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Web-based automation of green building rating index and life cycle cost analysis

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Abstract. Sudden decline in financial markets and economic meltdown has slow down adaptation and lowered interest of investors towards green certified buildings due to their higher initial costs. Similarly, it is essential to fetch investor’s attention towards more development of green buildings through automated tools for the construction projects. Though, historical dearth is found on the automation of green building rating tools that brings up an essential gap to develop an automated analog computerized programming tool. This paper present a proposed research aim to develop an integrated web-based automated analog computerized programming that applies green building rating assessment tool, green technology and life cycle cost analysis. It also emphasizes to identify variables of MyCrest and LCC to be integrated and developed in a framework then transformed into automated analog computerized programming. A mix methodology of qualitative and quantitative survey and its development portray the planned to carry MyCrest-LCC integration to an automated level. In this study, the preliminary literature review enriches better understanding of Green Building Rating Tools (GBRT) integration to LCC. The outcome of this research is a pave way for future researchers to integrate other efficient tool and parameters that contributes towards green buildings and future agendas.

1. Introduction
The “green building” concept first emerged in the 1970’s when, in an attempt to incorporate sustainable development principles, the construction industry began to design and construct more sustainable buildings [1]. “Green building” also known as the ecological construction that save energy and protects environment. Whereas, ecological construction or eco-construction refers to the clean construction that reduces the environmental impacts of building throughout life cycle[2]. Many researchers have provided the definition of green building and exclusively Kibert elaborated green building as a “… healthy facilities designed and built in a resource-efficient manner, using ecologically based principles” (p.9) [3]. Accordingly, it can be further taken as a building that has better quality of life with higher efficiency and satisfaction level. The green building trend has increased rapidly worldwide in recent decades [4]. It is considered as a means of addressing growing concerns over climate change and global warming to reduce the impact of the building industry on the environment [5].

It has been promoted that the environmental sustainability is the major ingredient of sustainable design and construction and it should be kept on priority as main element in green buildings, which will be responsive to sustainable development [6]. For instance, if a construction has satisfied environmental
laws and regulation then it will be effective to the human that will directly impact to the well being socially, economically and environmentally. Conversely, [7] believes that all the aspects sustainable development principles are crucial in the nature and none of them can be left. Even though, if one aspect is completely satisfied that cannot bring the other to the upper level as desired by the concept of Triple bottom Line (TBL). Therefore, integration is necessary for green building movement to move towards the path of a successful paradigm shift. Green buildings not only integrates TBL elements but also incorporates too many other essential elements for better quality standards of life without compromising to the needs of future generations [8].

There have been extensive researches on the green building and green building rating tools, which have been developed in various countries from developed to developing world. However, lack of integration of green building rating tool and life cycle costing is found in existing body of knowledge. Such type integration plays essential part in discovering the streamline research. The aim of this research is to develop web-based automation of green building rating index and life cycle costing to attract more investors and developers with set objectives. This automated tool will eventually provide with the costing of green building, score and level of certification with return on investment to all the stakeholders. The objectives set for this study are to utilize MyCrest green building rating tool integrated with life cycle cost analysis and develop the automated web based program that results the above said output.

1.1 Background of Research Development

Malaysia has endured fast industrialization over the last 50 years, making between 5% to 9% annual economic growth [9,10]. This growth has urged the government, institutes and other stakeholders to bring up the epitome of development that is sustainable and takes holistic approach of green building development and its implementation [9]. The Malaysian government has a mission to promote green building within construction industry for sustainable built environment. Since the government of Malaysia is encouraging by developing policies providing platforms on green building, green technology and reducing carbon emissions. It has also been noticed that the green buildings costs higher compared to conventional buildings [11]. Since, Green buildings received a speculated claims that it is higher initial cost, therefore, it is difficult to attract building investors and developers to build green buildings [12].

In spite of Malaysian government strategic plans, building investors are not happily accepting this idea of green building [13]. Still there is a gap to attract and seek more interest of investors and developers in this challenging situation of fast moving era in decision making with advanced information technology. Some of the developed countries have paved their path for many decades toward this globalization of green building but developing countries are still moving rigorously to the same attention [8]. Countries individually are making efforts to meet the global challenges across various disciplines. World Green Building Council mentioned that there are more than 40 green building rating tools administered by their Green Building Councils that have 49% of green building certification systems in their countries’ [14]. Malaysia has embarked on green building rating tool since 2009 and recently in 2016 Construction Industry Development Board of Malaysia has established Malaysia Carbon Reduction and Sustainability Tool (MyCrest) for green building assessment. This MyCrest tool provides critical evaluation of green building from design, construction to operation and maintenance stages.

The green building investors and facilitators need a centralized green building rating automation solution. Which is easy, efficient and workable on the web based system that justifies the score, level of certification, and Return on Investment (ROI), to handles their work more efficiently. To meet this challenge green building rating assessment tool and Life Cycle Cost Analysis are necessitated. This automated tool will provide a better solution towards a better green building decision making with economic solution for its development. However, the proposed tool with a centralized web based automation solution offering the integrated systematic solution between the green building assessment tool and life cycle cost analysis. This innovative tool moderates and indicates the potential level on the score that reflects the level of certification, and ROI. If an automation tool is available to uplift mind set for long term viability of green buildings then construction industry can be fully directed towards the well being of environment, economy, and society. This will also lead to transparent, efficient and in a
quick time self-assessment. This new innovative tool will increase the investors and building developers interested to proceed with green building development in Malaysia and very potentially to be extended globally.

2. Literature Review

2.1 Integration of Green Buildings and Building Life Cycle
In global scenario, natural resources are depleting due to over usage by humans and their activities [15]. This dramatic change of human activities and style of living has devastatingly increased the green house gases and diminished many other natural resources such as water and soil. At the larger extent, the construction industry is considered as a major causative for this all environmental degradation [16]. Thus, it caused from design, construction and significantly to operation and maintenance stages, since O&M stage is considered as very crucial. The scientific research has admitted that the construction activities will affect the environment by direct or indirect implications [12]. These stages of activities involve a large number of trading from conception to demolition called building life cycle [17] furthermore, various processes involved in the building life cycle and every action is followed by some process. There is a total of six major phases starting from the conception when it’s brought to the table as an idea of developing some infrastructure that’s called inception, design, construction, commissioning, operation and maintenance, and demolition. Some of the researchers are saying that inception is a process of a brain storming, while some call as nurturing of idea besides that main owner and designer starts thinking about the product to be selected and used [18]. On the second and third phase, design and construction process start where most of the stakeholders are called in the eco-charrette meeting to navigate the potential pitfalls and a better understanding of conflicting priorities [17].

Due to increasing level of human luxury demands natural resources are depleting day by day and being the versatile industry, the construction industry is considered as one of the major contributors to the consumption of natural resources [20]. Green building is a holistic concept that starts with the understanding that the built environment can have profound effects, both positive and negative, on the natural environment, as well as on people who inhabit buildings every day. Green building is an effort to amplify the positive and mitigate the negative of these effects throughout the entire life cycle of a building [19]. The green building is taking a serious course of actions with in construction industry to emphasize the better, effective and efficient living. There has been lots of research carried on green buildings since the start of the conceptualization. The traditional way of building a building has started reaching towards its end of an era.

2.2 Triggers of the Green Buildings
In 2016, the smart market report of world green building trend was published with the partnership of Dodge Data and Analytics [21]. This report depicted the global picture of green buildings with the firm analysis of over 1000 respondent surveys from 69 countries of developed and developing world with statically significant results of 13 countries. The world green building report evaluated top triggers for green buildings and green building activities from the year 2008, 2012 and 2015 shown in Figure1. Four categories were kept, on the first category client demand was mentioned and it has increased by 1-4% with the passage of time. Secondly environmental regulation that was found 2% decreased from 2008 to 2012 and 12% increased by 2012 to 2015; which is a positive approach and shows strict formation and follow of environmental protection of law.

However, the third category was a market demand that decreased by overall 2 to 3% from 2008 to 2012. The last and final category was the right thing to do where results show that it has declined from 2008 to 2015 cumulative 17%. The decrease in last category elaborates lack of knowledge and understanding in accepting concept of green buildings. In line with the said research, [22] defines that this pitfall is a lack of strategic green building development, and this can be reduced but providing knowledge and filling research between traditional and green buildings.
After understanding the concept and triggers of the green building, scientists and researchers have started to evaluate the question “what is the need of green buildings”. From the emergence of the 1970’s concept many ideas floated around and certainly some of the them were leading cause such as climate change, global warming, environmental (air, water and soil) pollution, degradation of natural resources, sea level rises, melting of glaciers and many more facts brought up the idea of green buildings [23] [3]. This thought breaking idea of green buildings emerged as a source of inspiration towards the achievement of set goals. Though, [24] remarkably argued that scientists have drawn their attention to the most common problems associated with the environmental, social and economic (Triple bottom line) perception of the global cause, where people, planet, and profit need to be balanced.

In line with the above statement, this people, planet and profit formula has been generally accepted in all the corners due to their correlative bonding with each other. Researchers have always seen this kind of tranquillity and mentioned that it is contesting in the better interest of all three elements forming a better and balanced eco-system [25]. Thus, formation of better eco-systematic should be balanced otherwise it not be called as balanced eco-system. Due to the deterministic approach of the widespread argument of the triple bottom line all the elements need to be taken together and every activity with in every field need to be more or less contributing in the better interest of TBL argued by [26]. However, [27] claimed that every project needs to be the green project and that resembles the concept of the green building where the green approach is taken into account towards any building. This green approach will reduce the impacts of the building with the increase in efficiency, water; energy and material usage. Nevertheless, it should not affect on human health, ecological foot prints and to the environment throughout its life cycle. The awakening of construction industry stakeholders towards sustainable development triggers the green building development; which not only confers its entities towards better quality of life but also maps prosperous way for future generations. Future generations needs to have natural resources saved therefore this generation has to be sustainable enough to save natural resources directly or indirectly. However, construction industry being one the major contributor to environmental and natural resources degradation has to establish a new trend of development that support rigorous paradigm. The paradigm is considered as “Traditional Building development to Green Building Development”.

2.3 Emergence and Development of Green Building Rating Tools

Due to the idealized and defined approaches of the all stakeholders belonging to construction industry forced to develop assessment system. Then, to rate the project for getting that sustainably certified and name the project as “Green Certified Project”. The authors in the research [28] pointed out that hundreds of the building evaluation tools are available worldwide focusing on various aspects of green buildings and sustainable development. Around 382 registered building software tools were available by March 2010, for evaluating buildings’ sustainability. These tools have been taking faster pace by time and moving the construction industry towards better and innovative level. Similarly, [24] mentioned in their
research that assessment tools measure the progress towards the goal and objectives of the projects. Although, these tools vary in various contexts but still direction is towards the sustainable development. On the other hand [12] developed an argument that these tools enhance the capability of organization and stakeholders to work sustainably throughout the life cycle of the project. However, [12, 24, 28, 29] evaluated in their researches that sustainability rating assessment tools vary by country to country, region to region, state to state and project to project with more or less difference in elements. Researchers also added that green building rating tools have potential to assess every project falling under the construction industry and potentially coping green buildings sustainability as shown in Figure 2.

![Diagram](image)

**Figure 2.** Emergence from Sustainable Development to Green Buildings and then towards Green Building Rating Tools

The green building rating tools were established to incorporate and help architects, designers, builders, owners, investors, developers and government bodies to understand the overall impact of each choice and solution [30]. The development of green building rating tools has evolved from time to time. For the past several decades there has been debates going on in construction industry for moving towards sustainable development through some strategies and action plans. These strategies and action plans has formed a way in 1990 in the essence of BREEAM green building assessment tool [31]. This BREEAM (Building Research Establishment's Environmental Assessment Method) was developed by the United Kingdom, followed by LEEDS (The Leadership in Energy and Environmental Design) developed by the United States [20]. Then Australia has initiated its green building movement of Green Star through GBCA (Green Building Council for Australia) [32]. Similarly, Green Mark was developed by Singapore for their green building assessment [33]; also Hong Kong has developed HK BEAM for the assessment of green buildings in Hong Kong [34]. Likewise, Malaysian construction has started developing their green building rating system with the help of industry professionals, academician, and researchers. In 2009, GBI (Green Building Index) was developed by Malaysia to assess the green building development [24, 35]
Figure 3. Evolution of GBRT in different countries (Source: [35,36])

The above Figure 3 shows that the in early 1990’s there was not much on awareness of green building assessment tool or even building assessment tool. But as time has passed construction industry and researchers have drawn their attention to the development of building assessment tools to green building rating systems [37]. The above figure shows that from 1990 to 2000 there was not much of interest and development in GBRS (Green Building Rating Systems). Though, from 2005 to 2009 there is an exponential growth in the development of GBRS around the globe from developed to developing world this trend has remarkably achieved its peak [12,35,36,38]. The tool used in United Kingdom is called BREEAM; and it was the first green building rating assessment tool in the world developed in 1990. BREEAM was developed by BRE (Building Research Establishment) and this tool is widely accepted due to its versatilities [37,39,40]. All the other green building rating systems developed later such as LEED, GBCA, Green Mark, HK BEAM, GBI and MyCrest are deeply influenced by BREEAM [20].

2.4 The Life Cycle Costing (LCC) Analysis

Life cycle costing (LCC) is significant element with respect to cost related phenomena. LCC was initially introduced by the US Department of Defence for procurement purposes [41]; still it is widely used in most of the military and construction sectors as well [42]. This LCC tool provides prior information of the cost related items for every project and stage. Though the adaptation of the LCC has been found very minimum and low paced in many other industries due to the fact of low knowledge in the utilization of this tool [43]. In line with the above statement, low interest and lack of knowledge of this tool is one of the factors. Construction industry has been lacking behind in utilization this dynamic tool within construction projects. However, LCC has to be the firm choice in the built environment projects with the focus starting from the design phase to demolition phase and it must be utilized to optimize cost efficiency and assets value [18]. LCC not only incorporated to manage costs related items but also help to manage the project from start to end in a better way. Many researchers assert that the LCC is a focused approach of early stages that intends to examine total expenditure of a project by evaluating cost associated to all the phases throughout its entire life cycle [44]. Cost has been a premium factor within the construction industry and it plays superficial role in revitalizing the concept of green development by using more money to get better, effective and efficient building called as “Green Building”. This adds up an outstanding and robust way of development that is sustainable for this and future generations as well. LCC takes into account three costs effectively design cost, construction cost and operation and maintenance cost. Thus, at very first research and development (R&D) stage to salvage stage it idealize the worth of the building [45,46] as mentioned in Figure 4. In accordance with the R&D stage LCC provide a venue to understand cost related to complete project and can compare green and traditional buildings. Chakravarty and Debnath [45] asserted that LCC performs its best in decision making processes for all the aspects in every project and industry.
3. Methodology and Research Development
The sustainable development has acquired a great applause and success in past from developed to developing countries but soon after the economical turmoil throughout the world, investors are lacking interest in green building development. The in depth critical literature review of journal articles, thesis’s, books, reports published, and conference proceedings lead to a problem formulation, “how to attract more investors and developers towards green buildings”. Thus, after problem formulation and identification it needs to be solved by a holistic approach. An approach that sustains the credibility of rules, agenda and strategies set by government agencies and provides a sustainable way on return on investment, level of certification and cost of a green building. To solve such a problem the initial steps were carried out at the beginning the research from identifying the problem, determining research area, aim, objectives and scope of the research study followed by significance and novelty of the research as mentioned in Figure 6.

In accordance with the aim to develop web based automation of green building rating index and life cycle costing. Some of the objectives were developed in which firstly MyCrest green building rating tool developed in 2016 has been selected for this research. Therefore, MyCrest elements and criteria are analysed that are to be integrated with life cycle costing elements (NPV, FV, and PV). Significantly, MyCrest tool has three certification stages, Design stage certification, Construction stage certification and Operation and Maintenance (O&M) stage certification. Solely, MyCrest tool is consist of 11 major elements all are emphasizing on the sustainable green building development. However, each element has other criteria to achieve points of the elements within three stages. Moreover, Design stage has 63 major criteria’s followed by Construction stage certification that has 45 major criteria’s and then O&M has 39 major criteria’s. Though, some of the elements and their criteria in each section do not qualify as a costing factor therefore those will be segregated. The followings Figure 7 depicts the detailed flow chart of the research study methodology; this vital framework of the research is to achieve objectives set for study.
Followed by the objectives, this research will tend to integrate LCC into the MyCrest tool; this will provide the novel of cost and score for the green building assessment. Once the green building score is achieved it will lead towards the level of certification for MyCrest (Green Building Assessment). This whole process will further append to accomplish return on investment element of the research which will help investors and developers to gain more attention towards green building development. In addition, proposed research will develop web-based automated analog computerized program which help in decision making of a project from research and development (R&D) stage to final stage. The qualitative and quantitative methods have been considered as a research method for achieving the aim and objectives of the research. Under qualitative method, this research is seeking to identify and develop integrated web-based automation tool for the green building rating index MyCrest and life cycle costing which will be further validated by qualified professional. Though, for the quantitative method, content analysis method, critical literature review along with selective literature review will be used. However, the expert reviews by interview session will be done by the Qualified Professionals (QP) of the green building rating assessment tool recognized by the regulatory body to know applicability of the tool. Moreover, questionnaires will be distributed amongst industry practitioners for the design standard framework validation as the respondents that will elucidate the pertinence of the automated tool in real time projects. Once the tool is developed then it will be commercialized and if necessary a pilot project can be developed as a case study.

**Figure 5. Interoperable Structural Functionality of the Research**
4. Findings and Conclusion

There is a deficit of decisive actions to embark on green building at higher pace. Investors and developers are hesitated to move farther for green building development due to the lack of automated tools within construction industry. Significantly, there is lack of automated green building rating assessment tool integrated with life cycle costing in the available green building research. This research proposed to develop new framework tool for MyCrest-LCC transformed into web-based automated analog computerized programming which fills the gap of green building rating assessment tool and life cycle costing. This MyCrest-LCC tool will bring a new innovative approach towards the green building development and construction industry. This integrated tool will also give efficient, easy, quick and better platform to calculate cost, score, and level of certification more importantly return on investment. It will cut the project and green managers preliminary work, which effects on the reduction of building planning timeline and cost and will also provide better decision making and strategic planning. The research will develop new trend and technique of automation in green building technology in compliance with life cycle cost analysis. This automated MyCrest-LCC tool will also help investors in their decision making to calculate their initial and future costs in a systematic automation. Such type resilient green technology potentially can build human to move faster, robust, and transparent in strategizing projects decision making and can be adopted by governmental agencies locally and globally.
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