Environmental Impact Assessment Software for Constructed Wetland Parks' Sustainability Performance

Aya ElMeligy[1]

[1]Anhalt University, Hochschule Anhalt/Germany · aya.elmeligy@gmail.com

Abstract: Landscape Architecture is not particularly a tangible field; where most factors incorporated in this area are primarily intangible factors. However, the illustrative aspect of this realm is where the digitization age can shine. Accordingly, the architecture realm could definitely capitalize on the unlimited opportunities the digital space has to offer. In fact, actively demonstrating sustainable development using digital software for landscape architecture is one key means of taking the framework to the next level. The goal of this study is to create a new assessment instrument that is more appropriate for constructed wetland parks (CWPs) impacts and activities, in terms of convenient environmental features. The study is based on a structured questionnaire that examines the accuracy and application of selected indicators, with the participation of professionals from various related areas from across the world. A suggested assessment tool to evaluate the sustainability performance of CWP is discussed in the study, and raises the question of whether the created tool would be appropriate or practical as software. It appears that the proposed approach can be more extensively employed in landscape architecture projects if it is published as a globe app to enable comparison of global park performance.

Keywords: Digitized sustainable landscape, constructed wetland parks, sustainable landscape, Environmental Impact Assessment, digital landscape

1 Introduction

There are several ongoing problems and catastrophes that the world should indeed manage effectively. Climate change and water scarcity are two major issues that many nations face across the world. Several approaches to overcoming these challenges have been widely researched. Reducing the detrimental effects of climate change and natural catastrophes on urban areas has been a priority for researchers. The key to this mitigation's success in achieving beneficial environmental effects is to embrace nature-based techniques. This might be accomplished by implementing a catalyst project that encourages positive changes and has a beneficial influence on the environment. One of the most well-known nature-based initiatives that helps cities deal with the consequences of the two primary crises is constructed wetland parks (CWPs), which views wastewater as a resource for reuse. It is challenging to assess the performance benefits and how CWP contributes to attaining sustainability since there are few instruments available for assessing the effectiveness of CWP projects and their multi-functionality. Consequently, it is proposed that CWPs be evaluated using a set of key influencing impacts. These impacts are employed to develop an assessment method for determining the sustainability of CWPs. The anticipated performance is assessed using the suggested tool to determine the favourable benefits of CWP in attaining municipal sustainability. In this paper, this research gap is being tackled through addressing intangible factors in a modern, digitized way. The paper discusses the proposed assessment tool that could gauge the sustainability performance of CWPs, raising the question of whether the developed tool would be suitable or feasible as software.

Journal of Digital Landscape Architecture, 8-2023, pp. 84-91. © Wichmann Verlag, VDE VERLAG GMBH · Berlin · Offenbach. ISBN 978-3-87907-740-3, ISSN 2367-4253, e-ISSN 2511-624X, doi:10.14627/537740010.

2 Methods

Many researchers throughout the years have established and improved evaluation methodologies to highlight the relevance of environmental change in a clear and consistent manner. (MARTIM 2013). The ad hoc technique, checklists, interaction networks, system diagrams, overlaying charts, and matrices are among the most important environmental impact assessment methods (MORAES 2013). The simple matrix primarily consists of a collection of environmental factors that are presented on the vertical axis and is used to determine if an action will have a negative, neutral, or positive influence on the environment with a "check mark" in the relevant column. Different matrix approaches have been created throughout the years for evaluating various types of project in order to find the best assessment method based on each project's requirements. One of the early techniques, the Leopold Matrix, was first proposed in 1971 (LOHANI et al. 1997). In 1974, Environment Canada introduced a different kind of matrix, the Component Interaction Matrix, to systematically determine the indirect effects. After gaining international recognition, EIAs gradually began including matrices in their impact analyses (BABU 2017). Further advances included the creation of Modified Graded matrix, Impact Summary matrix, and Loran matrix (LOHANI et al. 1997).

2.1 Leopold Matrix

Leopold Matrix offers a simple method for summarizing and categorizing environmental impacts and full review of the project's activities, consequences, and impacted environmental factors to determine the most significant actions and conditions (FIGUEIREDO 2020). It offers a framework for mathematically examining and weighing potential implications. The analysis doesn't offer a comprehensive quantitative evaluation; instead, it shows a variety of value assessments, ensuring that the effects of various actions are evaluated and taken into consideration while designing a project is the major goal. It offers a thorough study of the connections between planned human activities and environmental factors as a qualitative indicator of a project's environmental/social effect. A list of 100 activities indicating environmental actions is depicted on the horizontal axis. On the vertical axis, about 88 environmental/social factors are presented, representing the current environmental aspects and impacts that can be altered by each of the project activities on the horizontal axis. Few interactions are expected to have impact of the degree and relevance to require extensive treatment (PONCE 2009). A custom developed matrix should be tailored according to the distinct situations and features of each park for a precise and accurate assessment of park performance. Table (1) shows a sample of a Leopold matrix, for a model of 5 activities with effects on 2 environmental aspects, with blank cells indicating no influencial activity. The technique enables systematical comprehension of the assessor's reasoning, and spot matches and contradictions. As a result, the matrix is actually a synopsis of the EIA text.

Table 1: Leopold matrix sample (ELMELIGY 2022)

		Project Activities of Impacts				
		Activity 1	Activity 2	Activity 3	Activity 4	Activity 5
Envir. Aspect	Aspect 1	2 / 1	1 / 4		8 / 6	2 / 1
	Aspect 2		10 / 5	2 / 1	3 / 4	

2.2 Leopold Matrix for Environmental Impact Assessment, EIA

The Leopold Matrix EIA is an examination of the cells with higher Magnitude and Significance values. Regardless of the allocated numbers, columns containing several components and Rows containing several actions are explored in depth (PONCE 2009). The justifications for assigning the score values of the impact's magnitude and relevance are discussed in the EIA text. A symposium on the essential characteristics of the proposed action, including the associated ecology (PONCE 2009, IISD 2021).

2.3 URBIO Index

URBIO Index is a method for evaluating the sustainable design of green spaces and is meant to help various specialists and designers in creating green, sustainable infrastructure. It assesses the project's six thematic indicator groups (Planning, Materials, Amenity/Value, Biodiversity, Climate/Water/Soil, and Management), totalling 25 indicators. Each theme is presented on its own sheet, and the overall assessment is presented on a collective sheet facilitating park evaluations based on all areas of sustainability (MÜLLER 2016).

3 Proposed CWP Assessment Index

Urban sustainability indicators are developed to investigate the interconnections between environmental, economic, and social factors and their mutual impacts to assess the CWPs performance as a multifunctional sustainable landscape project. The suggested metrics are assessed for this purpose in connection to the National SDGs, the UN SDGs, and performance-based evaluation techniques for CW projects for wastewater treatment (LEE 2020, ROBATI et al. 2021). The developed new assessment tool is more suited to CWPs operations and activities. Including a diverse proposed tools to aid in the assessment of each criterion for providing practitioners a cohesive set of information and interpretation of the collected data for assessent and decision making.

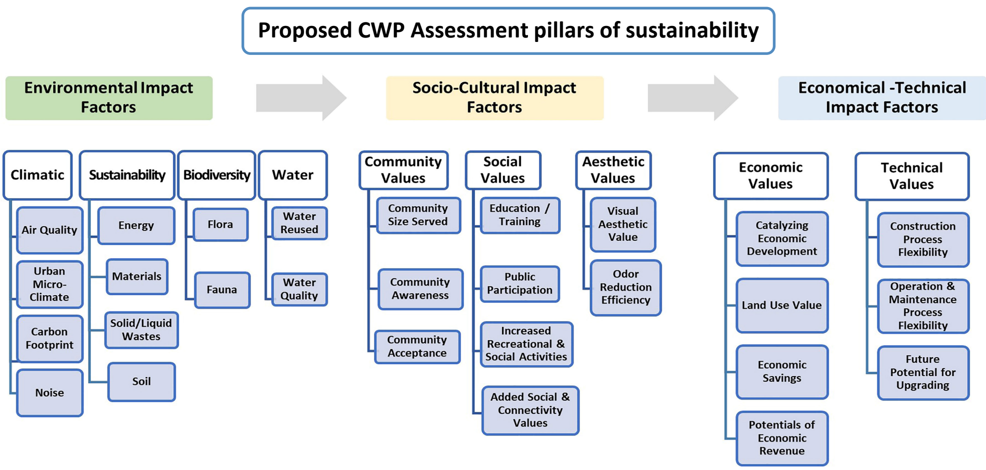


Fig. 1: CWP Sustainability pillars (Source: Author)

3.1 Proposed Framework

Existing methods in landscape design do not represent all aspects of sustainability, and owing to their complexity and problems in implementation, the proposed tool aims to provide a digital evaluation software that incorporates all aspects of sustainability and is reasonable and unexpensive, to aid landscapers and small local projects in improving sustainability internationally. The chosen strategy focuses on categorizing indications into criteria and sub-criteria. As a result, each relevant environmental component's effect factors would be assessed independently and given a score for Impact Magnitude and significance. In addition to the conventional Leopold matrix, new criteria of Probability and Duration were applied.

The proposed tool used the Leopold matrix technique, with the CW Parks' convenient activities added to the horizontal axis and the recommended environmental aspects added to the vertical axis. Each was then classified according to quantifiable parameters. To overcome the limits of the Leopold matrix, the Social Impact and Economical-Technical Factors were added, and each was further subcategorized with detailed factors. Based on relating suggested indicators to the two primary phases of the CW Parks' life cycle: construction and operation (LOHANI et al. 1997). Each was assigned a weight based on its lifespan. While the third phase, Demolition Phase, was omitted owing to its limited impact as it is thought to have no specific substantial actions other than water path backfilling (DAVIS 1995).

3.2 Validation Methodology and Criteria Weighting

Since CWP encompasses several distinct impacts and factors influencing sustainability, it necessitates the development of a distinctively designed CWP assessment tool capable of effectively targeting those various impacts while also accommodating the different projects in significance to their different concepts, types, conditions, and attributes. A quantitative approach is necessary to validate the outcomes of the suggested indicator categories. The study is based on a structured questionnaire, that assesses the applicability of the chosen indicators, with the involvement of specialists of related disciplines from all over the world. The suggested CWP Index is a simple and dedicated assessment tool that evaluates the major three areas of CWP sustainability performance, each according to its significance importance weight that define their respective relevance, based on the findings of the questionnaire.

3.3 Suggested Main Phases

Efficient EIA relies on detailed management of project concerns, their effects on key aspects, and a clear mitigation plan for impacts reduction. It correlates impacts with the project phases in which they occur; **construction**, and **operation**. This Tackling clearly reveals which project's components need mitigation measures through design adjustments and alignment of mitigation options with the project execution timeline (LOHANI et al. 1997).

Phases' weight Assessment to attain a rational indicative overall sustainability achievement of the CWP. Each of its two stages, construction and operation, was examined based on their effect weight in the CWP's life cycle. **Lifespan of CWP** is ruled by sewage pollution, capacity to filter and store pollutants, and waste accumulation. It has so far demonstrated a lifespan of more than 20 years with minimal efficiency loss. While the construction phase typically lasts 1 to 3 years on average, the operating phase might last 20-30 years (DAVIS 1995).

3.4 Suggested Main Categories of Impacts, Calculations and Outcomes

Environmental, social, and economic sustainability are the three primary pillars on which the suggested tool is based. The environmental factors are then divided into four major categories, which are the most important vital environmental aspects that can explain the impact of parks on the surrounding urban areas. Climatic, Sustainability, Biodiversity, and Water are the four factors that are evaluated quantitatively and descriptively. A 4-division cell represents a full assessment of each impact factor (IF). According to a scoring scheme, the assessor evaluates each impact's magnitude, significance, probability, and duration. The proposed Matrix will automatically calculate the Impact value relevance (IV), total Environmental Impact Value (EIV), Ratio of Impact Factor (R), and IV Weight Relevance Value (IVWR), as well as the percentage achieved for each factor. All are displayed in charts that compare the assessed CW Park's obtained score to the overall score that might be reached allowing for a better understanding of the CW Park's performance and thus assisting in decision making.

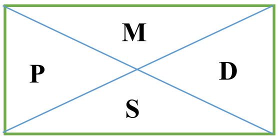


Fig. 2: Proposed Matrix Cell (Source: Author)
(M) Impact's Magnitude (on a scale from 0 to 5)
(S) Impact's Significance (on a scale from 0 to 5)
(P) Impact's Probability (on a scale from 0 to 5)
(D) Impact's Duration (on a scale 1 to 2)

Table 2: Scoring of impact's evaluation categories (Source: Author)

Score	Magnitude (M)	Significance (S)	Probability (P)	Duration (D)
0	Unobservable	No impact	Less than 5%	
1	Low effect	1 – 20%	5 – less than 25%	Short-term/Temporary
2	Tolerable effect	21 – 40%	25 – less than 50%	Long-term/Permanent
3	Medium high effect	41 – 60%	50 – less than 75%	
4	High effect	61 – 80%	75 – less than 100%	
5	Very high effect	81 –100%	100%	

Proposed CWPs Assessment Tool Outcome encompasses a comprehensive matrix, sustainability performance summary charts for overall park performance and for both construction and operation phases, a summary chart for sustainability categories assessment analysis, together with three detailed charts for each of the sustainability pillars. In the Matrix sheet, the assessor must simply provide the project name, location, and his personal evaluation score for both the construction and operation stages. Suggestions for various measuring methods and instruments are provided to assist the assessor in evaluating and assessing each impact.

4 Application of the CWP Index on a Project

As an initial test of the developed tool, the expected performance of a case study of CWP in an arid climate in Egypt was assessed using the proposed CWP Index to confirm the tool's effectiveness in assessing the positive impacts of CWP in achieving city sustainability.

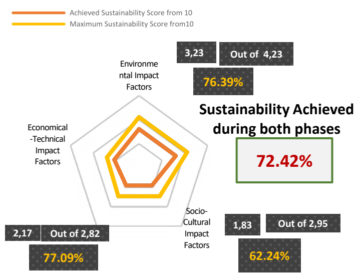
Table 3: Proposed CWP Index Matrix sample of Climatic Aspects Impacts (Source: Author)

Project Title:	**10th Ramadan CWP**
Project Type:	**Constructed Wetland Park**
Location:	**10th City, Cairo Governorate, Egypt, 30°20'17.9"N 31°47'19.2"E**
Climatic Zone:	**Arid Climate, BWh**
Hardiness Zone:	**10**
Asses. Author:	**xxxxxxxx**

Impacts / Activities			Project Activities											
			Construction Phase						**Operation Phase**					
Category		Impact Factors (IF)	Construction Phase Assess-ment	IV= Impact Value rel. S*M*P*D	**EIV**= Impact Factor Ratio **R= IV/EIV**	Weight	**IV Weight Relevance (IVWR)**	**Percentage Achieved**	Operation Phase Assess-ment	IV= Impact Value rel. S*M*P*D	**EIV**= Impact Factor Ratio **R= IV/EIV**	Weight	**IV Weight Relevance (IVWR)**	**Percentage Achieved**
Environmental Impact Factors	**Climatic Aspects**	**Air Quality**	2 / 5 / 2 / 5	100	0.0485	0.8	**0.038816**	40.00%	5 / 5 / 2 / 5	250	0.05	0.9	0.04505	100.00%
		Urban Micro-Climate	2 / 4 / 2 / 2	32	0.0155	0.7	**0.010869**	12.80%	5 / 5 / 2 / 5	250	0.05	0.9	0.04505	100.00%
		Carbon Foot-print	1 / 3 / 2 / 2	12	0.0058	0.7	**0.004**	4.80%	3 / 4 / 2 / 3	72	0.0144	0.8	0.01153	28.80%
		Noise	0 / 0 / 1 / 3	0	0	0.7	**0**	0.00%	3 / 2 / 2 / 1	12	0.0024	0.8	0.00192	4.80%

Project Title:	**10th Ramadan Constructed Wetland Park**
Project Type:	**Constructed Wetland Park**
Location:	**10th City, Cairo Governorate, Egypt, 30°20'17.9"N 31°47'19.2"E**

nr.	Category	Total Score	Max Score	**Sustaina-bility Weight**	**Sustainability** Achieved Sus. Score from 10	Max. Sust. Score from10	Percent Achieved
1	Environmental Impact Factors	**2064**	**2702**	0.4234	3.23	4.23	**76.39%**
2	Socio-Cultural Impact Factors	**1237**	**1988**	0.2947	1.83	2.95	**62.24%**
3	Economical -Technical Impact Factors	**1015**	**1317**	0.2819	2.17	2.82	**77.09%**
Total Impact Assessment				**1.00**	**7.24**	10	**72.42%**



nr.		Category	Category score	Max. Score	%	Phase Weight	Category Total Score	Max Score	**Percentage Achieved**
1	Environmental Impact Factors	Construction Phase	805	2375	33.89%	0.074	**2064**	**2702**	**76.39%**
2		Operation Phase	2003	2525	79.33%	0.926			
3	Socio-Cultural Impact Factors	Construction Phase	139	1850	7.52%	0.074	**1237**	1988	**62.24%**
4		Operation Phase	1226	1850	66.27%	0.926			
5	Economical -Technical Impact Factors	Construction Phase	716	1225	58.47%	0.074	**1015**	1317	**77.09%**
6		Operation Phase	961	1225	78.45%	0.926			
		Total Sustainability Achievement in Construction Phase							**33.05%**
		Total Sustainability Achievement in Operation Phase							**75.24%**

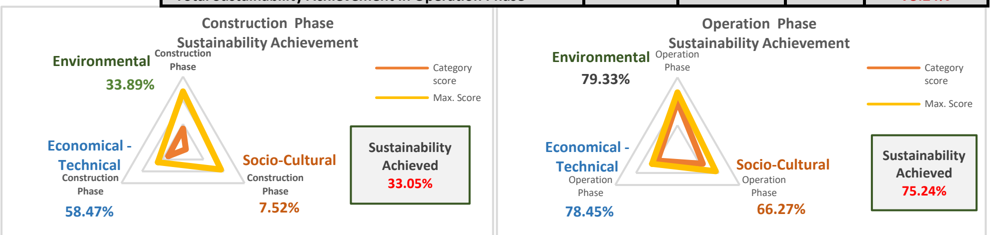


Fig. 3: Sustainability analysis and Categories Performance Charts (Source: Author)

			Construction Phase						Construction Phase					
nr		Category	Case study score	Max. Score	%	Category Total Score	Max Score	Percentage Achieved	Case study score	Max. Score	%	Category Total Score	Max Score	Percentage Achieved
1	nvironmenta l Impact	Climatic Aspects	111	725	15.3	805	2375	33.89%	517	850	60.8	2003	2525	79.33%
2		Sustainability	508	775	65.5				696	800	87			
3		Biodiversity	186	425	43.8				385	425	90.6			
4		Water	0	450	0				405	450	90			
5	ocio-Cultura Impact	Community Values	80	600	13	139	1850	7.52%	251	600	42	1226	1850	66.27%
6		Social Values	56	825	7				630	825	76			
7		Aesthetic Values	4	425	1				345	425	81			
8	Econo mical -	Economic Values	291	800	36	716	1225	58.47%	536	800	67	961	1225	78.45%
9		Technical Values	425	425	100				425	425	100			
Total Impact Assessment						1660	5450	30.46%				4190	5600	74.83%

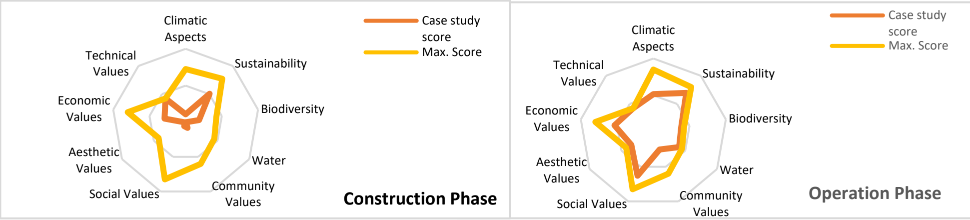


Fig. 4: Wetland Park's Categories performance analysis (Source: Author)

5 Conclusion, Challenges and Recommendations

The proposed tool allows rigorous analysis of CWP's entire sustainability performance as well as during construction and operating phases. The assessment is simplified over quantitative matrix and simple visual charts for a better review and assessment of opportunities for development, as well as identify environmental weaknesses and strengths. It simplifies the evaluation of the CWP performance to achieve an optimal and feasible project that improves social, economic, and environmental aspects of a sustainable city. It could be used to examine predicted sustainability performance aiding in the management of both existing CWPs and plan and design of future CWP projects. The suggested tool evaluates each effect based on its important weight while measuring the park's overall sustainability performance based on the relevant value of the project's phases' sustainability success. To avoid having an oversimplified and hypothetical attribute rather than a coherent picture, the tool should be improved to consider the cross-interaction of the sustainability factors across categories. It is recommended that the introduced matrix be tested in a variety of test cases for potential adjustments and improvements. The proposed assessment matrix and charts are alleged to be a strong assessment tool, making the proposed CWP Assessment Index user-friendly and easy to grasp for users of all levels, and serve as a summary of the project's impact assessment reports for early project appraisal and assessment of improvements prospects as well as identification of environmental impacts' strengths and weaknesses for later application of appropriate mitigation measures using a set of quantitative matrices and simple visual charts. To pave the path for a new, digitized sustainable landscape era, this paper recommends that the proposed tool be further developed as a digital software, automated and shared as a globe app to allow for comparison of global park performance.

Bibliography

BABU, S. (2017), Matrices in Environmental Impact Assessment 2, Eco-intelligent™. https://eco-intelligent.com/2017/03/20/matrices-in-environmental-impact-assessment-2/#modified-graded-matrix (22.09.2021).

DAVIS, L. (1995), A Handbook of Constructed Wetlands, for the USDA-Natural Resources Conservation Service and the US Environmental Protection, Agency-Region III. epa.gov/sites/default/files/2015-10/documents/constructed-wetlands-handbook.pdf.

ELMELIGY, A. (2022), Environmental Impact of Constructed Wetland Parks towards achieving Sustainability, Case Study Wetland Park, 10th Ramadan City, Egypt, Anhalt University, Germany. doi:10.25673/86447, researchgate.net/publication/362698426.

FIGUEIREDO, R., SANTOS, V. & RAMOS, J. (2020), Turbining the Leopold Matrix. International Journal of Advanced Engineering Research and Science, 7 (7), 492-505.

IISD (2021), International Institute for sustainable development, The 7 Steps to EIA, Canada. https://www.iisd.org/learning/eia/eia-7-steps/step-3-impact-assessment-and-mitigation/ (07.02.2023).

JOSIMOVIĆ, B., PETRIC, J. & MILIJIC, S. (2014), The Use of the Leopold Matrix in Carrying Out the EIA for Wind Farms in Serbia, Energy and Environment Research 4 (1). doi:10.5539/eer.v4n1p43.

LEE, H.-S., EUN-YEONG, P., et al. (2020), Developing a Landscape Sustainability Assessment Model Using an Analytic Hierarchy Process in Korea, Sustainability 12 (1). doi:10.3390/su12010301.

LOHANI, B., EVANS, J., LUDWIG, H. et al. (1997), Environmental Impact Assessment for Developing Countries in Asia. 1, 356.

MARTIM, H. et al. (2013), Evaluation of Environmental Impacts in Copper Mining Companies Using Interaction Networks, Electronic Magazine in Management, Education and Environmental Technology – REGET. doi: 10.5902/2236117010382.

MORAES, C. & AQUINO, C. (2016), Environmental Impact Assessment: A Systematic Review from Methodological Perspective. 5th Symposium on Scientific and Technological Integration of Southern Santa Catarina – SICT-Sul. doi:10.18607/ES201876616.

MÜLLER, N. & ELSNER, K. (2016), Proceedings URBIO Index Workshop, University of Applied Sciences Erfurt, Department Landscape Management and restoration Ecology, Germany.

PONCE, V. (2009), The Leopold Matrix for Evaluating Environmental Impact. http://ponce.sdsu.edu/the_leopold_matrix.html (22.09.2021).

ROBATI, M. & Rezaei, F. (2021), Evaluation and ranking of urban sustainability based on sustainability assessment by fuzzy evaluation model, International Journal of Environmental Science and Technology. doi:10.1007/s13762-021-03128-1.

SACHS, J., KROLL, C., LAFORTUNE, G. et al. (2021), SDR 2021, Sustainable Development Report the Decade of Action for SDGs. University Press, Cambridge, United Kingdom. doi:10.1017/9781009106559.

ZAKARIA, Y., ELGENDY, A. & ELHAGGAR, S. (2021), Sustainability Assessment for Wastewater Treatment Systems-Case Studies in Egypt. Journal of Environmental Protection, 12, 90-105. doi:10.4236/jep.2021.122007.