



## Embedded Life Cycle Costing Elements in Green Building Rating Tool

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### Abstract

Green Building rating tools are the essential need of this era, to cope up with the sustainable development goals, climate change, and natural resource degradation through buildings. Realization of green building incentives decently increased within past few decades with abrupt declination in real estate markets and economic depletion has decelerated the interest of investors towards the green building projects. This research calculates influence of costing elements in MyCREST (IS-design) using questionnaire survey distributed amongst qualified professionals (QP'S) of green buildings and expert practitioners. Firstly, factor score and then weightage factor was performed to produce the final result with weightage output for evaluating weightage and ranking of the relevant criteria of MyCREST and life cycle cost elements respectively. It is found that the criteria of storm water management has weightage of 0.236 as highest and criteria environmental management plan (EMP) as 0.061 as lowest. Research also identified another perspective by finding association of cost element at design stage of MyCREST and found that management cost is highly associated at design stage with the value of 87.7%. The outcome of this research will add value to green building development and map road towards sustainable development using green building tools to uplift quality of life. Furthermore, this paves a way to integrate various stages of MyCREST with life cycle costing tool to potentially contribute in evaluating cost association through green building rating tool.

*Keywords:* Green Building Rating Tools; Life Cycle Cost Analysis; Sustainable Development.

### 1. Introduction

The world is moving faster towards a sustainable global cause, and green building rating tools (GBRT's) have emerged as a new trend in the innovative technological field of built environment [1]. Many developed and developing countries have set their goals and strategies to prioritize need of time and capture green building ventures. Zuo & Zhao, (2014) mentioned that the concept of green buildings has evolved in an astonishing way to achieve sustainable development [2]. Vyas & Jha, (2018) evaluated that green buildings have drastically increased footprints in past one decade in 2004 it was observed as 20,000 square feet and in 2015 drastically increased to 3 billion square feet thus, aims to achieve 10 billion square feet green buildings footprints by the year 2022 [3]. Similarly, Hamid et al., (2014) assessed that green building is delineated as the building that is designed, constructed and operated to be effectively resource efficient [4]. It is also speculated that there is need in various aspects of social, economic and environmental perspectives to set strategies for construction industry to bring innovative approach in infrastructure development from conventional to green buildings that can be assessed as green [5].

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However, being prudent development there is still dearth in various countries for green building developers due to higher costs association. Developers and investors are wavered to embark upon green building with the view that green buildings don't provide life cycle costing at any stage; thus investors and developers need such type of cost calculation for each of the green building element significantly at design stage to know the worth of investment. In the same way, such approach will evidently emboss on building projects to fetch more interest of investors, builders, developers, owners and occupant to the next level of quality within built environment [6]. Higham, Fortune, & James, (2015) mentioned that these cost benefits are firmly linked with cradle to grave process; significantly known as start to an end process [7]. Whereas, life cycle costing is a procedure of determining organized economic approaches in predefined scope [8].

Life cycle costing integrates an additional benefit in every aspect of cost that is considered as vital element of project in decision making. However, green building rating tool BREEAM, UK also plunged life cycle cost partially in its green building rating tool called Man-02 [9]. This partial indulgence was considered for 4 points to render services of ISO-15686-5-2008 "*Buildings and constructed assets - Service-life planning - Part 5: Life-cycle costing*" to evaluate the life costing of building [10]. The life cycle costing elements considered in Man-02 BREEAM, UK was mostly derived from IS-15686-05-2008. Therefore, with the help of content analysis through literature review some of the prominent costing element have been identified and then considered as cost criteria's for green buildings. Various researchers mentioned that these costing elements have high influence on a project in general and are identified as seven most influencing cost elements: management cost, operation cost, maintenance cost, replacement cost, construction and installation cost, development cost, contingencies / risk cost [11–15].

Potential focus of life cycle cost (LCC) analysis desires to have the best cost performance of green buildings in near future. Keeping in view the life cycle cost, there is necessity to provide green building rating tool with life cycle costing that is embedded as an innovative structured approach within built environment and construction industry. Therefore, aim of the research is to connect integrated association of green building rating tool (GBRT) MyCREST (IS- Design Stage) with life cycle costing (LCC). The outcome will provide ease to stakeholders of construction projects and researcher's to assess GBRT's and LCC approach to find out LCC association with criteria and sub criteria's in GBRT's at design stage. MyCREST (Malaysian Carbon Reduction & Environmental Sustainability Tool) is Malaysia's latest green building rating tools has been taken into account to find out life cycle costing association with its Infrastructure Sequestration (IS) criteria and sub criteria's at design stage significantly.

## 2. Rise of Green Building Rating Tools in Malaysia

Global trend has emerged to help in combating social, economic and environmental rising issues, this trend has been initiated in the year 1987 by "World Commission on Environment and Development" to lean towards sustainable development [16]. This embossed lean triggered every aspect of life to be sustainable socially, economically and environmentally. However, the construction industry paved its way towards sustainable development (SD) and that enlightened the concept of green buildings [17]. To assess green buildings, a tool was postulated therefore BREEAM, UK developed green building rating tool in the year 1990 followed by LEED, USA in the year 2000, CASBEE, Japan in 2002 and Green Star developed by Australia and Green Globes by Canada. Thereafter, various countries started developing green building rating tool based on their region, culture, trend and topography. Malaysia has also prevailed flying industrialization with innovative globalization in last five decades reflecting 5 to 9% of annual growth [18, 19]. This growth has exhorted all stakeholders to come to a platform that persists the paradigm that actuate holistic approach of green building certifying through green building rating tools [18]. The Malaysian government has a strategic diligence to encourage green buildings through green construction and green technology for better sustainable built environment. Researchers identified that compared to conventional buildings the green buildings costs higher [20, 21] and due to higher cost influence it is very strenuous to appeal building investors towards green buildings [22]. Similarly, Nafis Abas et al., (2018) evaluated that despite providing with strategic forums and plans investors are not happily accepting innovative idea of green building development and assessment [23]. But due to global and local drives of green building development it started persuading green building in most of the countries around the world and countries started developing their own green building rating tools. Since, Malaysia also started embarking upon green building so there was need to assess green building Malaysia developed first developed green building rating tool in the year 2009 named as Green Building Index (GBI), then second was developed in 2012 named as Green PASS (Green Performance Assessment System) [24, 25]. In the same year 2012 another GBRT was developed called as PHJKR (Skim Penilaian Penarafan Hijau JKR), and then it was followed by fourth called GreenRE (Green Real Estate) in 2013. Thus, these rating tools pretend to be implemented at different stages of projects such as (design, construction, operation & maintenance).

However, approximately after three years, another landmark was developed with more intrusive innovative ideas, techniques and tools named as MyCREST (Malaysian Carbon Reduction & Environmental Sustainability Tool) officially launched on 12th May 2016. It has three stages (Design, Construction and Operation and Maintenance) where various criteria, sub-criteria and super sub-criteria's are given to assess green building project.

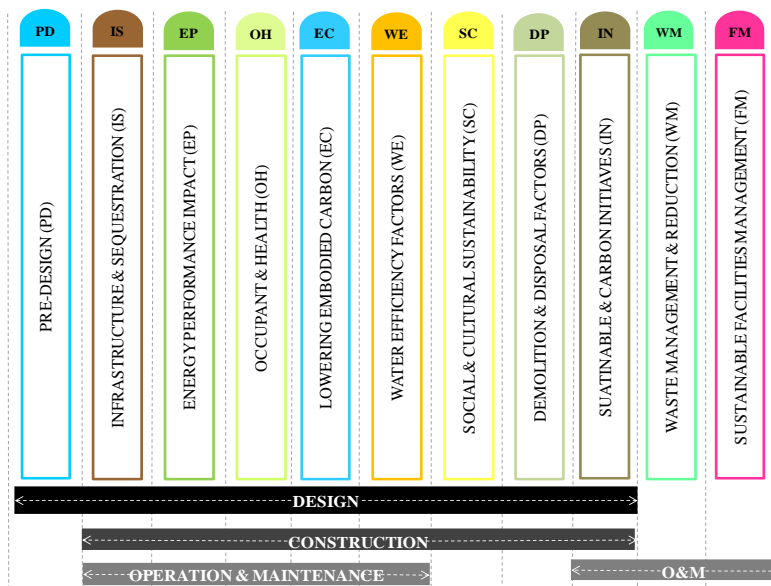


Figure 1. MyCREST Tool stages with Criteria [26]

MyCREST tools was developed and introduced by Construction Industry Development Board (CIDB) Malaysia that is the regulatory body of construction industry within Malaysia. MyCREST has total of 11 core criteria’s divided into three stages as mentioned in Figure 1. Various criteria’s of MyCREST over lapses in other stages that significantly fulfils the need of the stage and also implied all the factors that are embedded for an effective green building rating tool. Following Figure 1 outlines the comprehensive view of criteria’s given in MyCREST at various stages (Design, Construction, Operation and Maintenance). In accordance to this study MyCREST (IS Design Stage) criteria was taken into account therefore, Table 1 outlines MyCREST (IS-Design stage) criteria and its sub-criteria.

Table 1. MyCREST (Design Stage) Criteria’s and Sub-Criteria

ID	Core Criteria	ID	Criteria	ID	Sub Criteria
IS	Infrastructure and Sequestration	IS-1	Low Carbon City Characteristics and Factors	IS-1.1	Development Within Defined Urban Footprint
				IS-1.2	Urban Connectivity
				IS-1.3	Brownfield Development
		IS-2	Carbon Accounting of Site for (Greenfield or Graded Land)	IS-2.1	Carbon Sequestration - Preservation (For Mature Trees)
				IS-2.2	Carbon Sequestration - Preservation/Restoration/New Planting
		IS-3	Environmental Management Plan (EMP)	IS-3.1	Environmental Management Plan (EMP)
		IS-4	Factors in Stormwater Management	IS-4.1	Control Of Storm Water Run-Off On Site
				IS-4.2	Storm Water Design - Quality
				IS-4.3	Integration Of Carbon Sequester Strategies
		IS-5	Low-Carbon Transport Factors	IS-5.1	Covered Pedestrian Walkway
				IS-5.2	Low-Emission Vehicle Designated Parking
				IS-5.3	Accessible Public Transport- Bus Line And LRT Station
		IS-6	Urban Heat Island Mitigation	IS-6.1	Heat Island Mitigation - Roof/Wall
				IS-6.2	Heat Island Mitigation - Non-Roof
IS-7	Control in External Light Spill and Brightness	IS-7.1	Control In External Light Spill And Brightness		

### 3. Methodology

Research adopted questionnaire survey technique within expert practitioners and Qualified Professionals (QP’s) who are qualified as green building facilitator and assessors of green buildings through green building rating tool. This tends to identify costing elements that are important and high in ranking. MyCREST (IS-design stage) criteria and sub-criteria along with seven life cycle cost element were considered for questionnaire instrument development. According to Abidin et al., (2018); Jaromír Klemeš et al., (2017); and Zakaria et al., (2016) questionnaire survey performed through focused group discussion is one of the best option to acquire and analyze qualitative data [13, 27, 28]. Another research

conducted on the rationale of the green buildings and their market related to the investment in green building business in Hong Kong and Singapore; used questionnaire survey along with the theoretical concepts to analyze obstacles and favorable factors [29]. This research evaluated all eleven core criteria's of MyCREST, thereafter this research takes into account infrastructure sequestration (IS) - design that has 7 criteria and 15 sub-criteria. The research adopted factor score analysis and weightage factor analysis as a method of analysis. This analysis is interconnected with each other by getting mean index and factor loading (FL). Then factor score (FS) was performed followed by weightage factor (WF); thus, results are acquired based on factor score analysis. Performed analysis is finally taken into account to further evaluate output for weightage that will prioritize and rank to form arrangement according to influence.

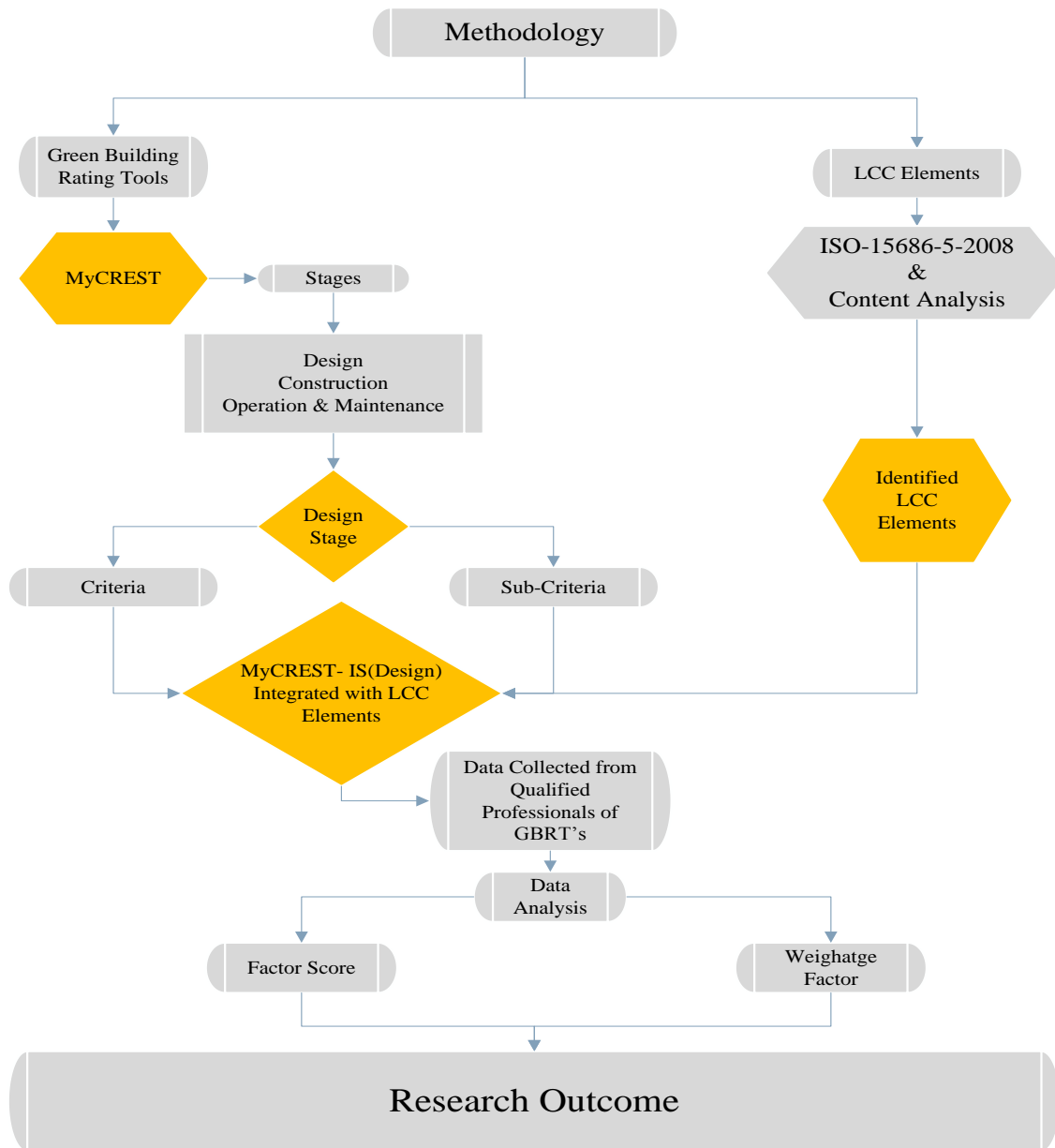


Figure 2. Explicated Flow Chart of Research Methodology

### 3.1. Factor Score

Once mean index and factor loading (FL) is achieved for each of the variables then factor score can be carried out, the findings obtained were further analyzed with weightage factor analysis. Factor score is conducted with the aim to recognize rankings and find score between various categories and elements of a group [30]. However, obtained factor score entitles furthermore justification that achieved variables on the basis of numerical value. The method used to calculate factor score is by Equation 1 of pragmatic process will produce factor score for sub-criteria (FSsc) [31, 32].

$$Factor\ Score\ (FS) = \frac{FL}{Y} \tag{1}$$

Where:

$FS$  = Factor score

$FL$  = Factor Loading

$Y$  = Mean Index

### 3.2. Weightage Factor

The interpretation begins with weightage factor analysis (WF) on the result obtained from above method of Factor Score (FS) to produce its own weightage. Balubaid et al., 2015 mentioned that weightage factor entitles each variable to see comparison or influence within group [31]. Further, steps were taken to assess weightage factor that is initially achieved by summing up all value of FSsc obtained from the FS in order to get  $\Sigma FS_c$  then each of FSsc is divided with  $\Sigma FS_c$  value. Once it is achieved then the summation of all values should be equal to 1 with a percentage 100 [33]. Thus, the number obtained as a weighting number shows more importance to one number over another. Maletta & Aires (2007) stated that a significant action using proportional weights specifically in each division of which homogenous sampling ratio can be designed in general form as follows [34]:

#### 3.2.1. Weighting Factor

$$\pi_k = \frac{\% \text{ of Stratum in Population}}{\% \text{ of Stratum in Sample}} \quad (2)$$

However, for example, to identify the weightage factor for elements, sub-criteria, and criteria the stratum refers to the factor score for criteria and main criteria respectively. Following are the amended formula in determining weightage factor for IS-Design stage of MyCREST [35].

#### 3.2.2. Element Weightage Factor

$$\pi (\text{Elements}) = \frac{\% \text{ of Stratum in Variables } (\Sigma FS (E))}{\% \text{ of Stratum in Sub-Criteria } (\Sigma FS (sc))} \quad (3)$$

#### 3.2.3. Sub-Criteria Weightage Factor

$$\pi (\text{Sub - Criteria}) = \frac{\% \text{ of Stratum in Sub-Criteria } (\Sigma FS (sc))}{\% \text{ of Stratum in Criteria } (\Sigma FS (c))} \quad (4)$$

#### 3.2.4. Criteria Weightage Factor

$$\pi (\text{Criteria}) = \frac{\% \text{ of Stratum Criteria } (\Sigma FS (c))}{\% \text{ of Stratum in Core-Criteria } (\Sigma FS (cc))} \quad (5)$$

Where:

$FS (E)$  = Factor score in the variables for each item

$FS (sc)$  = Factor score in the Sub-Criteria for each item

$FS (c)$  = Factor score in the Criteria for each item

$\Sigma FS (cc)$  = Cumulative of factor score in the Core-Criteria

## 4. Results and Discussion

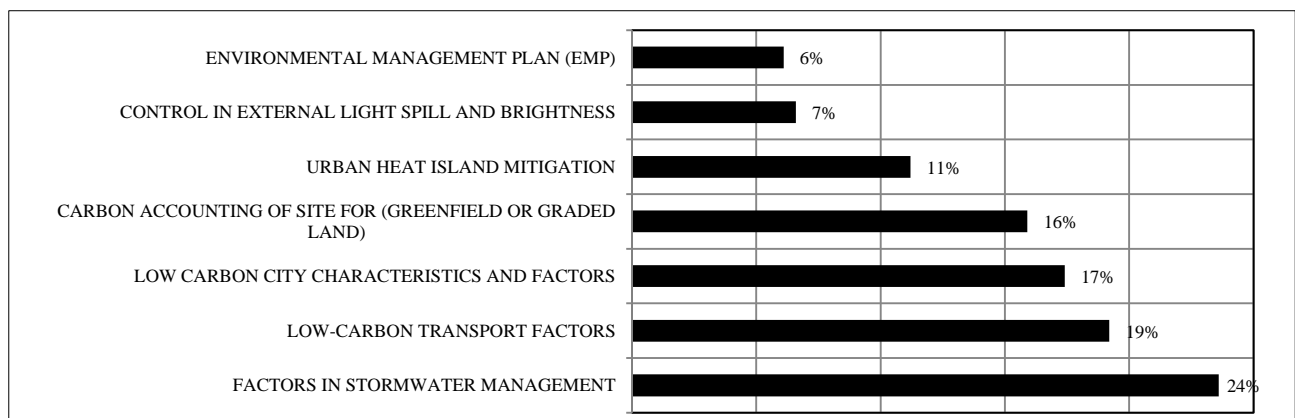
Research followed factor score analysis (FS) and obtained weightage factor for each of the criteria and sub criteria. Study analyzed data on weightage factor of LCC elements then after obtaining output of weightage criteria then sub-criteria and criteria of FS was obtained. Table 2 shows design stage criteria and sub-criteria results that are gained from the factor score and weightage factor analysis for IS (Infrastructure Sequestration). For weightage factor analysis performed after the factor score analysis each of the sub-criteria that are considered for its own main criteria category to achieve its weightage value that is arranged accordingly.

In the sub-criteria the environmental management plan (EMP) and control in external light spill and Brightness achieved 100% respectively that postures the avidity of its factors to contribute for better environmental perspectives. Carbon sequestration - preservation (for mature trees) also achieved 57%, urban connectivity 24% and Brownfield development 40% that shows that low cost is associated with sub-criteria's. Thus, sub-criteria integration of carbon sequester strategies achieve 23% as lowest weightage with respect to cost. However, further analysis of factor score of sub-criteria are given in Table 2 that synthetically defines each sub-criteria weightage score.

**Table 2. MyCREST (Design Stage) Criteria's and Sub-Criteria Weightage Factor**

ID	Criteria (C)	ID	Sub Criteria (SC)	$\sum$ FSsc	$\sum$ FS <sub>c</sub>	WFsc	%	WFc
IS-1	Low Carbon City Characteristics and Factors	IS-1.1	Development within Defined Urban Footprint	2.0	5.5	0.354	35%	0.174
		IS-1.2	Urban Connectivity	1.3		0.243	24%	
		IS-1.3	Brownfield Development	2.2		0.404	40%	
IS-2	Carbon Accounting of Site for (Greenfield or Graded Land)	IS-2.1	Carbon Sequestration - Preservation (For Mature Trees)	2.9	5.1	0.574	57%	0.159
		IS-2.2	Carbon Sequestration - Preservation/Restoration/New Planting	2.2		0.426	43%	
IS-3	Environmental Management Plan (EMP)	IS-3.1	Environmental Management Plan (EMP)	1.9	1.9	1.000	100%	0.061
IS-4	Factors in Stormwater Management	IS-4.1	Control of Storm water Run-off on Site	3.1	7.5	0.415	41%	0.236
		IS-4.2	Storm water Design - Quality	2.7		0.358	36%	
		IS-4.3	Integration of Carbon Sequester Strategies	1.7		0.227	23%	
IS-5	Low-Carbon Transport Factors	IS-5.1	Covered Pedestrian Walkway	2.1	6.1	0.342	34%	0.192
		IS-5.2	Low-Emission Vehicle Designated Parking	1.8		0.289	29%	
		IS-5.3	Accessible Public Transport- Bus line and LRT Station	2.3		0.369	37%	
IS-6	Urban Heat Island Mitigation	IS-6.1	Heat Island Mitigation - Roof/Wall	1.9	3.6	0.541	54%	0.112
		IS-6.2	Heat Island Mitigation - Non-Roof	1.6		0.459	46%	
IS-7	Control in External Light Spill and Brightness	IS-7.1	Control in External Light Spill and Brightness	2.1	2.1	1.000	100%	0.066

By extracting criteria's from Table 1 to evaluate their cost association with each life cycle cost elements at design stage of MyCREST (Infrastructure Sequestration). This provides with the analysis of each criteria that might be highly adherent to life cycle cost elements that are given. Figure 2 is developed that significantly shows that the criteria IS-4 of factors in storm water management has the ranked first with weightage of 24%; second is IS-5 low-carbon transport factors with weightage 19%. It was followed by IS-1 for low carbon city characteristics and factors of 17%, then IS-2 carbon accounting of site for (green field or graded land) 16%. While, IS-6 urban heat island mitigation has weightage of 11% and IS-7 control in external light spill and brightness 7%. Lastly, IS-3 criterion for environmental management plan has weightage of 6% as given in Figure 2.



**Figure 2. Weightage Factor for Criteria (Design Stage)**

The cost elements considered for this study elucidates the association cost of seven elements in MyCREST at design stage. The results outlined that the management cost is found 87.7% as the highest, operation cost 3%, development cost 2%, both maintenance and construction and installation cost are found as 1.9% followed by contingencies / risk cost as 1.8% and last one replacement cost found as 1.7%. These results shows that the management cost will be highly associated at design stage of MyCREST due to the fact that the management cost is one the crucial cost element in construction projects [10, 24, 36]. The Following mathematical model equation 5 is developed and used as a resultant equation to calculate cost weightage distribution of all seven life cycle cost elements; where  $x = \sum$  FS of Sub-Criteria and  $Y$  is number of sub-criteria.

#### 4.1. Mathematical Model Equation Cost Weighatge Distribution

Significantly study outlined that the cost association examination is one of the crucial elements in moving towards a new system of innovative design from traditional buildings to green buildings. This also encompasses a pivotal knowledge of the new technologies to be used to meet the required level of certification with cost. Most of the stakeholders from high ups hesitate to embark upon green buildings because of higher initial costs and prior knowledge of meeting the requirements of green certification. Therefore, this study was culpably involved to analyze green building rating along with its cost association to the life cycle costing elements to provide with ample solicitude of green building development. Though, such analyzes helps stakeholders identify cost association with respect to each criteria and sub-criteria at even design stage to better understand their worth of investment.

$$N = \frac{\sum X (IS1+IS2+IS3+IS4+IS5+IS6+IS7)}{y} \quad (6)$$

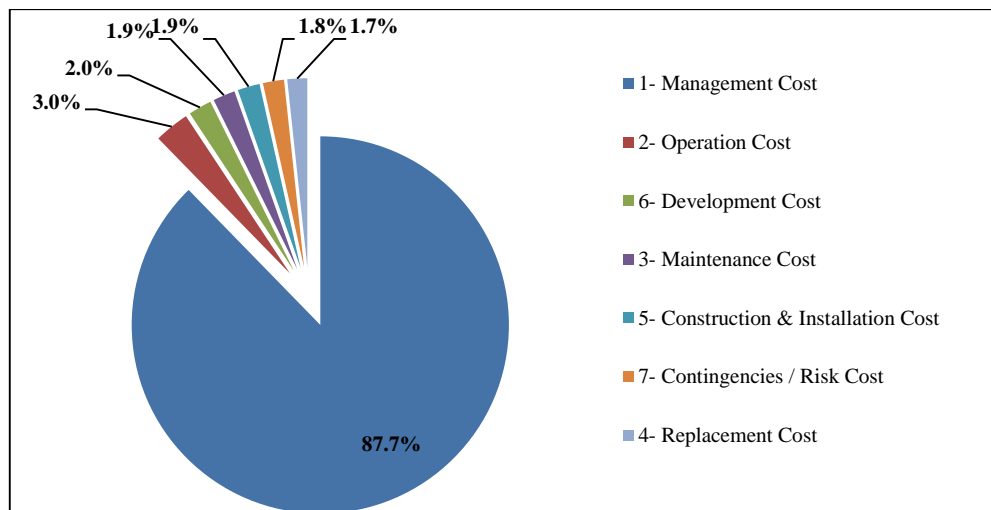


Figure 3. Design Stage LCC elements ranking

#### 5. Conclusion

Stakeholders significantly governments and other governing institutions of various countries are striving for the betterment in quality of life thorough transformation from conventional to a building that is green; and are developing various green building rating tools for assessment. Thus, the dearth is still found on integration of other tools with GBRTs. This research indentified cost associated criteria and sub-criteria of MyCREST green building rating tool through factor score and weightage factor analysis. Results followed by methodology outlined potential of life cycle costing integration into green building tools. The research developed a baseline as a prototype by analyzing MyCREST (IS-design) emergence to life cycle costing and found cost influential of each element at assorted stages and found management highly associated 87.7% followed by maintenance 3%. The difference between management cost elements shows that the management cost is one the major cost element at design stage. Since design stage plays vital role in successful completion of project and all the management factors are firmly integrated at this stage. Therefore, this study can be potentially extended by considering other stages of MyCREST and finding their weightage correlation with life cycle costing element and bringing them to the next level of assessment for better decision support system in decision making.

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#### 8. Conflicts of Interest

The authors declare no conflict of interest.

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