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Development of an automated optimizer for sustainable urban landscape design

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ABSTRACT

Current practice in selecting plants in the field of landscape design is based largely on aesthetic criteria, rather than cost and water consumption needs. This typically results in a design that neither minimizes the Life Cycle Cost (LCC) to the fullest nor optimizes the sustainability of water resources. This paper presents an Automated Optimizer for Sustainable Urban Landscape design (SEOUL) that supports landscape architects in overcoming the drawbacks of current practice. It consists of a database module that includes the list of plants from which the tool makes its selection, as well as an optimization model that uses dynamic programming to optimize the plant selection through minimizing initial cost and water needs. SEOUL is applied on selected case study projects in Egypt to demonstrate the functionality. It was validated by comparing SEOUL's results to those received from current practice through three actual projects. The results obtained shows a 44% and 33% savings in initial cost and water consumption respectively when using SEOUL versus traditional landscape design tools. In addition, the application's ergonomics was evaluated for ease of use, simplicity and efficiency for the end-users.

1. Introduction

Urban landscaping plays an essential role in driving the real estate market forward. With the real estate industry reaching a volume of US $ 241 billion in the Americas, US $ 195 billion in the EMERA and US$ 127 billion in Asia Pacific [10], the industry is a driving factor of the global economy. The Egyptian real estate and construction industries present similar trends, with the construction industry constituting approximately 7% of the Gross Domestic Product (GDP) [22]. Urban landscaping constitutes 3.5% of real estate investment in Egypt, with an average investment of EGP 1.3 billion per year [5], illustrating the importance of landscaping to the national and global economies.

Landscape design that reduces water consumption is vital for Egypt. According to UNICEF and WHO [33], 884 million inhabitants currently suffer from lack of safe drinking water. Furthermore, the United Nations Environment Programme [32] states that Egypt is expected to reach a level of water scarcity by the year 2025 with per capita rate of 1000 m^3/person/year. Hence, according to Rohwer et al. [28] irrigation in Egypt presents high inefficiency, resulting in wasting a high percentage of the scarcely available water.

Accordingly, developing a tool that minimizes water consumption while optimizing project Life Cycle Cost (LCC), and considering the designer's aesthetic requirements would be of great benefit both at the resource and practice levels. The main objective of this study is to develop a landscape design tool that assists landscape architects in their plant selection. This tool should consider the project water consumption requirements while optimizing the project LCC. Furthermore, the landscape architect's design concept and aesthetic requirements should be accounted for.

2. Literature review

2.1. Current practice design process

At present, new automated tools are introduced to help architects, landscape designers and planners in analyzing and communicating their designs. The majority of the available tools focus on the aesthetics and the visual aspects of landscape design while underemphasizing other influential factors such as cost and water conservation. As the world resources become scarce, these factors gain importance, resulting in an ever growing need to introduce tools that account for the environmental and sustainable facets of design. Looking into recent

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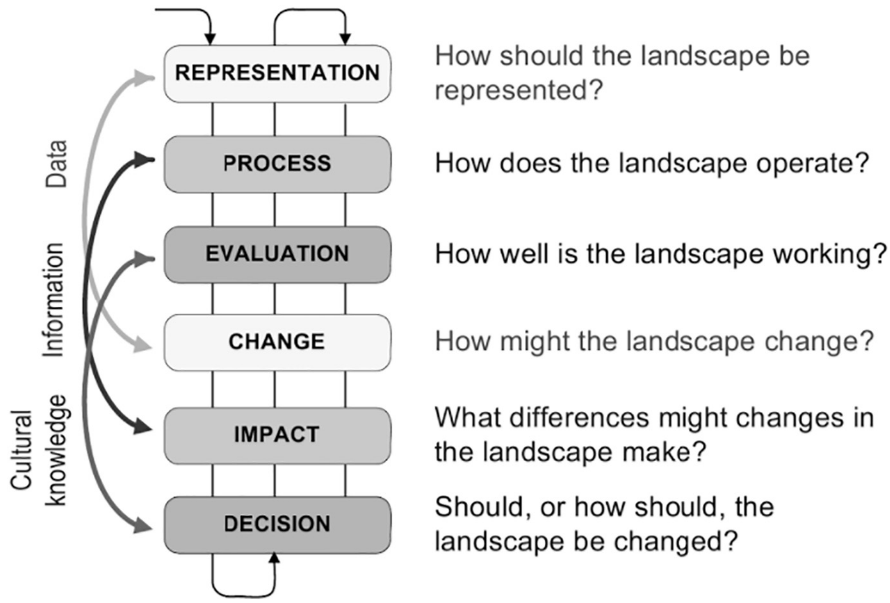

Fig. 1. Landscape Decision Framework Steinitz [30].

studies and literature it can be realized that within the current practice there is an emerging need to integrate both the conceptual and representational aspect of the design within automated tools that will facilitate and allow designers and architects to achieve a universal approach to landscape design while also optimizing cost and fulfilling water efficiency.

It is important to initially define the "current practice" of landscape architecture in order to identify its shortcomings and recognize room for improvements. Several sources cite the current practice such as Steinitz [30] that believes there is a strong similarity in the process and framework undertaken by landscape designers in current practice. Fig. 1 highlights a "Landscape Decision Framework" that Steinitz [30] concluded and is shared among designers. The interrelationships and sequence of tasks shown in this framework also form an important basis for improving existing landscape design solutions and gaps in current practice. Accordingly, this research improve and further identify shortcomings with the current practice.

Filor [6] further highlights the lack of certainty in the outcome of the design process, where an experiment was conducted in which a number of landscape architects were asked to provide their design solutions for the same project. Nonetheless, while the landscape architects were given the same design briefs, each provided a different design solution. This highlights the importance of the designer's vision in the outcome of the design solution, and the lack of defined design criteria. If design were solely based on a set of rules that governed the design process, eradicating the designer's vision from the process, then one should expect that a single solution is reached for all designers, given the same design brief. Nonetheless, in the event that a lack of such rules is evident, and a greater weight is given to the designer's own vision then one should expect that multiple solutions are reach between the designers. Accordingly, such an experiment highlights an important aspect of the current practice, in which the designer's vision and perception plays an important role in the design process and its outcome.

Additionally, Lawson [17] offers an insight into the industry's current practice through defining design as a process, where the route between the problem and its solution is mapped. His research highlights that design is an amalgamation built on conversation and perception, where each members of the design team share their expertise with one another in order to form the design solution. The use of "perception" in defining the design process is key in understanding the shortcoming of the current practice. Since design is based on perception then it will differ between each designer, thus creating a process that lacks a structured framework and whose outcome lacks certainty.

Furthermore, Jienan [15] used three case study in China in order to present shortcoming associated with current landscape design practice. The study concluded that there is a lack of energy and resource conservation techniques in current design practice, as well as lack of consideration for project Life Cycle Cost.

2.2. Urban landscape water conservation

With the ever growing scarcity of water there is an essential need for conservation. Landscape irrigation compromises (40–70%) of the household water use, thus reducing landscape water demand should be a primary focus on water conservation [11]. While, as previously stated, water consumption has mostly been underemphasized as a factor in landscape design, a number of studies have recently been undertaken with the aim of reducing water demands of landscape design solutions. Few tools among other landscape water consumption calculators have been created with this aim. The earliest generation of calculators was created by Al-Kofahi et al. [1] for residential urban landscape designs in Albuquerque, New Mexico. The study provides a web-based interface that enables users to input the project's zip-code in Albuquerque, while defining the plant types, including a limited number of plant species, to be vegetated along with their areas. Based on these inputs the calculator provides the overall water consumption for the design solution.

The second water consumption calculator was developed by the United States Green Building Council [34], as part of their Leadership in Energy and Environmental Design (LEED) certification in promoting sustainable design [34]. In the LEED "Water and Atmosphere" category the intent of the credit is to promote the elimination of invasive species and reduction of water consumption and synthetic chemicals. In order to reduce water consumption, LEED offers users the "*Outdoor Water Use Reduction Calculator*" [34], a calculator used for computing and monitoring outdoor water usage. This calculator can aid designers in assessing the water consumption of their designs, thus enabling them to make necessary changes if their design solution results in exceeding the desired available water budget. Nonetheless, the tool enables users to define a limited number of plant types (Trees, Shrubs, Groundcover and Turf grass), with no possibility of defining individual species of plants within each type. Moreover, the water consumption of each plant type