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Decision making tool for retrofitting of existing building for energy reduction in higher learning institution

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Decision making tool for retrofitting of existing building for energy reduction in higher learning institution

N I A Abidin[1], R Zakaria[1]*, E Aminuddin[1], S M Shamsuddin[2], M Mustafa[1] and J S Khan[1]

[1]School of Civil Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, Johor Bahru, Malaysia
[2]Faculty of Built Environment and Survey, Universiti Teknologi Mara, Shah Alam, Selangor, Malaysia

*Corresponding Author Email: rozana@utm.my

Abstract. Retrofitting of existing building in Higher Learning Institution (HLI) has becomes the priority action due to the concern to improve the current energy utilization and indirectly to overall environmental impact. However, prior to retrofitting, it is crucial to evaluate several factors because it's dealing with complex process such issues of design, type of green technologies and system efficiency which regards to decision making in order to ensure the achievement of realistic and rational solutions. This paper highlights a development of decision-making tool for retrofitting of existing building for energy reduction known as Multi-Criteria Retrofitting Building Energy Efficient Building (M$_C$REEB). M$_C$REEB helps to directly indicate the type of practice (best practice, good practice, moderate practice and basic practice) and preferences (exemplary, proficient, apprentice and novice) based on the weightage achieve and the number of criteria selected. Two case studies on building which is M50 Faculty of Civil Engineering and T05 Faculty of Science at Universiti Teknologi Malaysia were used to assess the utilization of M$_C$REEB tool. The assessment considered all relevant retrofitting criteria which identified in this study. The radar chart is cast to portray the most likely influence of criteria during the decision of retrofit. Lighting and occupancy sensor are among green technologies used for retrofitting in the case studies, and its response to criteria of design, economic, environmental, occupants comfort, building physical and technical. This study contributes to the stakeholders in HLI, building industry professional, national or international organization who preferred to ops for sustainable building practices. McREEB provide a way to conduct retrofitting idea through the assessment criteria which would benefit to the actual implementation and aid the decision makers in retrofitting evaluation.

1. Introduction

Higher Learning Institution (HLI) is a commercial building stock consists of universities and colleges which known to have high energy consumption, especially from electricity. It often becomes a subject to foster an action to lower the energy use by increasing the building energy efficiency such as an installation of efficient HVAC technology, improve the building envelope by replacing the existing window, new window insulation and many others [1]. The need for improvement with the current energy condition in university campuses has been addressed by many due to their physical structures and activities contribute to negative impacts on the environment. For that reason, retrofitting has

become part in devising ways to transform the HLI into sustainable university and directly contribute to the world [2]. The implementation of retrofitting has been given much attention through awareness and establishment of successful case studies portfolio, however, the focus on the decision making process as part of energy efficiency investment to give benefit for the owner, asset manager and occupants is still lacking [3]. Since retrofitting involve the adoption of innovative technology, it is usually encountered with an issue to achieve for long term reliability and effectiveness. Besides, with every proposed retrofitting technology, there are many factors require to consider such as financial, environmental, social, energy, risk and many others in order to maximize the retrofitting achievement and to deliver the best solution that satisfies the owner, user and occupants [4]. For that reason, decision making in retrofitting helps to provide the best possible range of options to choose that enables to offer for long term plans of retrofitting investment towards in achieving for energy saving [5].

2. Retrofitting in higher learning institution

Retrofitting is defined as to make changes to the interior space of the building systems and also to its structure after the building has been occupied. It is typically conducted with an expectation to improve building performance and occupants amenities [6]. Retrofitting involves activities such as replacement with existing light fitting, changing the heating system, installation of control system [7]. According to [8]. The implementation of retrofitting capable to offer the owner with the benefits of investment since it involves an improvement of environmental, energy and air quality performance.

There are several studies focused on retrofitting in HLI by implementing various improvement in their existing building campus. Usually, the campus energy demand is influenced by its existing components such as lighting, mechanical system and building envelope. Improvement with lighting system can be conducted through integration with daylighting, installation of sensor or conversion to high performance lighting. Whilst for building envelope can be retrofit with shading, glazing, painting and insulation [9]. Table 1 shows the summary of retrofitting initiatives which commonly implemented in HLI building.

Table 1. Retrofitting initiatives in existing HLI building.

Retrofit Initiatives	Lighting	Ventilation	Wall	Window/glazing	Floor	Shading	Occupancy sensor	Roof/atrium	Daylight	Solar	Heat Pump
1. Izmir Institute of Technology [10]											√
2. Northern California campus [11]	√										
3. Tianjin Campus [12]											√
4. Brescia Smart Campus [13]		√	√			√		√		√	
5. National University of Singapore [14]	√	√	√					√			
6. University Campus in Toronton, Canada [15]								√			
7. Northern Italiy [16]	√	√	√					√		√	
8. University of Sannio [17]		√	√					√			
9. Highfield Campus University [18]										√	√
10. Massachusetts Institute of Technology [19]	√							√			

Legend:

|					
Lighting	Solar	Window/glazing	Heat Pump	Refrigeration	Daylight
Ventilation	Roof/atrium	Occupancy sensor	Shading	Wall	Floor

3. Decision making in retrofitting

Decision making is a process to select for the best alternatives based on the presence of multiple criteria. The decision is relying on the decision maker's values and preferences especially when involving with investment, economic evaluation, project evaluation and others [20]. Building retrofitting is conducted with various reasons such as to reduce energy usage, improvement in indoor quality, to improve the user's level of satisfaction with the building condition. When the reason has been clarified, it will influence the process of decision making development, such as consideration with the energy savings potential, economic assessments, architectural, technical information and technologies involved. The best decision could be obtained through an expert's but for optimization purpose, the selection of alternatives or criteria could be implemented through the development of databases, intelligent technology and decision support system [21]. According to [22], since some retrofitting has to involve with refurbishment works, it has numerous choices and decisions to take into account. The decision making is crucial for the owner to minimize the project cost but at the same time has to achieve the quality standard requirement, the adoption of technology which satisfies the need, architectural features and comfort requirements. [23] mentioned that the possible challenges faced by the decision makers during the retrofit decision making are to deal with some uncertainties include the changes of human behaviour, building market value, limitation with financial, possibility with operation interruptions and long payback periods. The effect of these uncertainties is with successfulness of the project and to make an optimal selection for strategy in retrofitting.

4. Method

The decision making tool of McREEB was developed by using Microsoft Excel 2010 which act as a calculator that consists drop-down list of criteria(s) and the weightage. The result of the selection able to produce the categorization which indicated as Practice and Preferences. There are four types of Practice namely; Best Practice, Good Practice, Moderate Practice and Basic Practice. Each of the Practice has its own level of Preferences vary from Exemplary, Proficient, Apprentice and Novice. The flow in conducting the McREEB can be seen in figure 1.
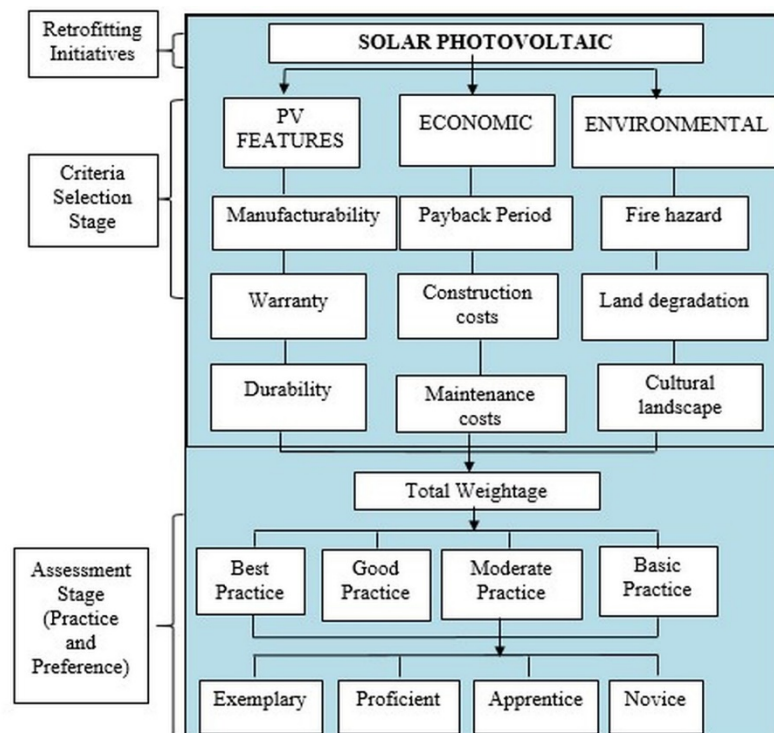
Figure 1. Flow of decision making process in retrofitting.

Referring to figure 1 the McREEB is firstly conducted by choosing the required retrofitting initiatives (i.e: solar photovoltaic, shading devices, sensor and etc). Secondly, is the selection with the provided main criteria and sub-criteria. A weightage from Weightage Factor will be produced based on the sub-criteria selected and its total weightage value will give an indication of the Practice Category. Best Practice indicated that the decision makers achieve for highest weightage, whilst Good Practice is when the weightage achieved is above the intermediate level in which, lower than the Best Practice. After that, Moderate Practice is at an intermediate level whereby the weightage is much lower in comparing to the Practices above. Lastly, Basic Practice demonstrated as it is at the lowest weightage from the criteria selected.

All of the Practice Category is categorized based on score ranges by using the class interval method. According to [24], the class interval helps to determine the interval boundary by adopting a few steps. Firstly is to determine the desired maximum and minimum score. In this research 100 is used as a maximum score and 1 as minimum score. Secondly is to determine the class interval which is four that represents four Practice Category. Through identification of all the required information, the following formula can be applied:

Class interval = (Maximum score – minimum score) / number of interval class
= (100 - 1) /4
= 25

Following the result achieved from the above formula, the third step is to set the interval boundaries by taking the minimum score and class interval using the formula below:

Interval boundaries = minimum score + class interval
= 1 + 25
= 26

Therefore, the indication of Practice Category score ranges as per table 2. Towards in achieving for Best Practice, the weightage should be in a range of 81-100%, Good Practice is 54-80%, Moderate Practice is 27-53% and Basic Practice is 0-26%.

Table 2. Retrofitting initiatives in existing HLI building.

Practice	Score
Best Practice	100-81
Good Practice	80-54
Moderate Practice	53-27
Basic Practice	26-0

Subsequently, the Practice category is linked to the Preference category that consists of exemplary, proficient, apprentice and novice whereby it is influenced by the total number of sub-criteria selected. Exemplary occurs when decision makers select for a maximum number from the produced sub-criteria. Whilst Proficient happens when there is a reduction with the number of sub-criteria selected after exemplary. Then, further reduction with the number of sub-criteria falls into the category apprentice and novice.

All of the process mentioned above has been developed with an automated tool by using Microsoft Excel 2010 known as Multi Criteria Retrofitting Energy Efficient Building (McREEB). The purpose is to aid the decision makers from manually conducting the mathematical calculations in which, the final weightage will be produced automatically based on the selection made toward the sub-criteria. This also helps to directly provide an indication to the decision makers which type of Practice and Preference Category that they achieved. Figure 2 illustrates the format of McREEB which produced from Microsoft Excel 2010. The tool is developed based on the Steps of Sustainability(SBS) Initiatives that consist of 13 lean energy initiatives varies from daylighting, glazing, shading, green roof and others; 4 green technology initiatives such as occupancy sensor, lighting, automatic daylight harvesting and variables frequency drives. Lastly is for clean energy initiatives that consist of solar photovoltaic, wind turbine, geothermal heatpump and small-scale hydropower.
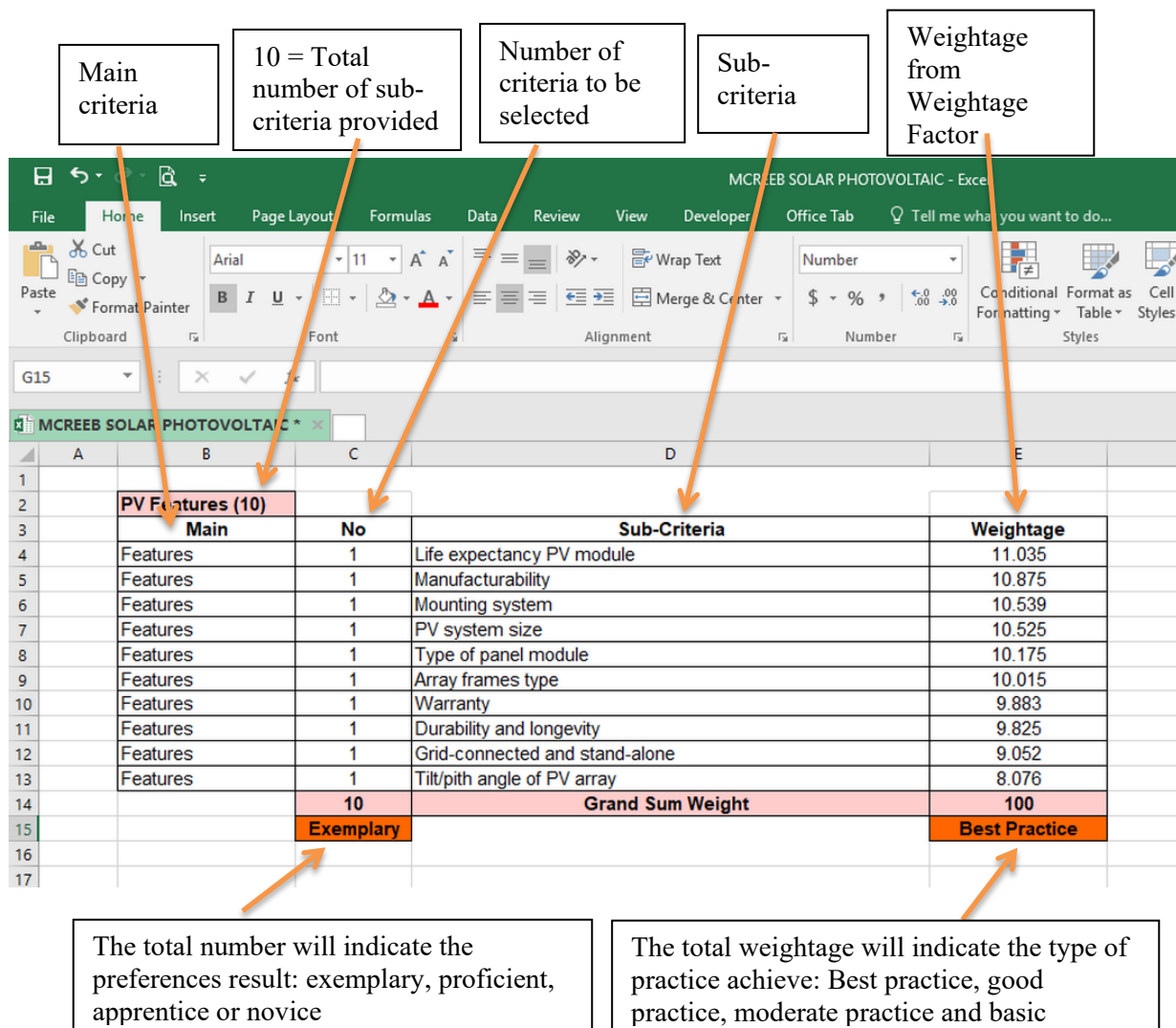
Figure 2. Format of McREEB.

5. Analysis and results

5.1. McREEB utilization in a case study

Based on the establishment of McREEB tool, two case studies building has been selected at existing HLI.which is M50 building School of Civil Engineering and T05 building Faculty of Science, Universiti Teknologi Malaysia (UTM) in order to test the tool for real scenario application of retrofitting in a building. It is because both of these building has become among the pioneer and involve with retrofitting implementation in UTM as an effort towards energy reduction. Therefore, testing the tool allows in exploring and to get insight with the criteria that have been taken into account that influence the building successful approach in their retrofitting implementation.

With that, McREEB tool was developed based on the existed retrofitting initiatives at the two case buildings which is motion sensor and lighting. It requires the Engineers and Assistant Engineers in Office of Assets and Development, UTM who has experience with the retrofitting process in the case studies building to make selections with the criteria that have been taken into account during the decision of retrofitting. The selection made able to indicate which type of Practice and Preference

category achieved. The overall criteria results are portrayed in a radar chart to see the most likely influence criteria.

5.1.1. Utilization of McREEB Tool for Decision Making in Retrofitting of M50 Building Faculty of Civil Engineering, UTM. The development of McREEB tool for M50 building is for motion sensor and lighting that represents the retrofitting features existed in the building. For the motion sensor, the retrofitting has more focuses on the main criteria of technical, economic, physical, and occupants. Whilst, for lighting it focuses on the main criteria of design, economic, ballast features, environmental and visual comfort. The detail of the result that consists of its sub-criteria, weightage, Practice and Preference results are tabulated in table 3 for motion sensor and table 4 for lighting.
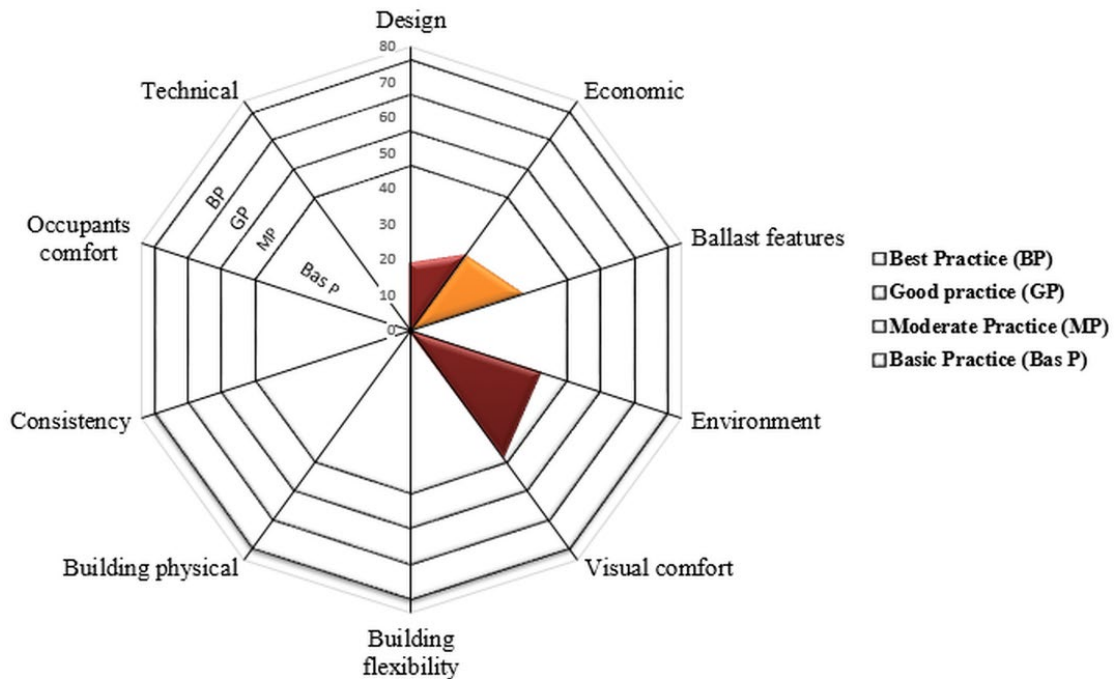
Table 3. Results of McREEB tool utilization for Motion Sensor for M50 building.

Motion Sensor			
Main Criteria	Sub-Criteria	Weightage	Practice and Preferences Results
Technical Criteria	The time delay or cycle time	7.622	
	Supply circuit layout	10.766	Moderate Practice- Novice
	Device sensitivity pattern	11.229	
	The life span/ service	10.617	
	Grand Sum Weight	**40**	
Economic Criteria	Energy and cost saving	17.550	Moderate Practice- Apprentice
	Initial cost	17.397	
	Grand Sum Weight	**35**	
Physical Criteria	Determine the room size of the space	18.444	
	Occupancy pattern	14.963	
	Requirement for extensive rewiring	16.770	Moderate Practice-Proficient
	Grand Sum Weight	**50**	
Occupants Comfort Criteria	Comfortability and convenience	50.727	Best Practice-exemplary
	Acceptance and satisfaction	49.270	
	Grand Sum Weight	**100**	

Table 4. Results of McREEB tool utilization for lighting for M50 building.

Lighting			
Main Criteria	Sub-Criteria	Weightage	Results
Design Criteria	Lighting quantity	6.342	Basic Practice- Novice
	Integration with daylight harvesting	5.693	
	Compliance with code of practice	7.199	
	Illuminance	6.591	
	Grand Sum Weight	**26**	
Economic Criteria	Initial cost	11.360	Basic Practice-Novice
	Energy and cost saving analysis	11.750	
	Grand Sum Weight	**23**	
Ballast Features Criteria	Energy use for proposed ballasts	13.150	Moderate Practice-Novice
	Ballasts operating type	16.754	
	Grand Sum Weight	**30**	
Environmental Criteria	Reduce the carbon emission	13.959	Basic Practice-Apprentice
	Grand Sum Weight	14	
Visual Comfort Criteria	Light flickering level	23.873	
	Uniformity of lighting	17.418	Moderate Practice-Proficient
	Grand Sum Weight	**41**	

Both of the result of the main criteria for motion sensor and lighting derived from the McREEB tool being plotted into a radar chart towards in viewing the most important criteria considered and the overall level of Practice. The result illustrated in figure 3 and it shows that the overall retrofit implementation in this building is more likely to the consideration of environmental, economic and design criteria which falls into the Basic Practice category.

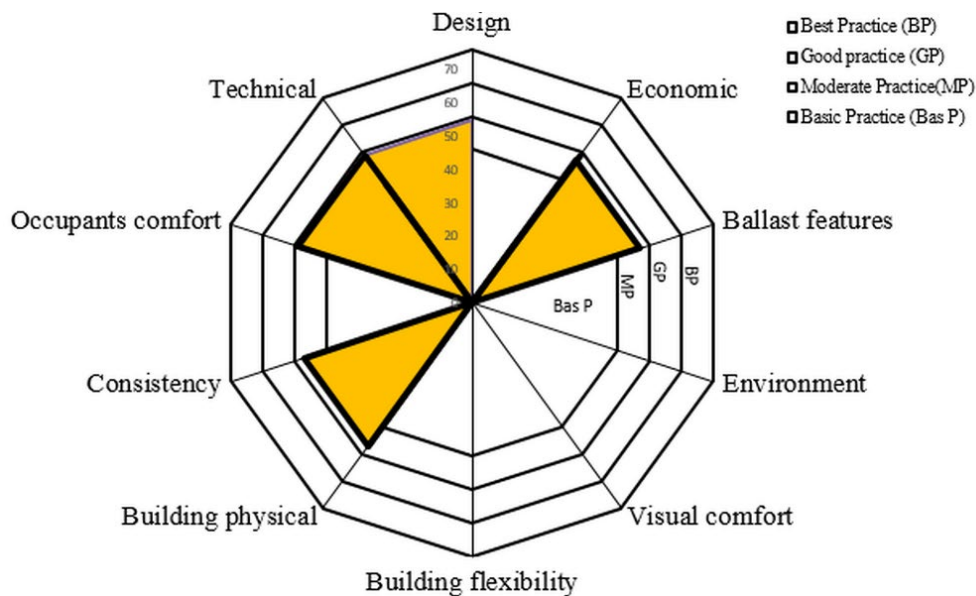**Figure 3.** The overall decision making result for M50 building.

5.1.2. Utilization of McREEB Tool for Decision Making in Retrofitting of T05 Building Faculty of Science, UTM. For T05 building, the McREEB tool was developed for motion sensor which represents as the retrofitting features existed in the building. The result with the selection of main criteria, sub-criteria, its practice and preferences as tabulated in table 5.

Table 5. Results of McREEB tool utilization for motion sensor for T05 building.

Motion Sensor			
Main Criteria	Sub-Criteria	Weightage	Practice and Preferences Results
Technical Criteria	The time delay or cycle time	7.622	
	Device sensitivity pattern	11.229	Basic Practice-Novice
	Grand Sum Weight	19	
Economic Criteria	Expected average energy and cost saving	17.550	Moderate Practice - Proficient
	Initial cost	17.397	
	Operation and maintenance cost	15.936	
	Grand Sum Weight	**51**	
Occupants Comfort Criteria	Comfortability and convenience	50.727	Moderate Practice - Novice
	Grand Sum Weight	**100**	

In order to view the overall important criteria that have been taken into account for the retrofitting of T05 building, the result was also illustrated in a radar chart by plotting the result derived from the selected criteria and this can be seen in figure 4. The overall decision of retrofitting in this building is more likely to focus on the economic, building physical, occupants comfort and technical criteria which all falls into the category of Moderate Practice.

Figure 4. The overall decision making result for T05 building.

6. Conclusion

Upgrading the existing building through retrofitting method can lead to the issue in deciding the best way for the implementation. It requires consideration with several important factors that have to be carefully chosen to ensure the goal of retrofitting are achieved. Since every building has its own unique features, it has a major influence on the decision taken in retrofitting. Therefore, the development of decision making criteria enables to have a rational selection and to decide what is important or priority to ensure in delivering the best for the project. The establishment of McREEB tool for retrofitting in HLI provides an informative approach and become an assistant during the decision making process by dealing with all the criteria provided. When the decision makers insert the criteria(s) that are related to the condition of their retrofit project, it able to attract owners to pursue with the project and assists to give them overview with the expected output.

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