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SUSTAINABLE CONSTRUCTION OF EDUCATIONAL BUILDINGS MODEL (SCEB)

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ملخص البحث:

تعتبر صناعة البناء والتشييد مستخدم رئيسي للموارد الطبيعية اثناء وبعد التشييد حيث تستهلك المنشآت ما يقرب من 30-25 % من الطاقة مما يشكل عبئا على التنمية المستدامة لجميع المدن في البلدان المتقدمة والنامية على حد سواء. وبناء علي هذا تم تحديد قطاع المنشآت التعليمية كأحد القطاعات الحيوية التي يهدف هذا البحث إلى أن يتمكن متخذي القرار الذين لديهم مشروعات تشييد منشآت التعليمية من معرفة وتطبيق متتطلبات الاستدامة. حيث يوضح هذا البحث وصف كامل لمكونات وأجزاء النموذج الذي تم تطويرة وتم تسمية "Sustainable Construction of Educational Buildings" (SCEB). حيث يشمل هذا النموذج ثلاثة محاور رئيسية اولا: تحقيق متطلبات (LEED BD+C) بإستخدام agile development، ثانياً: التعامل و الحد من نفايات التشييد و ذلك بتحديد الأداة والتقنية المناسبة لإدارة نفايات التشييد باستخدام المنطق الضبابي لتحقيق التنمية المستدامة، حيث يعتمد ذلك علي نوع المادة المستخدمة في التشييد، ثالثا: العمليات المالية بناء على حساب التكلفة الأولية بالأضافة الي تكلفة التشغيل باستخدام طريقة . Net Annual Worth

ABSTRACT

Construction industry is considered the main user of natural resources during and after the construction, where buildings deplete almost about 25-30% of energy, a burden on sustainable development of all the cities in both developed and developing countries and regions. Based on this the sector of educational constructions has been identified as a vital sector, which this research aims to help the stakeholders that have educational buildings projects can knowledge and apply the sustainability. The named of this model is "Sustainable Construction of Educational Buildings" (SCEB). This model includes three main parts: first; achieve the LEED BD + C requirements using agile development. Second; dealing with construction waste by identifying the appropriate tool and technique for managing construction waste using fuzzy logic to achieve sustainable development, depending on the type of material used in construction. Third; financial operations based on the calculation of the initial cost in addition to operation cost using the Net Annual Worth method.

1. Introduction

This research presents the framework model which developed using Visual Basic, MS Excel and MATLAB, the Model consists of three parts: LEED BD+C certification, waste management and financial process, in input data, then processing, and output results of this model is a report contains the number of iterations, possible points and certification level to LEED BD+C, waste management methods and tool for used materials in addition to the financial process base on net annual worth taking in a consideration the initial and running cost. The proposed framework model is tested and evaluated by check the results with the illustrative examples results. Figure 1 shows the model hypotheses.

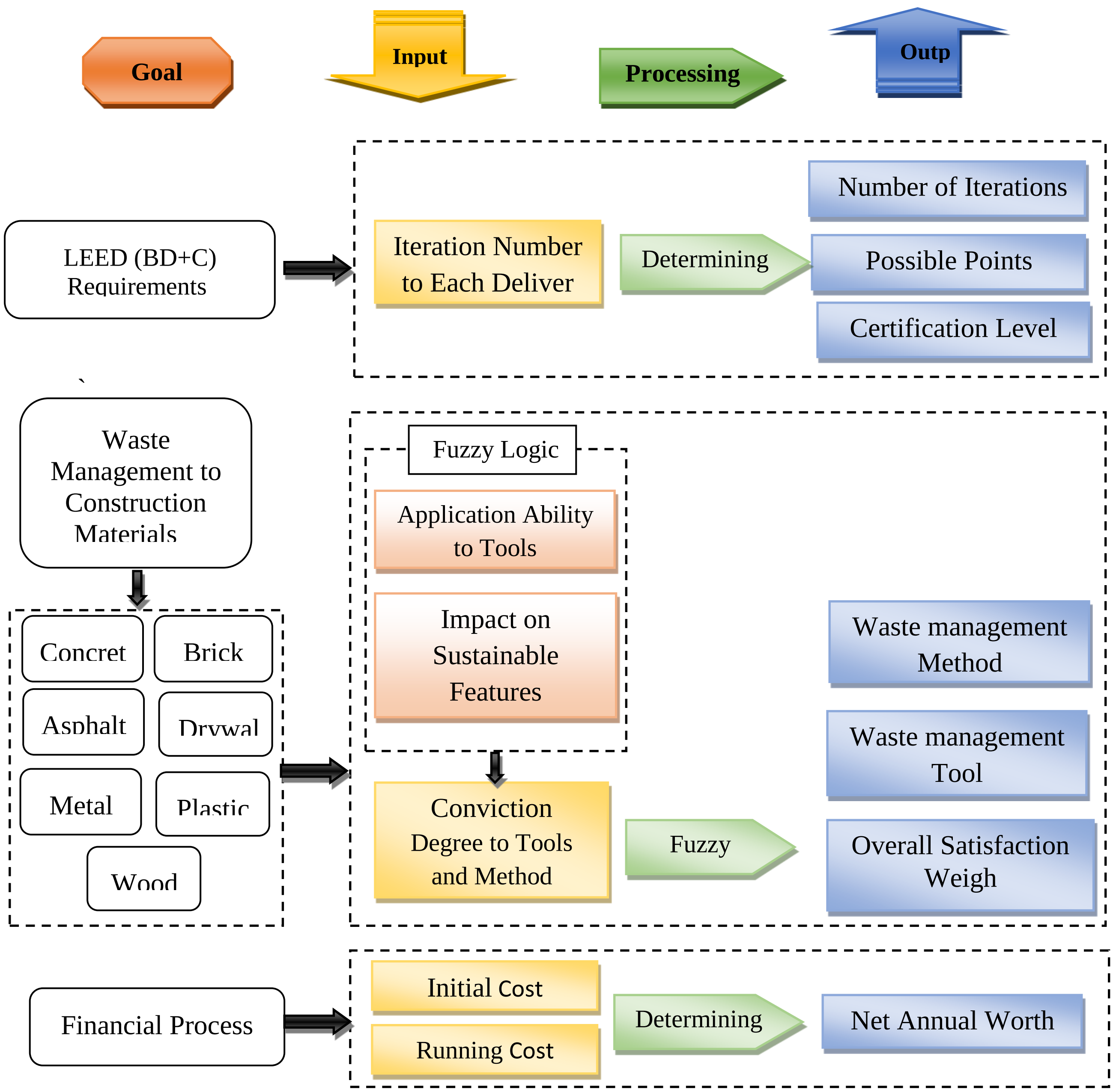

Figure 1: (SCEB) Model Hypotheses

2. LEED (BD+C) Requirements and Certification

(Ibrahim et al. 2017) Proposed a model to progress approach to apply sustainable requirements to design criteria and construction phase of educational buildings using an Agile model based on reference guide Leadership in Energy and Environmental Design version 4 for Building Design and Construction (LEEDV4 BD+C) requirements, the proposed a model consists of seven iterations to achieve the (LEEDV4 BD+C) certification in the design and construction of educational buildings to be sustainable. The proposed research depending on this iteration to check the validity of (SCEB) model as shown in Figures 2 and 3.

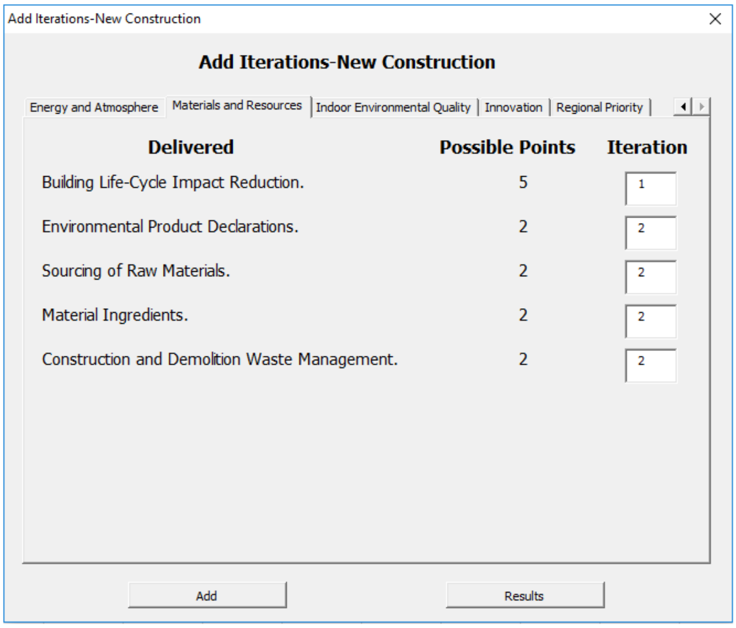

Figure 2: Add Iterations

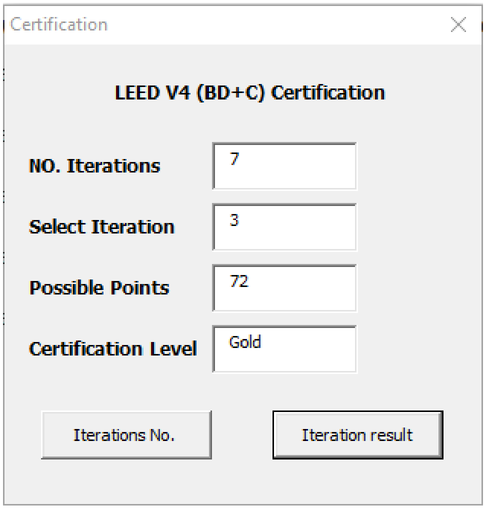

Figure 3: LEED (BD+C) Certification Form

3. Sustainable Waste Management Method

One of the major obstacles to sustainable development is the construction waste due to their negative environmental impacts. Where, the construction waste represents about 1/3 of overall waste value (Zhao et al. 2010).

3.1 Construction Waste Management Tools and Methods

The several of waste management tools are indicate to deal with construction waste in a sustainable manner to preserve the environment. Where Construction materials have direct impacts on the environment. the selected tools for waste management indicated in the following; demolition techniques (T1), management schema to waste during the construction (T2), application of standard specifications to waste recycling (T3), materials meet minimum quality requirements (T4), harmful substance limit (T5), collect waste by type (T6), return materials to manufacturer at the end of life use (T7), decrease waste disposal in the public landfills (T8), and establish licensed units for waste treatment (T9), (Eunomia et al. 2009). The nine waste management tools are integrated with the eight waste management methods, the work of the tool varies according to the method used to deal with the waste and depends mainly on the construction material used, but not all tools are suitable for integration with different waste management methods as shown in Table 1.

Table 1: Construction Waste Management Methods and Tools (Heble et al. 2014)

Instrument	Avoid	Minimize	Reuse	Recycle	Compost	Energy Recovery	Treatment	Landfill
T1				•	•			
T2								•
T3			•	•	•	•	•	
T4				•				
T5	•	•	•	•	•	•	•	•
T6	•	•						
T7			•	•	•	•	•	•
T8			•	•				
T9						•	•	•

3.2 Materials and Construction Waste Management Methods

A strategic hierarchy of the generalized waste management methods in a descending order of resource-saving and environment-friendliness is avoidance, minimization, reuse, recycle, compost, energy recovery, treatment, and landfill. Avoidance and minimization are not applicable to deal with the generated construction waste. Reuse refers to use the used item again for the same function. Recycle breaks down of the used item into raw materials that are used to make new items. Compost is a kind ingredient in organic farming which produces fertilizer and soil amendment. Energy recovery means the burning of construction waste to get the energy. Treatment decreases the volume of construction waste, such as combustion. Landfill disposes of construction waste by burial. Table 2 presents the possible waste management methods for each of the selected major construction waste materials used in the construction of educational buildings in Egypt.

Table 2: Management Methods for Construction Waste Materials (Tam 2008)

Material	Reuse	Recycle	Compost	Energy Recovery	Treatment	Landfill
Asphalt	•	•		•		•
Brick	•	•			•	•
Concrete	•	•				•
Drywall	•	•	•			•
Metal	•	•				•
Plastic	•	•		•	•	•
Wood	•	•	•	•	•	•

3.3 The Sustainable Features

the sustainability dealing using the waste management tools and methods the sustainable features have to take into consideration to deal with the environment better the sustainable features are the decreasing of the dissipation of energy, reduce the global warming, reduce the deleterious environmental emissions, protected the naturalist resources, analysis of financial process(benefits and costs), where this feature is considered the fundamental importance to companies, in addition to reduce the negative impact on the surrounding environment and Increase of job opportunities, where it is considered a social and economic service. The sustainable features for selecting preferable waste management method shown in Table 3.

Table 3. Sustainable Features (Yashuai 2013)

Code	Feature
F1	Decrease the dissipation of energy
F2	Reduce the global warming
F3	Reduce the deleterious environmental emissions
F4	Protected the naturalist resources
F5	Analysis of financial process(benefits and costs)
F6	Reduce the negative impact on the surrounding environment
F7	Increase of job opportunities

3.4 Impact Waste Management Instruments to Sustainable Attributes Using Fuzzy Logic

This section illustrate the integrated the waste management instruments (A1, A2,..., A9) with sustainable attributes (X1, X2...., X7) Using Fuzzy Logic by determining the degree of ability to apply (AA) waste management instruments and its Impact (I) on sustainable attributes to get the degree of satisfaction using linguistic assessments.

This part focus on the use of linguistic information for modeling performance evaluations. Where chooses the appropriate linguistic descriptors for the term set and their semantics. Where this target, a vital angle to break down is the granularity of data, i.e., the cardinality of the term set. One probability of creating the linguistic term set comprises of straightforwardly providing the term set by considering all terms conveyed on a scale on which a total order is defined (Yager 2007). A set of seven terms could be given as follows:

S = {S0: N, S1: V L, S2: L, S3: M, S4: H, S5: V H, S6: P}

In these cases, it is required that the linguistic term set satisfies the following additional characteristics.

1) There is a negation operator: Neg (Si) = Si such that J = g – i + (g +1 is the cardinality).
2) Si ≤ Sj where: i ≤ j Therefore, there exists a minimization and a maximization operator.

The used labels with triangular membership function assign the following semantics to the set of seven terms as shown in Figure 4.

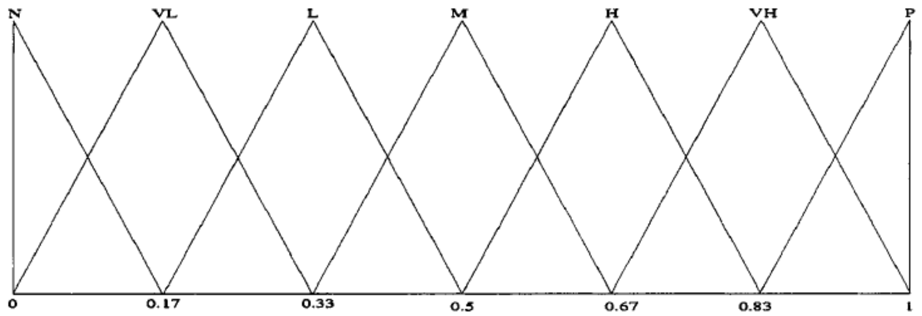

Figure 4: A set of seven terms with their semantics

3.5 Illustrative Example

An illustrative example is provided to determine a suitable waste management tool using "Recycle" method to the concrete structure by determining the satisfaction degree (S) to the waste management using fuzzy logic model as shown in Figures 5 and 6 based on the assumed percentage for both the degree of Application Ability (AA) to waste management instruments A= {A1…, Am…, AM}, and the Impact of it (I) on sustainable attributes X={X1,…,Xn,…,XN}, given by decision-maker as shown in Table 4.

Table 4. Application Ability (AA) and Impact (I)

Method	Tools	(AA)	(I)						
			F1	F2	F3	F4	F5	F6	F7
Recycle	**T1**	0.40	0.70	0.70	0.49	0.70	0.70	0.70	0.75
	T2	0.45	0.80	0.60	0.70	0.50	0.65	0.80	0.60
	T3	0.60	0.50	0.50	0.60	0.60	0.80	0.75	0.65
	T4	0.40	0.60	0.60	0.60	0.60	0.80	0.75	0.80
	T6	0.75	0.90	0.70	0.50	0.80	0.90	0.85	0.90
	T7	0.50	0.90	0.85	0.75	0.90	0.95	0.80	0.90

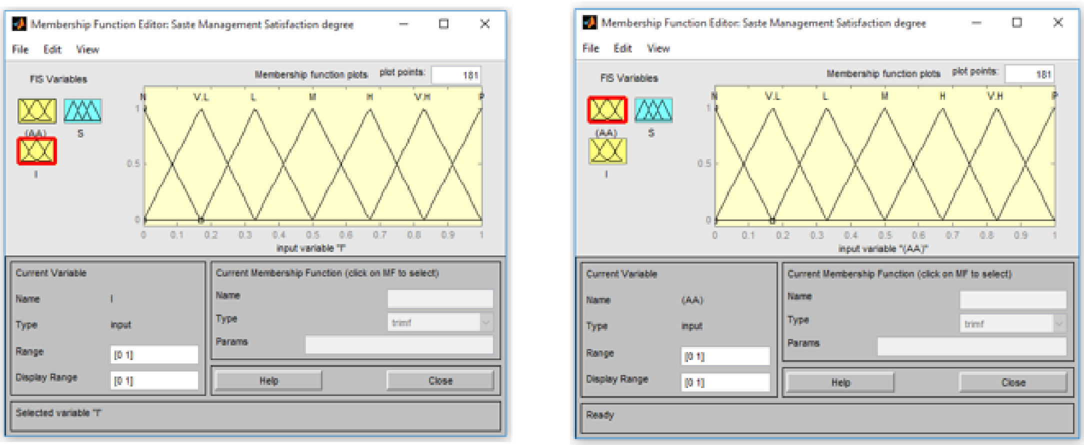

Figure 5: Membership Function for Application Ability (AA) of Waste Management Tool and Impact (I) to Sustainable Features

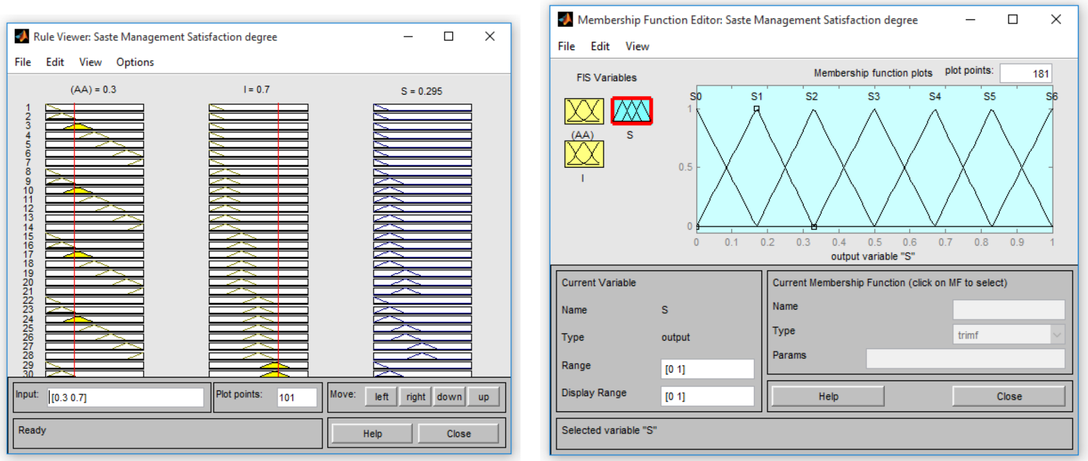

Figure 6: Satisfaction Degree (S) and Model Response / Defuzzified Values

The overall satisfaction values of alternatives are calculated by summation all satisfaction degree of sustainable features for all tools. Table 5 shows that overall satisfaction values for all waste management instruments. The tool (T6) "Collect Waste by Type" to use the "Recycle Method" is the favorite option for concrete block waste with overall satisfaction 4.71.

Table 5. Satisfaction Degree (S) using Fuzzy logic

Method	Tools	(S) using Fuzzy logic							Overall satisfaction
		S_{F1}	S_{F2}	S_{F3}	S_{F4}	S_{F5}	S_{F6}	S_{F7}	
Recycle	**T1**	**0.37**	**0.37**	**0.23**	**0.37**	**0.37**	**0.37**	**0.41**	2.49
	T2	**0.44**	**0.27**	**0.37**	**0.25**	**0.30**	**0.44**	**0.27**	2.34
	T3	**0.33**	**0.29**	**0.43**	**0.43**	**0.55**	**0.50**	**0.43**	2.96
	T4	**0.26**	**0.26**	**0.26**	**0.26**	**0.42**	**0.41**	**0.42**	2.29
	T6	**0.75**	**0.62**	**0.41**	**0.70**	**0.75**	**0.73**	**0.75**	4.71
	T7	**0.50**	**0.48**	**0.41**	**0.50**	**0.52**	**0.46**	**0.50**	3.37

4. Financial Process

This section presents the assessment requires the determination of initial cost and with operation cost, where the process is requiring knowledge management alongside decision maker responsibility assessment for providing the optimum decisions in cost assessment for the sustainable development. Increasing of the experience of engineers and contractors in building sustainable structures increases, the labor, equipment, and materials required throughout the project should be less, yielding a more economically competitive final product (Pitt, 2009).

4.1 Net Annual Worth

The third objective of the model is the financial process, the user inputs the initial cost, waste management method cost, annual use of energy and water cost, discount rate and expected lifetime (Year). Where, the sustainable buildings might need extra of costs in a comparison to traditional buildings, In case of the addition of developed technologies and application of high of LEED BD+C grades, or sustainability. However, they additionally offer huge cost investment funds after some time.

Net Annual worth (NAW) is applied on a large scale to evaluate the chances of investment. It used for comparing alternatives with different lives.
An alternative usually has the following cash flow estimates:
Initial Investment (P) – the total first cost of all assets and services required to initiate the alternative.
Salvage Value (SV) – the terminal estimated value of assets at the end of their useful life.
Annual Amount (A) – the equivalent annual amount; typically this is the annual operating cost.
Net Annual worth (NAW) can be calculated as the following:
NAW = PV x i (1+i)^n/((1+i)^n)-1 Eq. (1)

- PV = present value.
- N = Life time.
- i = discount rate.

4.2 Running Cost for Sustainable Buildings

When the concept of sustainable buildings began to infiltrate mainstream consciousness, there was a common perception that sustainable buildings were more expensive. Why? In certain instances, sustainable buildings did cost more – the technologies being implemented were new and not widely available or mass manufactured, who specialized in sustainable. A half dozen California developers in 2001 estimated that sustainable buildings cost 10% to 15% more than conventional buildings (Kats 2003).

- **Energy Use**

Energy is a substantial and widely perceived cost of building operations that can be decreased through energy efficiency and related measures that are part of sustainable building design. Therefore, the value of lower energy bills in sustainable buildings can be significant. Buildings use 30% less energy than conventional buildings (Kats 2003).

- **Water Use**

Water conservation not only saves money for the end user through reduced utility expenditures but also provides a construction of new desalination plants and prevents potential environmental damage.

- The efficiency of potable water use through better design/technology.
- Capture of gray water – non-fecal wastewater from bathroom sinks, bathtubs, showers, washing machines, etc. – and use for irrigation.
- On-site stormwater catch for utilizing or groundwater energize.
- Recycled/recycled water use.

Taken together, these procedures can reduce water use underneath by more than 30% inside and more than half (50%) to landscape (Kats 2003).

4.3 Illustrative Example

An illustrative example is provided to compare between typical and sustainable building with a LEED BD+C Silver level

- Typical educational building life = 30 years

- Sustainable educational building with a LEED BD+C Silver level = 60 years
- The discount rate is 5 %.
- Initial cost of typical educational building (assumed) = 30,000,000 EGP
- Initial cost of sustainable educational building with a LEED BD+C Silver level = (1+15%) *30,000,000 = 34,500,000 EGP
- Annual use of energy and water for typical educational building (assumed) = 25,000 EGP
- Annual use of energy and water for sustainable educational building = (1-30%) * 25,000 EGP = 17,500 EGP.

Determining the Net Annual worth based on Eq. (1) for both traditional and sustainable. The comparison between illustrative that the difference = 136,471 (7%) favor to sustainable educational building based on taken the running cost and building lifetime in a consideration and don't rely on the initial cost only as shown in Figures 9 and 10 respectively.

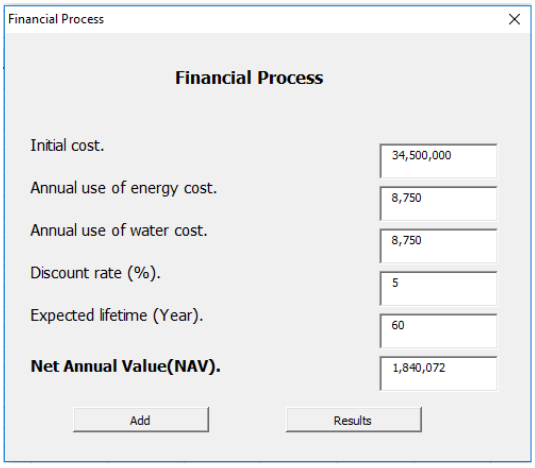

Figure 9: Financial Process for Traditional Building

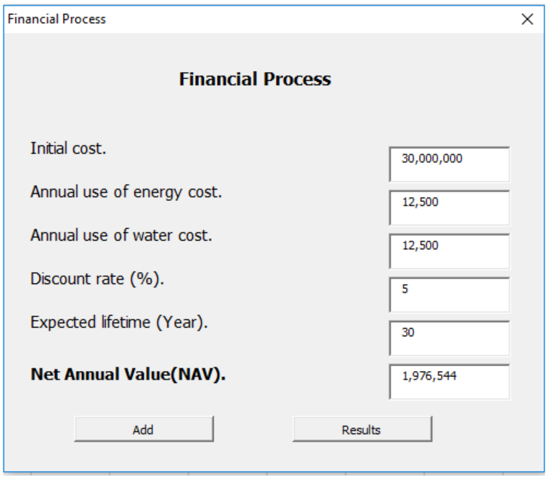

Figure 10: Financial Process for Sustainable Building - Silver Level

5. Conclusions

The (SCEB) model is developed to deal with the three main modules, the first part deals with knowledge of sustainable construction by achieving the requirements of the Leadership in Energy and Environmental Building Design and Construction LEED BD+C by using agile development, the second part of the model is dealing with construction waste management by determining the best method to deal with each type of waste Separately and its effect to sustainable development using the fuzzy logic technique and ordered weighted average (OWA), the third part deals with the evaluation of financial process (initial cost + operating cost) and not based on initial cost only.

References

Eunomia, T. C. E. Oko-Institute, Arcadis, Scuola Agraria del Parco di Monza, TBU Engineering, Eunomia New Zealand (2009).“. International Review of Waste Management Policy: Annexes to Main Report. In Department of the Environment, Community and Local Government of Ireland, Review of Waste Management Policy.

Heble, E. D., Wisniewski, H. M. and Heisel, F., (2014) "Building from Waste – Recovered Materials in Architecture and Construction". ISBN-10: 3038215848. Birkhäuser, Berlin.

Ibrahim, M., Elbehairy, H., and Nagy, A., (2017) " Agile Model to Sustainable Design and Construction for Schools in Developing Countries" International Journal of Scientific & Engineering Research, volume 8, issue 4, 388-393.

Kats, G., Alevantis, L., Berman, A., Mills, E., & Perlman, J. (2003). The costs and financial benefits of green buildings. A report to California’s sustainable building task force, 134.

Li, Y. (2013). Developing a sustainable construction waste estimation and management system. Hong Kong University of Science and Technology (Hong Kong).

Pitt, M., Tucker, M., Riley, M., & Longden, J. (2009). Towards sustainable construction: promotion and best practices. Construction innovation, 9(2), 201-224.

Tam, V. W. Y. (2008). “On the effectiveness in implementing a waste-management-plan method in construction.” Waste Management, 28(6), 1072-1080.

Yager, Y. Y. (2007). “Using stress functions to obtain OWA operators.” IEEE Transactions on Fuzzy Systems, 15(6), 1122-1129.

Zhao, W., Leeftink, R. B. and Rotter, V. S. (2010). “Evaluation of the economic feasibility for the recycling of construction and demolition waste in China – the case of Chongqing.”Resources, Conservation and Recycling, 54(6), 377-389.