Benefits of greening existing buildings

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Abstract. ‘Greening existing buildings’ is an approach to apply the principles of green building to old and existing buildings with environment responsive and energy efficient ‘green features’ or devices, e.g. through retrofitting, as and when required. It allows considerable reduction of energy consumption and greenhouse gas emission. However, the practice is not getting momentum, especially in Brunei. A study was therefore undertaken to generate and/or gauge the awareness of ‘greening existing buildings’, through identifying and assessing the key benefits of greening existing buildings. This paper presents the outcomes of 68 responses from an ongoing questionnaire survey of mainly clients and consultants. 15 benefits were identified, with “reduced energy/electricity consumption” topping the list, and “increase in building occupancy/usage rates” at the bottom. All the 15 benefits were found to be significantly important, both in the total sample, as well as in the groups of clients and consultants, and people with or without experience of green building. The two-way grouping also revealed that the above paired groups significantly showed their importance of different benefits in the same way. The outcomes are therefore considered as a general consensus of the respondents on the benefits of greening, despite some disagreements on the relative rankings of individual benefit by different groups of respondents. The outcomes are largely similar to elsewhere, and show a general awareness of the respondents to the overall benefits of greening existing buildings. Such outcomes are expected to inspire the clients to undertake more greening projects to demonstrate proven benefits. This is expected to help wider use of greening existing buildings in Brunei and elsewhere and thereby implement sustainable development.

1. Introduction

Buildings are responsible for degrading environment in many ways, e.g. they consume about 40% of world energy and use more than two-thirds of electricity [1-2], and generate about one-third of all CO2 emissions [3]. The concept of green building attempts to address these consequences, especially to ensure energy efficiency. This is approached through the practice of various environmentally responsible and resource-efficient processes throughout the life-cycle of a building, i.e. selecting location of the building, design, construction, operation, maintenance, renovation and deconstruction [4]. Such concept, along with its relevant design dimensions (e.g. energy and material conservation measures) and methodologies are relatively new [5]. These are incorporated by extensive analysis of architectural, structural and passive design strategies, along with green and project and/or client related design dimensions, and with the application of BIM (Building Information Modelling) [6]. Clearly, this can only be done when constructing new buildings.
On the other hand, there exists a vast stock of old buildings, which consume relatively more energy and water compared to green buildings [7]. According to Xu and Chan [8], 95% of the existing buildings are high-energy consumption buildings. Those buildings were constructed with less energy efficient and older technologies, before the concept of green building had developed and the consciousness had begun for agendas like preserving energy and natural resources and reducing the risk for climate change [9]. Many of those buildings are still economically viable, so not suggestible to demolish for preserving energy and improve the risk for climate change. Demolishing old buildings and constructing new buildings will need huge capital investment and more natural resources, which is uneconomical and grossly contrary to sustainable development [10].

The alternative is to greening existing buildings, i.e. to equip the existing buildings with ‘green features’, as and when suitable, with newer technologies and/or improved approaches, which are cost-effective and more energy efficient [10-11]. Saving potential (e.g. energy) is very high, as more than 80% of building life-cycle energy consumption occurs during the occupancy stage [12]. This may require renovations, retrofits, installations, or system upgrades, as well as the implementation of best practices and sustainable policies for operations and maintenance. For example, building system upgrade may include: replacing the boiler, chiller and water fixtures, upgrading lighting systems, and installing a building automation system [13]. Different shading device types are also available now-a-days to improve building energy performance, e.g. overhangs [14], external roller shades [15], venetian blinds and internal shading [16]. Such movable solar shading devices significantly improve energy performance and indoor thermal and visual comfort of the building [17].

The benefits of greening existing buildings have been reported to be many-fold, e.g. in terms of reduction of energy use, water consumption, waste generation and emissions; savings costs in operations and maintenance; and gains in productivity and health benefits [18]. Electricity consumption of a retrofit office building in Tianjin, China for heating, cooling and annual electricity consumption was reduced to 47%, 36% and 43%, respectively, compared to the office buildings of similar scale of the same city [19]. Due to such demonstrated benefits, the ‘movement’ of greening existing buildings through retrofitting and renovations, and installations or systems update, is gaining increased popularity globally. However, contrary to this trend, the movement is not getting momentum in Brunei, despite some initiatives taken by the government in partially retrofitting a few public office buildings. It was therefore decided to gauss the general awareness of the local construction industry towards greening existing buildings, through the perceptions of a cross-section of industry participants on benefits of greening existing buildings, as presented in the next section, outcomes from an ongoing survey.

2. Awareness of greening existing buildings

2.1. Questionnaire survey

A questionnaire was developed on the basis of a relevant segment of literature. It was then improved with the feedback from two construction industry experts, who had experience in both constructing new green buildings, and greening existing buildings, e.g. through retrofitting and green roofing. A total of 110 questionnaires were distributed to different groups of industry players, by visiting office and/or work sites of clients, consultants/architects, contractors, and quantity surveyors. The Ministry of Development (MoD) and Public Works Department (PWD) were also requested to distribute the questionnaire to their technical staffs. In order to increase the number of responses and develop interest, potential respondents were offered summary results of the survey. Although more responses are expected, this generated 68 responsive responses from the ongoing g survey: 33 from clients, 27 from consultants, and 8 from others, i.e. contractors and quantity surveyors. Cliental respondents are mostly engaged with repair and maintenance, energy efficiency and conservation, strategic planning, and architectural design of buildings. On the other hand, 37 respondents had some degree of experience in green building or the green building concept (ranging from 1 year to 15 years), 29 respondents had no experience, and 2 respondents did not mention if they had any experience. The
response rate cannot be precisely determined, since MoD/PWD sent the questionnaire through a single email to cover all their technical staffs, and the relevant responses formed the majority of the ‘client’ group. Moreover, the number of responses received from a few organizations was more than the number of questionnaire supplied to them. On the whole, the average experience of the respondents in construction was 9.9 years. Hopefully, this would show the quality of the responses.

The survey collected opinion of the respondents on 15 benefits of greening existing benefits, which are shown in tables 1-3 in their entirety. Respondents were asked to score the listed 15 benefits in terms of their ‘degree of benefit’ on a scale from 1 to 5: 1 being the ‘least benefit’ and 5 being the ‘most/highest benefit’. The average scores of individual benefits by different groups of respondents were computed and ranked. They were then compared between the groups of (a) ‘experienced’ in green building (37 respondents), and ‘no experience’ in green building (29 respondents); and (b) clients (33 respondents) and consultants (27 respondents). One-sample t-test was used to examine the consistency of the responses, and one way ANOVA was used to compare the means between different groups of responses (tables 2 and 3).

The one-sample t-test of the means was conducted at 95% confidence interval within the groups of total sample, clients, consultants, ‘with experience’, and ‘with no experience’. All the results were found as .000 (i.e. less than 0.05), indicating that the mean values are significantly important and that the respondents consistently assessed the importance of the 15 benefits in the similar way. Since all the values were .000, those results are not shown here for space restrictions.

2.2. Perceptions from total sample

Table 1 shows the perceptions of the respondents on 15 benefits within the total sample. It shows a general awareness of the respondents on the key benefits of greening existing buildings, with higher average of importance ranging from 4.07 at the top, and 2.96 at the bottom. ‘Reduced energy/electricity consumption’ with a score of 4.07 appears to be the most important benefit of greening existing buildings, followed by ‘resultant reduced impact on the climate change’ with a score of 3.80. ‘Improvement in indoor air/environment quality’ and ‘Resultant reduced impact on environment for GHG/CO₂ emission’ jointly ranks 3 with a score of 3.79. ‘Resultant reduction in environmental pollution’ ranks 5 with a score of 3.78, while ‘Improvement in indoor health & safety and hygienic situation’ ranks 6 with a score of 3.76. These are also the benefits that are frequently advocated through various means, e.g. Building and Construction Authority, Singapore [18], USGBC [20-21], different organizations [22-23] and academic publications [24-25].

| Description of the benefits                                      | Average | Rank |
|-----------------------------------------------------------------|---------|------|
| Reduced energy / electricity consumption                        | 4.07    | 1    |
| Resultant reduced impact on the climate change                  | 3.8     | 2    |
| Resultant reduced impact on environment for GHG/CO₂ emission    | 3.79    | 3    |
| Improvement in indoor air / environment quality                 | 3.79    | 3    |
| Resultant reduction in environmental pollution (i.e. air & water)| 3.78    | 5    |
| Improvement in indoor health & safety and hygienic situation    | 3.76    | 6    |
| Improvement in indoor working environment and productivity      | 3.67    | 7    |
| Conservation of non-renewable energy (e.g. fossil fuels)        | 3.66    | 8    |
| Improvement in dwelling quality of life                         | 3.51    | 9    |
| Reduction in cost due to reduced energy consumption             | 3.51    | 9    |
| Increase in building value                                      | 3.42    | 11   |
| Conservation of construction materials, e.g. not building new   | 3.3     | 12   |
| Savings of money / capital expenditure, e.g. not building new   | 3.03    | 13   |
| Reduced operation and maintenance cost of buildings             | 2.97    | 14   |
| Increase in building occupancy/usage rates                      | 2.96    | 15   |
So, respondents seem to have developed a keen understanding on greening existing buildings. Nevertheless, the mind-set of the respondents seems to be skewed on the ‘reduced energy/electricity’ consumption. This benefit not only tops the list, but also its difference from the other benefits are considerably high (i.e. 4.07 – 3.80 = 0.27), despite the fact that ‘climate change’, ‘indoor air quality’, ‘GHG emission’ and ‘reduction environmental pollution’ are all relevant to each other. These are frequently mentioned whenever there is any argument favouring green building, which might have shaped the perception relating to constructing new buildings.

‘Improvement in indoor working environment and productivity’ (score 3.67) and ‘conservation of non-renewable energy’ (score 3.66) took place in the middle of the table with ranks 7 and 8, respectively. ‘Reduction in cost due to reduced energy consumption’ and ‘Improvement in dwelling quality of life’ jointly rank 9 (score 3.51). These two, along with ‘increase in building value’ (rank 11), and ‘conservation of construction materials’ (rank 12) appear to be relatively less important benefits, indicating these are relatively ‘less known’ benefits and the respondents are not well aware of them.

On the other end of the table, ‘savings of money/capital expenditure, e.g. not constructing new building’ appears to rank 13 with a score of 3.03, ‘Reduced operation and maintenance cost of buildings’ ranks 14 with a score of 2.97, while ‘Increase in building occupancy/usage rates’ appears to be the least important (i.e. rank 15) factor with a score of 2.96. These relate to the existing stock of buildings, which can only be benefitted through greening. The average scores revolve around the mean of the measuring scale (i.e. 1 to 5), indicating their general importance, with relatively less importance than the benefits relating to constructing new ‘green buildings’ in general, despite the higher and attractive monetary savings from retrofitting (i.e. greening existing building) [19], and realisation of investment in greening from savings during a set pay-back period [13]. Such perception has been interpreted to have shaped from the mind-set that ‘sporadic’ benefits elsewhere may not be equally suitable and applicable globally.

Also, construction (including retrofitting and renovation) is one time ‘heavy investment’, so clients (who are mostly home owners and one-time clients) are suspicious of any major investment without any tried and trusted benefit. Some kind of proven or trusted demonstration seems necessary. If so, probably government is in a better position, since they can supply the much needed capital for greening projects for existing buildings through retrofitting or renovation, as and when necessary. This is expected to motivate various government departments and other private and single clients to uptake greening projects widely, and thereby contributing towards sustainable development.

2.3. Comparing perceptions between experienced and inexperienced respondents on green concept

Table 2 compares the perceptions of the respondents with, and without, the experience of greening concept, along with ANOVA results conducted at 95% confidence interval that examines if the two groups of respondents significantly agree of the importance of the benefits. It is seen that, in general, the ‘experienced’ respondents have rated the reported benefits on a higher scale than their ‘no experience’ counterparts. The range of the scores from ‘experienced’ respondents varies from 4.21 to 2.95 (i.e. 1.26), compared to those with ‘no experience’ respondents from 3.90 to 2.93 (i.e. 0.97). However, the pattern of the ranks of individual benefits within both the groups of respondents is similar, except two benefits. ‘Resultant reduced impact on environment for GHG/CO₂ emission’ ranks 2 within the group of ‘experienced’ respondents, compared to rank 7 within the group of respondents with ‘no experience’. And, despite very close score of 3.79 and 3.72, ‘improvement in indoor health & safety and hygienic situation’ is ranked 7 and 2 by the respondents with, and without, experience groups, respectively.

On the other hand, ANOVA results show that significance levels of 14 benefits are more than 0.05, i.e. both the groups of respondents assessed the importance of these benefits in the same way. Two groups of respondents only disagreed on the importance of only one benefit. So, the results can be taken to have expressed in the similar way by both the groups of respondents, i.e. there is an overall consensus on the importance and relative importance of individual benefits.
Table 2. Comparing the perceptions of ‘Experienced’ and ‘No experience’ groups.

| Description of the benefits                                                      | Experienced Average | No Experience Average | ANOVA |
|---------------------------------------------------------------------------------|---------------------|-----------------------|-------|
| Reduced energy / electricity consumption                                        | 4.21 1              | 3.90 1                | .817  |
| Resultant reduced impact on environment from GHG/CO2 emission                   | 4.05 2              | 3.45 7               | .102  |
| Resultant reduced impact on the climate change                                  | 4.00 3              | 3.55 5               | .287  |
| Improvement in indoor air / environment quality                                 | 3.95 4              | 3.59 4               | .235  |
| Resultant reduction in environmental pollution (i.e. air, water, etc.)         | 3.90 5              | 3.62 3               | .061  |
| Conservation of non-renewable energy (e.g. fossil fuels)                       | 3.85 6              | 3.41 8               | .239  |
| Improvement in indoor health & safety and hygienic situation                    | 3.79 7              | 3.72 2               | .217  |
| Improvement in indoor working environment and productivity                      | 3.79 7              | 3.52 6               | .428  |
| Improvement in dwelling quality of life                                         | 3.68 9              | 3.28 10              | .639  |
| Reduction in cost due to reduced energy consumption                             | 3.59 10             | 3.41 8               | .602  |
| Increase in building value                                                      | 3.53 11             | 3.28 10              | .084  |
| Conservation of construction materials, e.g. not building new                   | 3.34 12             | 3.24 12              | .292  |
| Savings of money / capital expenditure, e.g. not building new                   | 3.10 13             | 2.93 15              | .588  |
| Reduced operation and maintenance cost of buildings                             | 3.00 14             | 2.93 15              | .011  |
| Increase in building occupancy/usage rates                                       | 2.95 15             | 2.97 13              | .402  |

2.4. Comparing perceptions between client and consultant respondents

Table 3 compares the perceptions between the groups of ‘clients’ and ‘consultants’. Such comparison is necessary as consultants can analyze various greening options, provide investment and (monetary) return outlay, and can suggest a suitable option, but clients to eventually decide on the need for ‘present’ investment, as greening usually incurs higher investment at the first place [10-12].

Table 3. Comparing the perceptions of ‘Client’ and ‘Consultant’ groups.

| Description of the benefits                                                      | Client Average | Consultant Average | ANOVA |
|---------------------------------------------------------------------------------|---------------|-------------------|-------|
| Reduced energy / electricity consumption                                        | 3.91 1        | 4.30 1            | .156  |
| Resultant reduced impact on the climate change                                  | 3.78 2        | 3.77 7            | .963  |
| Improvement in indoor working environment and productivity                      | 3.75 3        | 3.56 9            | .424  |
| Improvement in indoor health & safety and hygienic situation                    | 3.72 4        | 3.81 4            | .686  |
| Conservation of non-renewable energy (e.g. fossil fuels)                       | 3.7 5         | 3.70 8            | .980  |
| Improvement in indoor air / environment quality                                 | 3.67 6        | 4.00 2            | .169  |
| Resultant reduction in environmental pollution (i.e. air, water, etc.)         | 3.67 6        | 3.78 6            | .297  |
| Resultant reduced impact on environment from GHG/CO2 emission                   | 3.66 8        | 3.89 3            | .364  |
| Improvement in dwelling quality of life                                         | 3.63 9        | 3.37 11           | .302  |
| Reduction in cost due to reduced energy consumption                             | 3.45 10       | 3.56 9            | .730  |
| Conservation of construction materials, e.g. not building new                   | 3.31 11       | 3.26 12           | .861  |
| Increase in building value                                                      | 3.22 12       | 3.81 4            | .035  |
| Savings of money / capital expenditure, e.g. not building new                   | 3.12 13       | 2.96 15           | .631  |
| Increase in building occupancy/usage rates                                       | 3.00 14       | 3.04 13           | .891  |
| Reduced operation and maintenance cost of buildings                             | 2.85 15       | 2.96 15           | .692  |
It is seen from table 3 that consultants placed higher scores on individual benefits in general, with a range of scores from 4.30 to 2.96, compared to 3.91 to 2.85 by clients. This can be associated with the fact that the consultants are involved in actual calculations, design and relevant outcomes, which have shaped their perception to a higher level. However, both the groups seem to agree on the ranking of 10 benefits, and disagree on five benefits. The largest disagreement is seen on the benefit ‘increase in building value’: consultants ranked it 4, compared to 12 by clients, which led to the rank of 11 in the total sample (see table 1). This was translated to the reason that consultants know the qualitative aspects of the benefits and their impact on the environment, which clients only know from the reports of the consultants. The smallest disagreement was seen on the benefit ‘improvement in indoor environment/air quality’: consultants ranked it 2, compared to 6 by the clients that led to the rank of 2 within the total sample (see table 1).

For the benefit ‘improvement in indoor working environment and productivity’ clients ranked 3, consultants ranked 9, which led to the overall rank of 7 in the total sample (table 1). Clients ranked 2 and consultant ranked 7 for the benefit ‘resultant reduced impact on the climate change’, and the overall rank in the total sample was found to be 2 (table 1). Lastly, clients ranked 8, compared to rank 3 by consultants, for the benefit ‘resultant reduced impact on the environment from GHG/carbon emission’, with overall rank of 3 in the total sample. All these disagreements were interpreted to have shaped due to the engagement of consultants in the actual calculations and design, and the knowledge of relevant outcomes. On the other hand, ANOVA results show that significance levels of 14 benefits are more than 0.05, i.e. both the groups of respondents assessed the importance of these 14 benefits in the same way. The groups of clients and consultant only disagreed on the importance of only one benefit, which is ‘increase in building value’. This appears to be due to the reason that the score by clients is 3.22, compared to 3.81 by consultants.

On the whole, despite some disagreements on the ranks of individual benefits, and the range of the scores of the identified 15 benefits by different groups of respondents, consultants and clients significantly asserted importance on the 14 benefits in the same way. It can therefore be said that a general awareness has been observed on the benefits of greening existing buildings. However, such awareness is not being practiced widely, probably due to the reason that greening needs considerable investment and construction industry is hesitant to invest in greening without further proven benefits. Demonstration projects are expected to help attract clients to adopt greening existing buildings.

3. Concluding observations

The concept of green building can be applied to old buildings through an approach called ‘greening existing buildings’, by adapting to newer technologies or installing cost-effective and more energy efficient ‘green features’, to offer considerable benefits, e.g. in terms of energy consumption and GHG emissions. However, it is not getting momentum in Brunei. It was therefore decided to identify and assess the benefits of greening exiting buildings of Brunei construction industry participants. A questionnaire survey was conducted using 15 identified benefits of greening existing buildings. It is observed that all the 15 identified benefits are significantly important both within the total sample, and the groups of clients and consultants, and people with or without experience of green building. The groups of (1) clients and consultants and (2) people with or without experience of green building assessed the importance of the benefits in the same way, despite some obvious differences in ranking of individual benefits and their degree of importance by different groups of respondents (i.e. clients and consultants). The ongoing study, as reported here, thus shows a general awareness of the 68 respondents, since the groups of people with, and without, experience of green building expressed their opinion in the same way. This, in turn, shows the motivation of the respondents to practice greening existing buildings, contrary to the actual state of adopting of the practice in industry. It is being suggested here to undertake some demonstration projects by government, and disseminating the outcomes to the public. Such attempt is expected to help wider adoption of greening existing buildings in Brunei. The similar approach may be undertaken elsewhere, to attract relevant segment of clients,
and thereby wider adoption of sustainable development through greening existing buildings, to benefit both environment and society.

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