 \), and for the sub-criteria is \( 15 \times 15 \). Each feature was rated by the experts using AHP 9-point scaling (9=extremely important to 1=equally important) through the input study questionnaires. For instance, the questionnaire asked them “to rate the importance degree of ‘site selection’ in respect to ‘biodiversity’ in urban wetland park design for ecosystem stabilization purpose”.

Step 3. Supermatrix development: The Output of comparisons has constructed the supermatrix. The AHP’s supermatrix was developed using the AHP SCBUK software (which was developed by SCB Associates Ltd. [44]). The AHP SCBUK software is a stand-alone AHP software for conducting decision-making analysis. The experts’ pair-wise comparisons have been transformed from the survey forms to the software to construct the relative supermatrix and analyze them. The \( W_j \) is the weight of the feature. The AHP supermatrix has been developed by applying Equation 1;

\[
A_{\text{AHP}}^{i} = \sum_{j=1}^{n} a_{ij} W_j \quad \text{for } i=1,2,3,...,n \quad (1)
\]

Table 1: AHP decision-making supermatrix of urban wetland park design

<table>
<thead>
<tr>
<th>Criteria</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>...</th>
<th>C15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alt.</td>
<td>W1</td>
<td>W2</td>
<td>W3</td>
<td>...</td>
<td>W15</td>
</tr>
<tr>
<td>A1</td>
<td>C1</td>
<td>C11</td>
<td>C12</td>
<td>C13</td>
<td>...</td>
</tr>
<tr>
<td>A2</td>
<td>C2</td>
<td>C21</td>
<td>C22</td>
<td>C23</td>
<td>...</td>
</tr>
<tr>
<td>A3</td>
<td>C3</td>
<td>C31</td>
<td>C32</td>
<td>C33</td>
<td>...</td>
</tr>
</tbody>
</table>

Step 4. Normalization: It is to normalize the comparison supermatrix by summing up entries of the columns. First, each column entry will be divided to the column sum; then the normalization will be conducted by making the sum of each column equal to 1 (i.e., each entry \( C_{jn} \) of the matrix of normalization) using Equation 2;

\[
C_{jn} = \frac{c_{jn}}{\sum_{m=1}^{n} c_{jm}} \quad (2)
\]

The criterion weight vector ‘\( w \)’ will be calculated by averaging the entries each row using Equation 3;

\[
W_j = \frac{\sum_{i=1}^{n} C_{ij}}{m} \quad (3)
\]

where \( C_{ij} \): entry of ith row and jth column of the normalized matrix and vi: ith feature v.

Step 5. Consistency analysis: It is to ensure that the initial rating is consistent. If the corresponding consistency ratio (CR) is less than 10% [40], then AHP output will be consistent. According to Table 2, dividing CI to RI will generate the CR (Equation 4);

\[
\text{CR} = \frac{CI}{RI} = \frac{(\lambda_{\text{max}} - n)/n - 1)}{RI} \quad (4)
\]

where, \( n \), is the rating value and \( \lambda_{\text{max}} \) maximum eigenvalue

<table>
<thead>
<tr>
<th>n</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<th>12</th>
<th>13</th>
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<tbody>
<tr>
<td>RCI</td>
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<td>0.09</td>
<td>0.11</td>
<td>0.12</td>
<td>0.13</td>
<td>0.14</td>
<td>0.15</td>
<td>0.16</td>
<td>0.17</td>
<td>0.18</td>
<td>0.19</td>
<td>0.20</td>
<td>0.21</td>
<td>0.22</td>
<td>0.23</td>
</tr>
</tbody>
</table>

2.3 Weighted Sum Method (WSM)

The UWP model was implemented in a real case study (Putrajaya Wetland Park) for validation through an expert input. The same group of experts involved in phase two were invited for validation. The experts were asked to assess the Putrajaya Wetland Park by applying the Weighted Sum Method (WSM). The WSM method can convert the multi-objective optimization to a single-objective optimization [41,46]. Indeed, these experts were such end-users of the UWP model and would apply it practically. According to the WSM method instructions, the experts have rated the features in 5-point Likert scaling (5=excellent to 1=weak). The WSM equations are as following:

\[
WSM(a_i) = (\sum_{j=1}^{n} w_j) a_i \quad \text{for } i=1,2,3,...,n \quad (5)
\]

where, \( w_j \), the assigned weight by the expert number ‘\( j \)’ in for the feature of discussion, ‘\( a_i \)’, is a feature of discussion with the given ordering number of ‘\( i \)’and ‘\( n \)’, is the number of features of discussion. Equation 6 indicates the consensus of WSM method. The consensus is accepted if more than 0.70 saturation on experts’ judgments was observed.

\[
WSM(a_i) / WSM(\text{a}_\text{max}) = \text{Consensus} \quad (6)
\]

where, \( WSM(\text{a})_{\text{max}} \), is the maximum sum of possible weight can be assigned for the feature. This research has applied the WSM to the Putrajaya Wetland Park in Malaysia. The Putrajaya wetland park is the first urban wetland park in Malaysia and largest fully constructed freshwater wetland in tropic (Figure 2). The Putrajaya wetland park also has received the Excellence Award in Green City Category in 2011 and 2012. It was mainly constructed to remove pollutants, and to clean catchment before entering the lake. The environmental management and modern technologies have implemented in the design and construction of this wetland [47].

3 UWP Model Development

This section presents the model development phase of the UWP model. By applying the Equations 2 and 3 of the AHP, first, the normalized supermatrices were computed for criteria, next for sub-criteria, and then for sub-criteria with respect to each criterion (Table 5). According to Table 3, the criterion Ecological Approach received the highest normalized weight (\( W_{C3} = 1.1035 \)); in opposite the Landscape Elements (\( W_{C3} = 0.8521 \)).
were Site Furniture and Route Accessibility, $W_{C1.2} = 19.9885$ and $W_{C3.3} = 20.0280$, respectively. The outputs of Table 5 were transferred to the linear equation index of the UWP model.

Table 5: Integrated Normalized Supermatrix of Urban wetland park design sub-criteria with respect to criteria

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Sub-criteria</th>
<th>Normalized Weightage</th>
<th>Normalized Weightage</th>
<th>Normalized Weightage vs. Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>C1.1</td>
<td>1.0532</td>
<td>25.2759</td>
<td>26.6206</td>
</tr>
<tr>
<td></td>
<td>C1.2</td>
<td></td>
<td>27.7670</td>
<td>29.2454</td>
</tr>
<tr>
<td></td>
<td>C1.3</td>
<td></td>
<td>24.6267</td>
<td>25.9380</td>
</tr>
<tr>
<td></td>
<td>C1.4</td>
<td></td>
<td>23.7204</td>
<td>24.9835</td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
<td>C1.6</td>
<td></td>
<td>23.2589</td>
<td>24.4964</td>
</tr>
<tr>
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<td>C2.1</td>
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<td>27.8401</td>
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<tr>
<td></td>
<td>C2.2</td>
<td></td>
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<tr>
<td></td>
<td>C2.3</td>
<td></td>
<td>24.1702</td>
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</tr>
<tr>
<td></td>
<td>C2.4</td>
<td></td>
<td>24.5783</td>
<td>27.1234</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>23.8753</td>
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<tr>
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<td>C3.1</td>
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<tr>
<td></td>
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<td></td>
<td>25.6431</td>
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<tr>
<td></td>
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<td>21.1561</td>
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<td></td>
<td>C3.4</td>
<td></td>
<td>23.4568</td>
<td>19.9885</td>
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</table>

The Consistency Index (CI) has been calculated (CI = 0.139). According to Table 2, RI is 1.58; hence CR coefficient was calculated as CR/RI = 0.087. The result of AHP is consistent enough because this ratio is less than 10% (< 0.10). Equation 7 presents the UWP index assessment model. The weights of sub-criteria have been extracted from Table 5 and applied as the coefficients in the UWP model;

**Urban Wetland Park (UWP) Index Model**

$$UWP \text{ Index} = \sum_i \left( a_{i1}X + a_{i2}Y + a_{i3}Z \right)$$

where, $a$ is coefficient of sub-criterion (Extracted from Table 5 column of Sub-criteria integrated Normalized Weight vs. Criterion), $i$ is Physical Design sub-criterion (for:1,2,3,4,5,6), $j$ is Ecological Approaches sub-criterion (for:1,2,3,4,5), $k$ is Landscape Environmental Elements sub-criterion (for:1,2,3,4), $X$ is Weight of Physical Design sub-criterion ‘i’ assigned by the experts in the case survey, $Y$ is Weight of Ecological Approaches sub-criterion ‘j’ assigned by the experts in the case survey and $Z$ is Weight of Landscape Environmental Elements sub-criterion ‘j’ assigned by the experts in the case survey.
Table 4: Normalized Supermatrix of Urban wetland park design sub-criteria

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4 UWP Model Validation

This section presents the model validation phase of the UWP model. The validation was to seek the unforeseen biases and errors of the UWP model. Although the UWP model could be applied in any wetland park, it was applied to Putrajaya Wetland Park. The same group of experts has been invited to for model validation. They were asked to evaluate the Putrajaya Wetland Park in respect to eighteen features of the UWP model using WSM method. According to the WSM instructions, the experts rated each feature using 5-point scaling. The experts’ inputs have been individually collected and then synthesized based on Equation 5 and Equation 6 (see Table 6). In Table 6 column ‘expert input’ presents the individual experts’ judgments, and column ‘consensus’ shows that cumulative judgment of all experts. The last column reveals the WSM final weight for each sub-criteria by multiplying the consensus values of criteria to the corresponding sub-criteria. Referring to WSM instructions, the features are approved with the saturation of more than 0.70. In the case of Putrajaya wetland park, almost all features have received the threshold saturation, except site selection ($W_{C1.1} = 0.588$), wetland multi-cell and multi-stage design ($W_{C1.5} = 0.604$), depth proportion ($W_{C1.6} = 0.652$), and biodiversity ($W_{C2.1} = 0.691$).

The UWP model calculates the index score for the Putrajaya wetland park. The weights of sub-criteria were extracted from Table 6 and then applied to Equation 7. Table 7 presents the index score calculation steps for the Putrajaya wetland park. Table 7 has extracted the coefficients from Table 5, and the case study weights from Table 6. The calculation results that Putrajaya wetland park received 285 index scores.

Urban Wetland Park (UWP) Index = $\sum$ Index $\cdot$ Design $\cdot$ Landscape $\cdot$ Environmental Elements

\[
\begin{align*}
\text{UWP Index} & = \text{Implementation of Design} \cdot \text{Features} \\
& = (26.6206 \cdot 0.588) + (29.2454 \cdot 0.846) + (25.9380 \cdot 0.846) + (24.9835 \cdot 0.883) + (26.0709 \cdot 0.604) + (24.9649 \cdot 0.652) + 116.117 \\
\text{UWP Index} & = \text{Implementation of Ecological Approaches} \\
& = (30.7227 \cdot 0.691) + (28.1135 \cdot 0.846) + (26.6719 \cdot 0.729) + (27.1234 \cdot 0.729) + (26.3476 \cdot 0.729) = 105.607 \\
\text{UWP Index} & = \text{Implementation of Landscape Elements} \\
& = (20.7113 \cdot 0.739) + (21.8514 \cdot 0.722) + (18.0280 \cdot 0.722) + (19.9885 \cdot 0.883) = 285.481 \\
\text{UWP Index} & = 116.117 + 105.607 + 63.757 + 285.481 = 875.960
\end{align*}
\]

The UWP model labels the wetland park as grade A to E, based on the index scores. As the maximum consensus for all sub-criteria (X, Y, and Z) can be 1, the maximum UWP index score equals to 380. The minimum index score is 0.2 of the maximum index score which equals to 76. The UWP model has established the following grades for different score ranges:

\[
\begin{align*}
\text{UWP Index}_{\text{Max}} & = 160 + 154 + 65 = 380 \\
\text{UWP Index}_{\text{Min}} & = \text{UFA Index}_{\text{Max}} = 380 \cdot 0.2 = 76
\end{align*}
\]

Table 7: UWP index score calculation for the case study (Putrajaya wetland park)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Sub-Criteria</th>
<th>Sub-criteria Coefficient</th>
<th>Case study weights</th>
<th>Sub-criteria index score</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1.1</td>
<td>C1.2</td>
<td>C1.3</td>
<td>C1.4</td>
<td>C1.5</td>
</tr>
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<td>0.588</td>
<td>0.846</td>
<td>0.846</td>
<td>0.883</td>
<td>0.604</td>
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<tr>
<td>15.65291</td>
<td>24.74161</td>
<td>21.94355</td>
<td>22.06043</td>
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</tr>
<tr>
<td>C2.1</td>
<td>C2.2</td>
<td>C2.3</td>
<td>C2.4</td>
<td>C2.5</td>
</tr>
<tr>
<td>0.691</td>
<td>0.846</td>
<td>0.729</td>
<td>0.809</td>
<td>0.729</td>
</tr>
<tr>
<td>C3.1</td>
<td>C3.2</td>
<td>C3.3</td>
<td>C3.4</td>
<td></td>
</tr>
<tr>
<td>20.7313</td>
<td>21.8514</td>
<td>18.0280</td>
<td>19.9885</td>
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</tr>
<tr>
<td>0.739</td>
<td>0.772</td>
<td>0.772</td>
<td>0.883</td>
<td></td>
</tr>
<tr>
<td>15.32943</td>
<td>16.86928</td>
<td>13.91762</td>
<td>17.64985</td>
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<tr>
<td>63.757</td>
<td>63.757</td>
<td>63.757</td>
<td>63.757</td>
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<tr>
<td>Total UWP index score = 285.481</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As Putrajaya Wetland Park has earned 285 scores, it achieved grade B (Good). Means, it is a well-designed wetland park, while some features do not perform well for stabilizing the ecosystem. Accordingly, the evaluator experts had some corrective comments (see Discussion section). Moreover, the research has drawn a multi-scatter plot which depicts the correlation between sub-criteria coefficients (AHP outputs) and sub-criteria consensus (WSM outputs) (see Figure 3). The multi-scatter plot benchmarks the ecosystem stabilization performance of the wetland case study (here, Putrajaya wetland park) against ideal wetland park (i.e., the best practice). As can be seen in Figure 3, the association between sub-criteria coefficients and consensus was approximated with a straight line; thus, the result identifies the linear relationship ($y = -0.004x + 0.8607$).
Table 6: WSM data collection and analysis process of criteria and sub-criteria evaluation of UWP index model in Putrajaya wetland park

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Experts inputs</th>
<th>Sum of Experts</th>
<th>WSM(a)_{max} of Criterion</th>
<th>Consensus For criteria</th>
<th>Sub-criteria</th>
<th>Experts inputs</th>
<th>Sum of Experts</th>
<th>WSM(a)_{max} of Sub-criterion</th>
<th>Consensus for sub-criterion</th>
<th>WSM final Cons. of Sub-criterion</th>
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<td>5 4 5 5 4</td>
<td>23</td>
<td>25</td>
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<td></td>
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<td>25</td>
<td>0.92</td>
<td>0.846</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>C1.3. Wetland Zoning and Water Treatment Processes</td>
<td>4 5 4 5 5</td>
<td>23</td>
<td>25</td>
<td>0.92</td>
<td>0.846</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>C1.4. Wetland Surface Flow (SF) and Subsurface Flow (SSF) Systems</td>
<td>5 5 5 4 5</td>
<td>24</td>
<td>25</td>
<td>0.96</td>
<td>0.883</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>C1.5. Wetland Multi-cell and Multi-stage Design</td>
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<td>18</td>
<td>25</td>
<td>0.72</td>
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<td></td>
<td>C1.6. Wetland Park Depth Proportion</td>
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<td>25</td>
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<td>C2.1. Biodiversity</td>
<td>3 4 3 4 4</td>
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<td>25</td>
<td>0.72</td>
<td>0.691</td>
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<td>C2.2. Reducing Air Pollution</td>
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<td>C2.5. Wetland Ecological Shoreline Revetment</td>
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<td>C3.4. Vegetation and Greening</td>
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</tbody>
</table>

Note: EX: Expert; Cons.: It refers to consensus calculated based on formula 6.
The case study regression coefficient \( (R^2) \) was calculated as 0.0225 which shows the weak impact of measured sub-criteria in the regression analysis. The regression line for the ideal wetland \( (y=1) \) was calculated assuming all sub-criteria consensus equal to 1.000, means, all criteria and sub-criteria received the maximum rating value (i.e., 5) in the WSM survey. The comparison of two regression lines shows that Putrajaya consensus has a minor deviation with the ideal wetland park. The maximum deviation is 0.412 (by C1.1. Site Selection), and minimum deviation is 0.117 (by C1.4. Wetland Surface Flow (SF) and Subsurface Flow (SSF) Systems and C3.4. Vegetation and Greening), while the average deviation is 0.240.

5 Discussion

An urban wetland park can enhance the efficiency of wetland functions and indirectly attract aquatic and wildlife habitats to form a balanced ecosystem. An urban wetland park design essentially provides interactions between humans and nature through ecosystem stabilization, flood reduction, water quality improvement, stormwater treatment, and the creation of spaces for wildlife habitat, as well as recreational and educational facilities and amenities.

\[
y = 0.004x + 0.8607 \\
R^2 = 0.0225
\]

Figure 3 The multi-scatter plot for benchmarking Putrajaya wetland park with the ideal wetland park

The research found that biodiversity is one of the major benefits of wetland parks. Hansson et al. [47] state that the relationship between the environment and biodiversity in urban wetlands has a great value. Also, the research found that wetland shape can intensively affect ecosystem stabilization. Mitsch and Gosselink [48] state that wetland convoluted or irregular shapes can further enhance edge habitats as opposed to edges in a rectangular shape and regular morphology. Hence, hard edges, which are straight and lack transition in their design, are discouraged. Soft edges with convoluted shapes have more ecological benefits compared with straight boundaries [49]. The convoluted shapes eliminate right-angled corners may lead to the dead water areas for contaminant removal. Moreover, manipulating the inlet width and outlet zones must facilitate certain functions (i.e., food source provision). Indeed, maximizing the shoreline length will benefit wildlife habitat, wildlife nesting, and resting areas.

Besides, wetland parks have a positive impact on reducing air pollution levels and increasing carbon sequestration, which is essential in environmental protection. Urban wetland parks can bring much higher cooling to the residential areas [50], and reducing urban heat islands. Moreover, suitable site and planting selection can enhance the efficiency of wetland function. The wetland park design is integral to the planning process, as the parkland can infuse human–nature interactions. By the end of UWP model validation, the experts have highlighted some bias in the model. The experts recommended the following comments should be incorporated in the revised UWP model;

i) to amend the questionnaire survey form to semi-structured questionnaire form; hence, the model users can add some sub-criteria not included in the UWP list, and rate them as well. This amendment aids to adapt the UWP model much properly to each wetland cases.

ii) to develop the stand-alone or web-based UWP model (using Excel, Python, C++, etc.) to compute the real-time data for the wetland cases, and thus, to compare the computation results with the benchmark wetland.

iii) to visualize the data manipulation of the wetland case through stand-alone or web-based UWP model, which aids to compare the real-time scatterplot results with the benchmark wetland.

iv) to draw a table that sorts the outputs of wetland case (i.e., outputs of WSM-survey form) to indicate the weights of the feature from maximum to minimum. The users then can understand strong to weak features of the wetland case.

v) to outline some recommendations/suggestions to release weaknesses of the wetland case.

vi) to prepare a database based on the wetlands’ survey reports and share them with local authorities, municipal, or other respected organizations for their future corrective actions.

In the case of Putrajaya wetland park, the UWP model found out that Putrajaya wetland park is not functioning well in some aspects (according to Table 7); included, site selection, multi-cell and multi-stage design, depth proportion, and biodiversity. In this regard, the experts have suggested the following recommendations which can release the weaknesses at Putrajaya wetland park;

- Putrajaya wetland parks can follow a single cell strategy, known as a constructed wetland basin with a forebay and micropool outlet which has a uniform water depth, length/width ratio and flow path equal to 2:1 or more, and an emergent wetland design.

- Putrajaya wetland parks can follow a multi-cell strategy in two forms, either a Multi-cell wetland or a combination that has diverse micro-topography with varying depths, length/width ratio and a flow path equal to 3:1 or more.

- For cell separation, each cell must be separated by a weir or earth bund (200 meters width and 2-3 meters height).

- The buffer width needs a minimum of 25 feet for wildlife habitat purposes.
• Putrajaya wetland park must provide the mudflat areas to attract shorebirds and waders.
• Putrajaya wetland park must increase lands for safe nesting areas.
• Putrajaya wetland park needs vertical revetment walls which require regular maintenance and inspection for those edge treatments.

6 Conclusion

The research has developed the UWP index assessment model to measure and quantify the performances of wetland parks in ecosystem stabilization. The model evaluates the urban wetland parks physically, environmentally, ecologically, and socially. The UWP model covers the ecosystem stabilization align with wildlife habitat conservation and recreational and educational activity improvements. The UWP model established a comprehensive list of wetland park design features clustered into three criteria (i.e., design application, ecological approaches, and landscape environmental elements), and fifteen sub-criteria. The UWP model has been designed based on the AHP methodology to measure the weight of each feature. The AHP analysis determined that the ecological approach is the most important criterion which play an essential role in ecosystem stabilization.

Besides, the AHP analysis resulted that biodiversity and wetland shape configuration is the most important sub-criteria in urban wetland park design, while site furniture and route accessibility have minor effects on ecosystem stabilization. The UWP model has been validated through a case study to minimize the unforeseen biases. While it can be applied in many cases, it was implemented at Putrajaya wetland park. As UWP model rates the wetland parks in five grades, A to E, the validation study resulted that the Putrajaya wetland park rated as grade B (i.e., Good).

Importantly, the UWP model is such a ‘qualitative’ model, since it is an opinion-based model incorporates direct observation, field notes (including, descriptions of activities, actions, interactions, and processes), and subjective features into wetland park assessment. This ‘quantitative’-based UWP model measures the weight of features through experts’ judgmental, iterative expert group process, consensus panel approach, experts, and in-depth expert group discussion. While, the authors plan to develop the ‘quantitative’-based UWP model in future works. The ‘quantitative’-based UWP model would measure the ecosystem quantity impacts (e.g., increased runoff, reduced infiltration, reduced base flow, stream geomorphology changes, aquatic habitat effects, pollutant loads, etc.). The ‘quantitative’-based UWP model shall be an experimental model to measure the ecosystem stabilization of wetland parks based on laboratory tests, numerical data, data manipulation, time-series, and causal forecasting methods.

Also, as future works, the AHP method can be coupled with other methods to reduce its inconsistencies and errors, in turn increasing coefficients accuracy. In the future, the UWP model can be designed as standalone or web-based software for comparatively more convenient usage by more users around the world.

References
wetland reconstruction in Denmark. Ecological Indicators, 77, 151-165.