# A Sustainable Environmental Optimizer for Urban Landscape Design (SEOUL)

**Ossama Hosny, Khaled A. Nassar, Elkhayam M. Dorra, Ayman Ibrahim, Michael Azer, Naglaa El Khoreiby and Zina Adly**
Department of Construction Engineering
American University in Cairo
New Cairo, 11835 Cairo, Egypt
ohosny@aucegypt.edu

**Sherif Zahran**
Smartwave Technologies
Al-Moqattam, Cairo, Egypt
s.zahran@smartwave.com.eg

## Abstract

Plant selection is an important element in landscaping planning and design. Based on previously conducted research it is reported that 44-50 percent savings in landscape annual operating costs can be made when applying optimization techniques in the selection of plant types. Nonetheless, a lack in the existence of optimization tools that minimize operating and replacement costs has hampered achieving such savings. Current practice is characterized by landscape architects making their plant selection based on their individual judgment and past experience with aesthetics playing a vital role in such decisions. This paper describes the framework for a Sustainable Environmental Friendly Optimizer for Urban Landscaping (SEOUL) that is capable of supporting architects in delivering landscape designs that are both aesthetically pleasing while being cost effective and environmentally friendly. The system creates such a selection based on inputs provided by the landscape designers of preset fields in a web-based platform to reflect their design intent. These fields have been chosen based on field research with architects, suppliers and contractors. These fields include: Plant Classification, Plants Type, Spread, Life Cycle, Height, Root, Salt Tolerance, Draught Tolerance, Bloom Season, Base Color, Flower Color and Fruit Color. Such inputs by the user are then processed through an optimizer and plant database in order to provide the most appropriate plant selection. The optimizer has been built using a knapsack dynamic programming model; this allows for the rapid solving of the multi-objective problem to reach a set of plants that minimize the cost, as well as the water consumption. Furthermore, testing of the application was conducted to ensure that the application meets its value added objectives.

**Keywords**
Landscape, Optimization, Water Demand, Life Cycle Cost, Sustainability.

## 1. Overview

Landscape design plays an important role in the real estate industry, with landscape accounting for 3.5 % of real estate investment in Egypt accounting for EGP 1.3 billion per year with a respective equivalent annual operating expenditure of approximately the same value (Fayad, 2014).

Moreover, the real estate industry is an important pillar in driving the global economy. In the year 2012 real estate volume reached US$ 241 billion in the Americas, US$ 195 billion in the EMEA and US$ 127 billion in Asia Pacific (Gordon and Strategist, 2014), while reaching US$ 5 billion in Egypt in the same year (GAFI, 2013).

Moreover, it is reported that Egypt is expected to reach a level of water scarcity by the year 2025, with 1000 m3/person/year per capita availability (UNEP, 1999). With average annual irrigation water consumption for urban landscaping currently reaching an estimate 820 million cubic meters, it is vital to minimize such consumption to deal with the expected water scarcity.

Thus, preserving natural resources is essential for sustaining the environment. Moreover, the reduction of costs has ease the financial burdens on all governments, companies and conscious individuals.

## 2. Literature Review

Designing urban landscaping that minimizes both cost and water consumption is a challenging topic that has yet to be fully addressed. With the ever increasing competition that exists in the real estate industry, ever party is seeking a competitive edge to edge ahead of its competitors. Moreover, with urban landscaping representing a major component of lifecycle cost, especially in large scale mixed use real estate projects and gated communities, it is essential to track the running costs of such designs, in order for such projects to transfer such costs onto the residents or end users. The landscape architect is expected is expected by their clients to select their plants to ensure a rich attractiveness, sustainability, attractiveness over the project's life, and reduction in water consumption.

Moreover, since different plants behave differently throughout their lifetimes, plant selection needs to be conducted in a dynamic manner to account for such changes. Thus landscape architects need also to select possible plant types when it is required to replace plants that have deteriorated. Selections that are performed in a periodic fashion enable landscape architect to select the adequate plant type, while at the same time meeting a number of additional requirements.

Nonetheless, as stated research in minimizing urban landscape lifecycle cost including initial cost, operating costs and water consumption has been lacking. Roberts et al. (2010) presented a study that provides optimum ecological design using an Evolutionary Multi-objective Optimization methodology for generating estimates of the Pareto optimal set of designs for an evolving landscape in the rural urban fringe of a major metropolitan area. Nonetheless, such work did not consider lifecycle cost in such an optimization model.

Furthermore, Jienan (2009) considered three dimensions that landscape designers should consider in their design:

1) Similarity in design and lack of own characteristics while designing residential landscape,
2) Lack of functions in the design of residential area, and
3) Energy consumption and lack of conservation techniques, e.g. solar and wind energy.

Nonetheless, these dimensions failed to consider plantation lifecycle cost, which is an essential element in the calculation of lifecycle cost.

Additional research has been conducted by Brunckhorst et al. (2006) in prioritizing the management of natural resources within different research. Such research presented three main principles in such prioritization:

1) Resource management within the regions should reflect the perception of local resident communities
2) Selecting a relatively homogeneous set of landscapes within similar climate
3) Ecological and geophysical characteristics.

Similarly, this study did not address sustainability of available resources e.g. irrigation water or lifecycle operation and maintenance cost as a criteria within urban landscape designs.

Moreover, commercially available packages exist to aid both landscape architects and homeowners in selecting their plants based on certain regions and climate conditions. Such packages are capable of presenting both a selected list of plants as well as visualization of such results in a two dimensional manner. Nonetheless, these packages provide such outputs without accounting for cost not water consumption in their formulation.

SULIS development at the Department of Horticultural Science at the University of Minnesota, aims at providing sustainable landscape information to the public. Such information enables homeowners, business owners, and related industry create urban landscaping that is functional, maintainable, environmentally sound, cost effective and aesthetically pleasing (UOMinn, 2014).

Additional software including CAD Pro (2014) and SmartDraw (2014) provide tools that enable end users to quickly visualize landscape design. This aids in the decision making process however is solely based on aesthetic evaluation of the design. On the other hands, the Department of Horticulture and Crop Science, Ohio State University developed software for static selection of plant type, however this does not provide real time dynamic visualization (OSU, 2014).

Fayad (2014) developed the **Sustainable Landscape Optimization Model** (**SLOM**), a proof of concept plant selection model that uses Artificial Intelligence (AI) as an optimization tool in order to reach optimal plant selections through minimizing of cost and irrigation water consumption. This model utilized a plant database collected from Egypt that takes into account lifecycle cost, capital and operating cost, and plant type mix design.

## 3. Research Objectives

This study aims to provide an optimization framework that overcomes the shortcoming of current practice by providing plant selection solutions that are aesthetically attractive, while minimizing cost and being environmentally friendly. This is achieved through the SEOUL's integrated framework that in order to provide the optimal plant selections through reduction of cost and water consumption. The remaining sections of this study aim to describe each of the model's framework as presented in Figure 1.

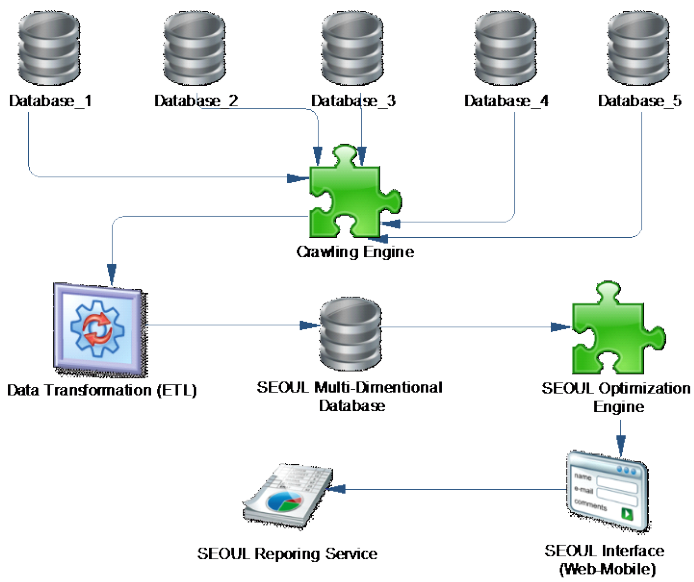



Figure 1 SEOUL integrated framework

## 4. Survey of Plants' Data

### 4.1 Research of Plant Data

In order to create a comprehensive database of plants field and literature research was conducted:

- Literature research was conducted to classify plants and identify fields upon which each of these plants can be filtered in a database. Such research was conducted through surveying of existing databases in Egypt and globally
- Field research was conducted in order to understand industry practice, through meeting with suppliers, architects and contractors.

By integrating each these sources of research, the SEOUL database was formulated. This formulation described the geographic plant classification, the attributes from which plants can be describes and the means from which such information can be collected.

Two main sources of literature were found available in the Egyptian market:

1. The plants Encyclopedia of Egypt (2009) published by the Red Sea Sustainable Tourism Initiative
2. A planting glossary of the Al-Azhar Park in Cairo (2003)

While the former presented a number of plants including descriptive information and cultivation information regarding each plant, the latter provided more in depth information and a large array of plants (palms, trees, shrubs…etc.), with related plant information available in a structural fashion. Moreover, the planting glossary provided design usage including irrigation requirements and dimensional features of each plant.

Moreover, online databases were used to provide plant information, some of the database surveyed included Online Plant Guide, Plant Encyclopedia, The Woody Plants Database and Florida Friendly Plant Database. The purpose of these databases was to provide additional plant information that is needed for the optimization model yet was not available in the two sources of literature previously stated. These online sources were used as a secondary reference for additional data collection purposes.

Moreover, to further validate and complement the results of the literature research, field research was conducted. By interviewing experts in the field with extensive experience in landscape design additional information was recovered. Such research was conducted through personal meetings, conference calls and a series of market surveys. **Table 1** presents the attributed that are depicted in the database based on the research conducted.

Table 1 : Selected attributes in surveyed databases

| | DB (3) | DB (4) | DB (5) | DB (6) | DB- (7) | DB (8) | DB (9) | DB (10) | DB (11) |
|---|---|---|---|---|---|---|---|---|---|
| Classification | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Type | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Genus | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Species | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Latin Name | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Common Name | Y | N | Y | Y | N | Y | Y | Y | Y |
| Arabic Name | Y | N | N | N | N | N | N | N | N |
| Dimensions | Y | N | Y | Y | N | Y | Y | Y | Y |
| Bloom Season | Y | N | Y | Y | N | Y | N | Y | N |
| Design Usage | N | N | N | Y | N | Y | N | N | N |
| Life Cycle | N | N | N | N | N | N | N | Y | N |
| Light | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Salt Tolerance | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Drought Tolerance | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Irrigation/Water Demand | Y | N | N | N | N | Y | Y | Y | Y |
| Cost | N | N | N | N | N | N | N | N | N |
| Maintenance | N | N | N | N | N | N | N | N | N |
| Hardiness Zone | N | N | Y | N | Y | Y | Y | N | N |
| Environmental Concerns | N | N | N | Y | N | N | N | N | N |
| Totals | 13 | 8 | 12 | 13 | 9 | 14 | 12 | 13 | 11 |

4.2 Automation of Plant Information Entry

While the information regarding the plants was found through literature and field research and inputted manually, a platform will be created to enable suppliers to enter their information on the web-based application in an automated fashion.

SEOUL can offer suppliers a platform on which they are able to login through supplier credentials and post information related to the plants available to them, including cost and water requirements. This creates a means to gather information in an automated fashion, where suppliers are approaching SEOUL to post and update their plant information rather than SEOUL contacting suppliers for updated information. This is highly advantageous in an era where cost is at a constant change, thus eliminating the operational cost associated with updating the information manually on a daily basis.

## 5. Plant selection: An Optimization problem

Landscape design can be formulated as an optimization problem in which the designer is required to select a limited number of plants from a large number of available plants, such that the plants satisfy his design intent through the selection of design requirements (e.g. height, bloom season, color, shading, spread, etc…) while optimization the collective selection by minimizing lifecycle cost and water consumption. Initially the landscape designer should decide upon his design intent and requirement, i.e. using evergreen trees, palms and hedge shrubs in three different location in the project. While the designer has decided that these are the plant classifications he wishes two use, as well as the location of these plants he has not selected the exact type of evergreen tree, palm or hedge shrub. Furthermore, the designer requires a certain quantity of each classification, i.e. 10 palm trees, 3 evergreen trees and 5 m run of shrubs. Thus, what is required is the exact type of plant in each classification, i.e. for palms whether to use Queen Palms, Data Palms or Bismarck Palm (these are three types of palm tree), same for evergreen trees and shrubs. Making such a selection manually from a tabulated database can be cumbersome and will not account for cost and water demands.

Moreover, for each type of plant the designer wishes to base his selection based on design requirements and conditions, i.e. height, flower color, spread bloom season for the plant. In such an event height and spread will be provided in numeric form, while flower color and bloom season are provided in textual form. If such criteria are used to filter through the available plant database, a list of plants will be provided that meet the required design criteria.

Nonetheless, such a process needs to also address lifecycle cost. Lifecycle cost includes initial cost, operation and maintenance cost. By accounting for lifecycle cost, the application is able to provide better information that improves the decision making process. In addition to lifecycle cost, water consumption also needs to be taken into account. In dry climate such as that in Egypt where water resources are limited such a criteria becomes vitality important in the decision making process.

Accordingly, by formulating the urban landscape problem as an optimization problem in which the exact plant selection i.e. Queen Palms, Data Palms or Bismarck Palm is chosen based on satisfying the design intent requirements (bloom season, height, spread, flower color…etc.) as well as minimizing cost and water consumption. Since the goal is to minimize two variables, thus the problem becomes a multiple objective optimization problem. In order to solve such a multiple objective problem the designer needs to evaluate the importance of each of the objectives are versus one another. If both objectives are equally important then a 50% weight is assigned to each. Nonetheless, if water is extremely scarce and is said to be 3 times more important than initial cost, thus a 75% weight will be provided for water requirements, with the remaining 25% for initial cost. To be able to accurately reflect each of the variables the values of each variable will be normalized to account for the difference in magnitude (one variable might be in the thousands, while another in the tens). Additional methods exist that eliminate the needs to assign weights to each of the variables, e.g. Pareto optimality, which will be further discussed in this study.

While the initial cost and water requirements of each design scenario that satisfy the design intent requirements (bloom season, spread, height, flower color…etc.) can be calculated, it is important to assess which of these scenarios satisfy the cost and water constraints. For example if a landscape designer wants to ensure that the water consumption through their project falls below a certain volume, then the solution includes a subset of the solution that satisfies the design intent requirements. Moreover, if initial cost is also assigned as a constraint, then the design scenarios will also be a subset of the solution that satisfies the design intent requirements. This becomes more mathematically extensive, especially when the plant database becomes large, thus must be formulated in an efficient manner. The following sections highlight how knapsack dynamic programming can be used to provide such an efficient process.

## 6. Mathematical Formulation

It is vitally important that the application and its imbedded formulation are capable of reflecting the design intent of the landscape designers. This achieved through the designer specifying certain fields that are capable of reflecting such intent (e.g. bloom season, height, spread, flower color…etc.). Thus initially the problem begins with a flat database that includes all plants, with all their respective fields. One of such fields is the plant type (palms, trees, shrubs…etc.), which the user needs to initially determine. Thus, if $k$ ($k$=1, 2, 3…$M$) are the different plant types of which $M$ types exist, and the user wishes to choose a particular plant $i$ of type $k$, then then this will be notated as $i_k$. Furthermore, within each type of plant $k$ exists a number of plants, i.e. if the designer is interested in selecting a Shrub which is a type of plant denoted by $k$=2, moreover, if 100 types of shrubs exist in the database, then $N_2$=100, therefore the total number of plants in the database $T$ can be said to be $T=\sum_{k=1}^{M} N_k$.

Moreover, the design intent fields that reflect the landscape designer's aesthetic and designer requirements are denoted by $P$ ($P$1, $P$2, $P$3...etc.), thus if Height=$P$1, and the designer requires a shrub that is over 50 cm in height by less than 100 cm, then the P1 is submit to the constraint P > 50 and P < 100.

Thus given the $k$ types of plants available, the designer must specify the quantity $Q$ desired for the $k$ types of $M$ types, denoted by $Q_k$. Based on such formulation the objective problem becomes attempting to minimize the cost $C_{ik}$ and water consumption $W_{ik}$ for the $T$ total plants available.

Since a particular plant type $i_k$ from the database can either be selected or not, then this becomes a binary variable denoted by $B_{ik}$. Thus the total cost $C_{ik}$ and water consumption $W_{ik}$ for the $T$ total plants available will change depending on which plants are selected and which plants are not, thus providing different possible selection scenarios from which the application needs to optimize.

Since cost and water consumption priority vary between each region and project within each region, each of the variables are given a weight $A$ and $B$ (where A+B=1) respectively. Thus, once the subset of possible plant selections scenarios that satisfy design intent through the defined field constraint, the problem becomes a multi-objective optimization problem in which cost and water consumption are minimizing based on the provided weights $A$ and $B$, as presented in **Equation 1**.

**Equation 1: Mathematical Formulation**

$$\min\left[\sum_{k=1}^{K}\left(A(C_{i_k}\times B_{i_k}\times Q_k)+B(W_{i_k}\times B_{i_k}\times Q_k)\right)\right] \quad (1)$$

Subject to

$P1_{i_k} \leq$ Upper Limit P1 …….(e.g. for k = 1,2,…..)

$P1_{i_k} \geq$ Lower Limit P1 …….(e.g. for k = 1,2,…..)

$P2_{i_k} \geq$ Upper Limit P2 …….(e.g. for k )

$P3_{i_k}$= Set Value P3, etc.

$B_{i_k} = \{0,1\}$

Where:

- $i_k$ denotes the chosen set of plants
- $B_{i_k}$ a binary variable indicating whether plant $i_k$ is selected or not
- $Q_k$ denotes the quantity of the plant
- $C_{i_k}$ denotes the life-cycle cost of the plant
- $W_{i_k}$ denotes the water consumption of the plant
- $A$ denotes the preference weight allocated for the life cycle cost
- $B$ denotes the preference weight allocated for the water consumption
- $P1_{i_k}$, $P2_{i_k}$, $P3_{i_k}$ ....the value of criteria P1, P2, P3, … for plant $i_k$

## 7. Selection of plants through filteration

The simplest form for the problem of selecting the plants is to choose from each type the exact plant type to minimize the cost and water consumption while meeting certain criteria. It is clear that equation 1 can be written as a linear sum of both terms, i.e. the minimum value for both terms is the minimal for each term separately. Also, the quantity term, $Q_k$ can be factored out of the equation.

## 8. Solutions of Dynamic programming

8.1. Mathematical Formulation as a Knapsack Problem

With cost and water consumptions for each plants available, the problem can thus be formulated as a classical knapsack problem in which plants from the database are selected that satisfy a knapsack of a certain capacity, i.e. satisfy the maximum allowable water consumption, in order to minimize the total cost of the knapsack. Moreover, the problem can be reversely formulated, with water consumption being minimized given a maximum allowable cost.

Thus, the subset selection scenarios for each plant $i_k$ available from the $T$ plants must satisfy the knapsack problem. Thus, the scenarios must provide the minimum cost given a maximum allowable water consumption, or the minimum water consumption given a maximum allowable cost. Moreover, a denoted by the binary variable $B_{ik}$, you cannot select part of a plant, the plant is either completed selected or not selected (0-1 property).

If a maximum allowable water consumption is provided, then the selection solution subset must satisfy all the design intent field constraints (e.g. bloom season, height, spread, flower color…etc.) As well as being less than or equal to the maximum allowable water consumption. Given such a subset, the optimal solution would be the scenario that provides the minimum cost from such a subset.

To consider all the possible subsets, two cases are possible the item is:

1. Included in the optimal subset
2. Not included in the optimal set.

The optimal solution to the problem from the selection of the $T$ plants is the minimum of the following two cases:

1. The minimum value obtained by n-1 plants and the allowable water consumption (excluding nth item).
2. The minimum cost value of nth plant plus the minimum cost value obtained by n-1 plants and meeting the allowable water consumption minus water consumption of the nth plant (including nth plant).

In the event that water consumption of the nth plant is greater than W, then only the first case is considered. Thus, such a formulation can be implemented in using an iterative recursive algorithm that uses Dynamic Programming.

By breaking down a complex problem into a set of simpler sub-problems, dynamic programming is able to solve such sub-problems and store their respective solutions. Moreover, once previously stored solutions to sub-problem are stored the algorithm will examine such solutions and combine them in order to provide the optimal solution to the problem.

8.2. Goal Programming Formulation

In the event that the landscape designer is unable to provide a maximum allowable cost or water consumption, then an alternative approach needs to be undertaken. One such approach is goal programming in which a single objective function of minimizing both cost and water consumption is required. This is done according to the following (Figure 1):

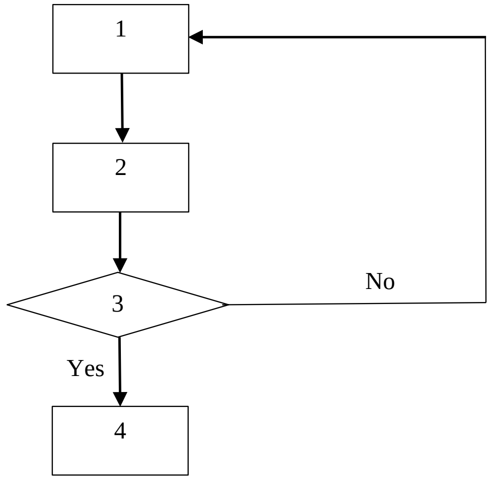



Figure 2 Goal Programming process

Where each step is defined as:

1. Run single objective optimization function for Life Cycle Costs considering all required design requirements/constraints. Determine minimum possible LCC (LCCmin).
2. Run single objective optimization function for Water Consumption considering all required design requirements/constraints. Determine minimum possible Water Consumption (WCmin).
3. Are all objectives set?
4. Formulate as goal programming problem.
   a. Calculate positive LCC deviation as the % of deviation from LCC goal:
   $$dLCC = (LCC – LCCmin)/ LCCmin$$
   b. Calculate positive Water Consumption deviation as the % of deviation from WC goal:
   $$dWC = (WC - WCmin)/WCmin$$
   c. Find the optimal design solution that minimizes the weighted deviation from goals:
   $$Z= w1* d LCC + w2*dWC$$

Where: w1 and w2 are the weights for LCC and Water Consumption respectively.

8.3. Case Study

The case study shown in **Table 2** is used to explain the mathematical formulation. This case study uses a generic database composed of 10 plants. For each of the 10 plants, the cost and water consumption is presented, as well as attributes that describe each plant physically. In this database the types of plants that exist are Palms, Shrubs and Trees, thus since three types exist then $M$=3, with palms $k$=1, shrubs k=2, and trees $k$=3. Moreover, there are three types of palms, thus $N_1$=3, three types of shrubs thus $N_2$=3 and finally four types of trees thus $N_3$=4, giving a total of 10 plants.

Thus using this database the landscape design is asked to undertake the design of a villa located in New Cairo Egypt. The project is to be built on a landscape area of 800 $m^2$, in hardiness zone, Cairo, Egypt (18-19). In order to ensure that the landscape design reflects the intent of the landscape design the designer sets the following constraints:

- 20% Trees, Height: 3 meters, Bloom Season: Spring
- 20% Palm Trees, Height: 3 meters, Bloom Season: Winter
- 60% Shrubs, Height: 1 meters, Bloom Season: Summer

Moreover, the client specifies that water is four times more important than cost, thus the following cost and water weights are used.

- Water consumption: 80% weight
- Cost: 20% weight
- Water price (per Liter): 0.78 EGP/Liter

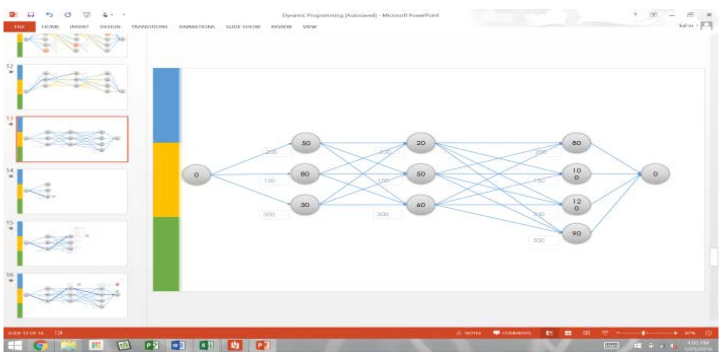
Table 2 : plant database case study

| Plant Number | Variables | Cost | Water Consumption | Height Criteria Lower Limit | Height Criteria Upper Limit | Bloom Season Criteria |
|---|---|---|---|---|---|---|
| Palm 1 | 0 | 50 | 200 | 2 | 3 | Sum |
| Palm 2 | 1 | 80 | 150 | 3 | 4 | Win |
| Palm 3 | 0 | 30 | 300 | 4 | 4 | Fall |
| Shrub 1 | 1 | 20 | 200 | 1 | 1 | Fall |
| Shrub 2 | 0 | 50 | 150 | 1 | 1.3 | Sum |
| Shrub 3 | 0 | 60 | 300 | 0.5 | 0.9 | Win |
| Tree 1 | 1 | 80 | 200 | 2 | 3 | Fall |
| Tree 2 | 0 | 100 | 150 | 3 | 4 | Spr |
| Tree 3 | 0 | 120 | 300 | 2 | 3 | Spr |
| Tree 4 | 0 | 90 | 150 | 3 | 3 | Spr |

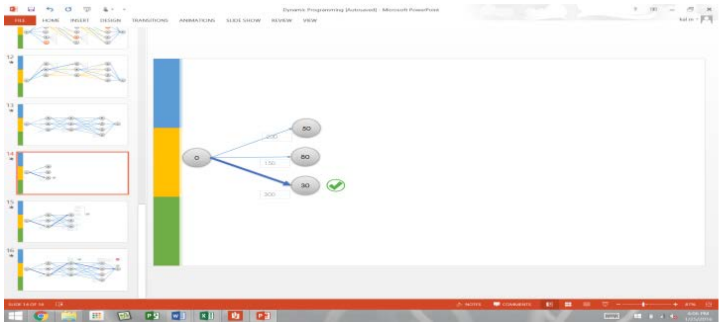
The landscape designer is then expected to use the application to aid in the selection process in which one plant will be selected for each of the plant types, such that cost and water consumption are minimized. This will be done based on the optimization steps described below (Figure 2):

1. By employing dynamic programming the complex problem above is broken down to smaller simpler problems.
2. The problem is solved first for the best selection of each plant type, i.e. best palm, tree and shrub
3. After plants are categorized according to their type, the plants that do not satisfy the criteria are not included
4. The optimization then is run based on the subset of solutions that remain after all criteria have been satisfied
5. The output of the optimization will be shown as the best plant from each type. This way the result of the larger complex problem will be shown. Figure 2 shows two selected options from the database.

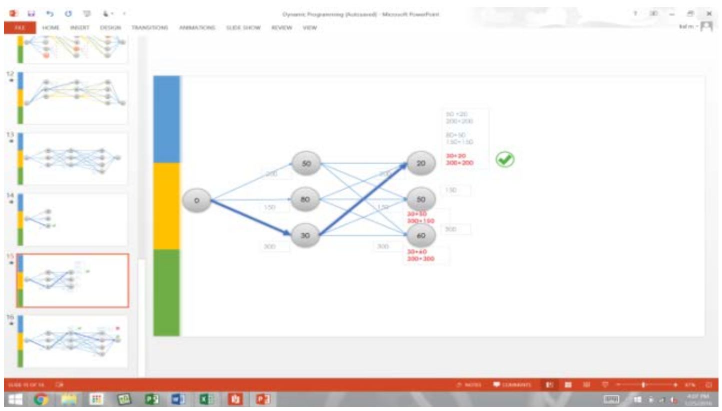
In order to also provide a solution of the system that has not taken into account the a priori assumption of weight, a Pareto-optimality is also performed. As shown in **Figure 3**, the Pareto presents non-dominate solutions, to the system that minimize cost and water consumption. Furthermore, a dominated solution that is defined as sub-optimal to a non-dominate solution, will be discarded. Moreover, for each of the non-dominated solutions provided by the system the end user can select the plant that best suits their design and aesthetic intent.



(A)



(B)



(C)

(D)

Figure 3: Four steps to the solution of the knapsack problem

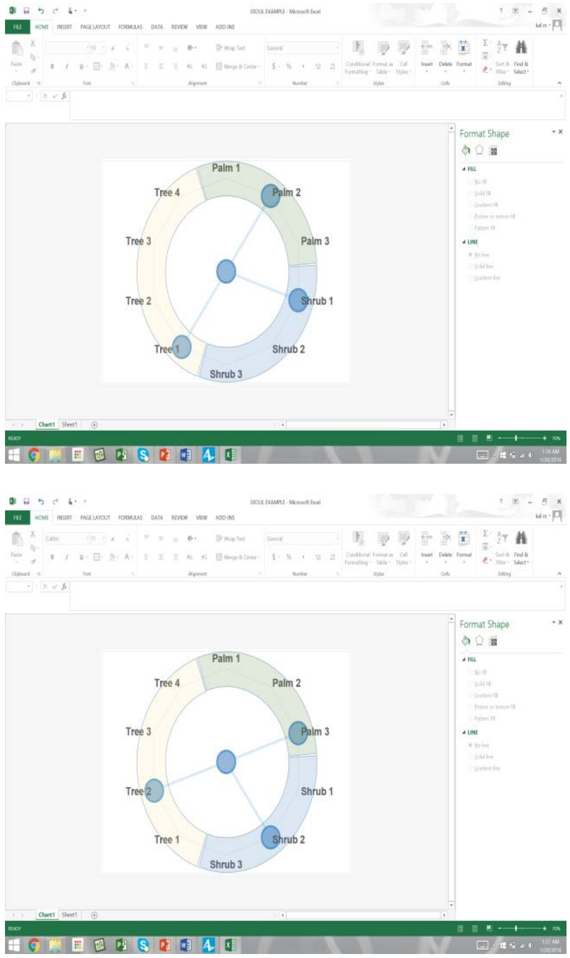


Figure 4: Two solutions that satisfy the solution subset

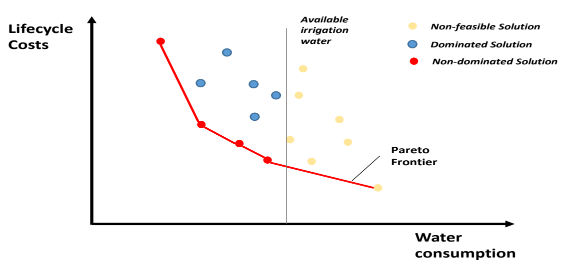


Figure 5: Non-dominated solution presented through a Pareto optimal frontier

## 9. CONCLUSIONS

Based on the literature and field research conducted with plant architects, plant suppliers, contractors and other experts, the following attributes were determined to best describe the plant information and reflect the designer's intent; Plant classification, plant type, bloom season, life cycle, height, root, salt tolerance, draught tolerance, bloom season, based color, flower color and fruit color, Latin Name, Common Name, Arabic Name, Irrigation/Water Demand, Cost and Maintenance.

Furthermore, in order to assemble the required information a number of databases were used, in addition to field surveys with suppliers. Nonetheless, while the cost and water requirements were collected through field surveys and entered manually by the design team, once the application platform is operational, suppliers will have their own credentials to enable them to automatically updated cost and water consumption information.

Finally, the SEOUL optimizer used the knapsack dynamic programming model to provide an efficient rapid solution to the system. Nonetheless to ensure test the efficiency of such an approach further research needs to be conducted to test the efficiency of dynamic programming against near optimization techniques such as Genetic algorithms and neural networks.

## Acknowledgements

This publication is based on work supported by an award made by the "Information Technology **Academia Collaboration** (**ITAC**)" program, **Information Technology Industry Development Agency** (**ITIDA**), Egypt.

## References

Boyd, S., and Vandenberghe, L. *Convex Optimization*. New York, NY, USA, 2004

Brickell, C. and Zuk., J.D. *The American Horticultural Society A-Z Encyclopedia of Garden Plants*. New York, NY : DK Pub., 2004.

CADPRO. *Landscaping Outdoor Designs*. http://www.cadpro.com/landscaping-outdoor-designs- planning, 2014

Chong, E. K., and Zak, S. H. *An Introduction to Optimization*. New York, NY, USA, 2001

El-Masry, Laila. *A Plant Guidebook for Al-Azhar Park and the City of Cairo*. Print. Cairo: El-Shorouk International hop, 2013.

Fact Sheets & Plant Guides. *USDA Plants*. N.p. http://plants.usda.gov/java/factSheet, 2016

Fayad, A. A Risk Mitigation Framework for Construction/Asset Management of Real Estate and Infrastructure Projects, a PhD Dissertation, *The American University in Cairo, Construction Engineering, Cairo*, Egypt. 2014

Fayad, A., Hosny, O., Elhakeem, A., Abu-Samra, S., and Hosny, M. Modelling and Optimization of Sustainable Landscape Design. *Engineering Project Organization Conference. Colorado, USA: EPOC*. 2013

Fitzsimons, P. C, Placing People at the Centre of Landscape Assessment, *Landscape Analysis and Visualization*, Australia, ISBN 9783540691679, pp. 277 – 304, 2008

Florida, R. U., *Trees and Shrubs Selection*. http://www.extension.org/pages/ 13082/trees-and-shrubs:-selection, http://hort.ifas.ufl.edu/woody/landscape-design.shtml. displayed online January 22nd, 2014.

Florida-friendly Plant Database. *University of Flirida/IFAS Horticulture Experts*. N.p., http://floridayards.org/fyplants, 2016

GAFI, A Snapshot of the Egyptian Economy, Cairo, Egypt, *General Authority for Investment and Free Zones*, 2014

Gordon, J. and Strategist, G., Global Outlook for 2014, *LasSalle Investment Management*, 2014

Jienan, Y., *Research of Landscape Design in Residential Area*. Sweden: Karlskrona, 2009.

Jubran, I.K. and Hizon., D.V., *Landscape Plants in the Arab Gulf Countries*. Jeddah : Floraprint KSA & Gulf, 1999

Odenwald, N. and Pope, T., Main Page. *Online Plant Guide* N.p. www.onlineplantguide.com, March 1, 2007.

Plants Encyclopedia of Egypt. Cairo : *Ministry of Tourism*, 2009.

The Plant Encyclopedia. Aden Earth. N.p., n.d. http://www.theplantencyclopedia.org, 2016

The Woody Plants Database. *Cornell University*. N.p. http://woodyplants.cals.cornell.edu, 2016

Wikibook https://en.wikibooks.org/wiki/Horticulture/USDA_Hardiness_Zone, 2015

UNEP. Global Environmental Outlook. Overview: *Geo-2000*, 1999