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Assessment of Smart Buildings in the City of Port of Spain, Trinidad and Tobago: Some Findings and an Approach

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Abstract: *This paper investigates into the levels of smart building (SB) designs, and reports the findings of a recent study on adopting a standalone versus integrated SB strategy in Trinidad and Tobago (T&T) namely the capital city of Port of Spain. It explains the need to initialising a SB Assessment approach and discusses how the approach could incorporate the SB elements into assessing building designs adopted in facilities management and construction sector. Incorporation of a review on various common SB strategies with related developments in T&T, a two-stage methodology comprising a questionnaire survey and a series of personal interviews, was employed to acquire views from building practitioners (including owners, developers, operators, and managers) in T&T. The analysis addressed multiple conditions of building strategies, and identified gaps between the design concepts and performance of SBs in T&T. The findings provided some empirical ground for deriving a five-step SB assessment approach, comprising 1) building governance, 2) defining SB, 3) deriving SB indices, 4) developing component/attributes index, and 5) mapping building design. The proposed SB assessment serves as a practitioners-oriented approach to assess SB solutions in T&T and a wider Caribbean region. Future study would validate the key elements identified for SB designs and strategies of varied residential purposes and commercial/operations nature.*

Keywords: *Smart Buildings, Design, Strategies, Assessment, Trinidad and Tobago*

1. Introduction

The Republic of Trinidad and Tobago (T&T) has had the construction boom in its fifty (50) years of independence, the first in the 1970s and then the 2000s. Many buildings have been constructed, such as the Eric Williams Financial Complex in 1986, the Waterfront Financial Centre, the Hyatt Regency Hotel, the Nicholas Towers, and the National Academy for the Performing Arts in 2009 (Barsatie, 2015). With these multi-million dollar projects, concerns were raised regarding the maintenance and after-life of such buildings over time. These buildings have been adopted some elements of smart building (SB) (or intelligent building (IB) technology either in part or as a whole. Many building owners and tenants also like the idea of ‘green’, but do not necessarily understand various components of a greener building (GBCTT, 2017). In T&T, there exists no national building standard to follow when venturing into SB or IB projects. The present Small Building Guide, TTS 599: 2006 is not suitable for large buildings, and has no information relevant to SB practices (Lalla 2011).

Although there are various rating methods for facilitating SB assessments (Chen, 2006; Ghaffarianhoseini et al., 2016), many building practitioners (including owners, developers, operators, and managers) pay little attentions to the functional variations amongst different types of buildings in T&T (Chen, 2006; Ragbir, 2014). The adoption of SB strategies would reside upon the architects, facility managers or building owners, and these strategies would either be implemented in the pre-design phase and/or post-construction of buildings (Villfana, 2014; Choy, 2014). Moreover, many practitioners would opt not to disclose the SB impact level of their building(s) with respect to any negative image on corporate and social responsibility. Some would even not be able to quantify the impact level of their building(s) (Burke and Ramsumair, 2014). This paper incorporates a review of common SB strategies, and presents the findings obtained from a recent study on the adoption of SB concepts in T&T. A 5-step SB Assessment approach is proposed, and an illustrated case is presented.

2. Notion of ‘Smart’ and ‘Intelligent’ Buildings

The terms, smart building (SB) and intelligent building (IB), are always used interchangeably. While the concept of SB (or IB) has been promoted since the late 1980s, on-going cost reductions in technology, broad deployment of networks and the development and widespread adoption of open standards for building system communications protocols have made these projects viable (Ehrlich and Diamond, 2009; Wang, 2010; Ghaffarianhoseini et al., 2016). Salsbury (2009) advocates that a building is made ‘smart’ through the application of intelligence or knowledge to automate the operations of building systems, which involves the installation and use of advanced and integrated building technology systems.

Although there is no single, universal definition of a SB, there exists an agreement about some of the key elements of the concept (ITU, 2017). Sinopoli (2010) contends that SBs are built on standards which make several characteristics possible: 1) inter-application communication; 2) efficiencies and cost savings in materials, labour, and equipment, and 3) interoperable systems from different manufacturers. These systems include building automation, life safety, telecommunications, user systems and facility management systems. The Asian Institute of Intelligent Buildings (AIIB, 2017) adopted a rating method for assessment with indicators centring on architecture, engineering, environment, economics, management and sociology. The idea of combining information from different systems to implement new and smart strategies extends easily to system groups that traverse traditional boundaries. The general trend is for the operation of systems and appliances to be connected to a common network as depicted in Figure 1.

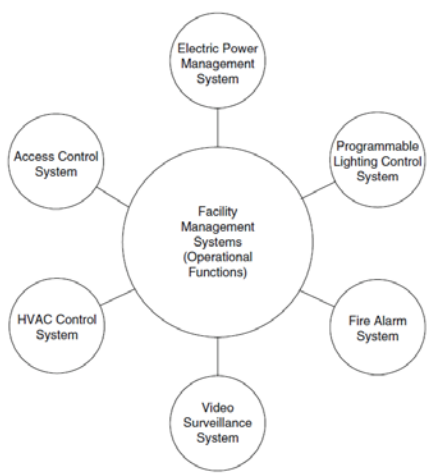

Figure 1: A Common network of SB Management System

SBs encompass a variety of technologies across various types of buildings, including commercial, residential and government buildings (Salsbury 2009). They are designed to leverage such systems as heating, ventilation and air-conditioning (HVAC), cabling, internet access, as well as access and security in the building. Building strategies are not only limited to the way a building has been made smarter, but also include planning, design, construction, commission operating and maintenance (Salsbury, 2009). A key part of the consensus is that SB strategies improve the productivity of people and processes in buildings for the improvement of the facility (Simens, 2013). Optimal building intelligence is the matching of solutions to occupant needs (So, Wong and Wong 1999). These buildings would maintain an effective working environment, run automatic systems and be flexible enough to adapt to future changes in the needs of the working environment (Barsatie, 2015).

3. A Two-Stage Stage SB Study in T&T

In 2015, an exploratory study was undertaken to investigate into the challenges associated with the current SB designs, and identify the factors affecting the SB adoption in T&T (Barsatie, 2015). A 2-stage methodology was employed, comprising a questionnaire survey and a series of personal interviews. Similar approach was adopted by researchers to define the sustainability assessment indicators and their weights in the sustainability assessment of large services buildings (hospitals) in Portugal (de Fátima Castro et al., 2017). For the survey stage, a sample technique advocated by Krejcie and Morgan (1970) was adopted, and a targeted sample of 40 respondents in facilities management and building designs and constructions were determined. The main goal of this purposive sampling was to focus within the capital city, Port of Spain, because of its developed infrastructure in T&T. A set of structured questionnaire was designed, and Likert-scale was employed to facilitate the analysis of findings. Questions being raised varied from number of years' experience in building management, types of systems employed at locations and perceived benefits of the building that were considered just to name a few. Administration and analysis of returned questionnaires was done via the means of Google Survey. For the conduct of personal interviews, a group of targeted building practitioners were invited. Profiling of the participants was undertaken in determining the population decision-making capability within respective organisations.

4. Stage-1 Survey Finding and Analysis

4.1 Response Rate and Respondents' Profile

Twenty (20) completed questionnaires were received, yielding a response rate of 50% from the targeted sample size. Because of the reduced dimension of the country, this targeted number represents a high percentage of the T&T facility management and building designers in T&T (Barsatie, 2015). The majority of respondents held mid-level decision-making ability in respective organisations. About 10% of the respondents held senior positions involved in decision-making in building design and associated operations, and another 40% outsourced the responsibility of management. From this, some 85% of respondents had been in control of at least one building for multi-site operations.

Approximately, 38 acres (or 1,668,700 square feet) of building space were included in the study of which many office buildings were once residential homes in the Port-of-Spain area. Most buildings fell under a range of 10,000 square feet, and the age of these buildings varied.

About 45% of buildings had been constructed over 10 years. Moreover, many respondents (70%) indicated that there had been upgrades of building undertaken over the last 10 years. The results showed that 55% stated fire alarm system followed by HVAC system at 40%. Video surveillance system and electric power management control totalled 35%. Data network 30%, access control system 25%, wireless system 20%, facility management system 20%, intrusion detections system 15%, uninterruptible power supply (UPS) system 10%, video distribution system 10%, audio visual system 10%, programmable lighting control system 10%, structured cable 5%, grounding system 5% and Voice over Internet (VoIP) 5%. However, usage of green technology (such as solar or wind) has been non-existent. Security, data networks and facilities management systems were seen to be important.

4.2 Identification of SB Performance Attributes, Benefits and Obstacles

While questioning how building practitioners/operators' ranked their performance attributes of building, the highest record, as seen in Figure 2, was environmental friendliness and safety of structure. Space utilisation and flexibility was second, followed by human comfort and management process and security. The remaining attributes (including health and sanitation or the life cycle costing) were of less attention among respondents. The findings also provided evidences that the adoption of SB designs had not been popularised in T&T.

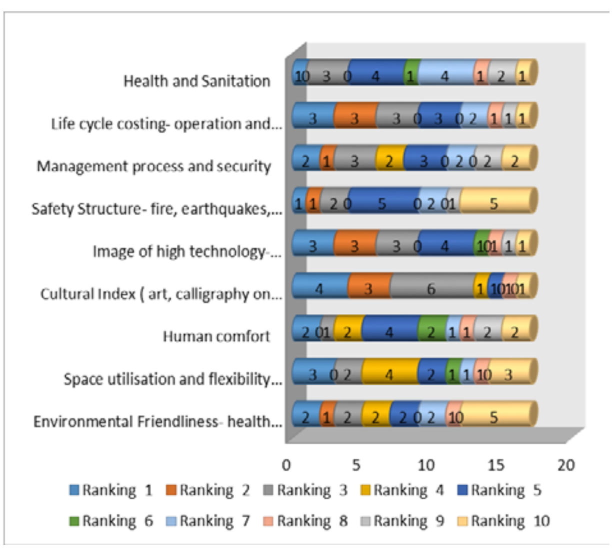

Figure 2: Respondents' Ranking of SB Attributes

Respondents were also asked to share views on a list of benefits from adopting SB strategies. An average of 2.15 responses per person was recorded. The result shows that a better working environment was perceived to be the highest benefit. A safer working environment was the second and financial savings was the third. Respondents shared multiple views on various obstacles preventing SB adoption. About 40% of respondents indicated that the organisation budget was the main reason for not implementing any smart strategies in their buildings. When comparing with the importance of the building and business continuity, only 5% of respondents regarded this to be high, while 15% found it to be low. The remaining 80% was distributed between the ranges of 1-9. From which, 25% was within the ranges 4-5, giving it a medium impact ranking. The results provided insights into the importance of SB adoption with respect to the business operations of respondents' organisations.

4.3 Ranking of SB Strategies

Respondents were asked to rank the importance of the strategies using a 100-point scale. Table 1 shows a breakdown of the ranking of respective strategies. In total, seventeen (17) respondents (i.e., 85%) shed their knowledge about the importance. Of the SB strategy categories, access control, HVAC, and fire alarm systems were noticed to be the most important elements. Computerised management systems (CMS), electrical power management, video surveillance and intrusion detections systems had between 6-9 respondents been acknowledged as a smart strategy used in their building. The results lend support that a few elements comprised as a strategy for a SB in T&T. As such, only 30% of respondents considered their buildings to be smart or intelligent. Most respondents (70%) shared that their SB strategies did not integrate with another building strategies. Some argued that costing implications for the concept of SB would always be an issue.

In identifying elements for a SB, half of respondents (50%) indicated that 'Green' building concept with design should be first and important. Twenty-five percent (25%) saw integration of building automation and software as the key. While asking respondents to share views on implementing SB strategies, an average response was 5.15 per person as more choices were allowed (see Table 2). Results show that safety and security are high as strategy, followed by fire protection, HAVC systems and CMS. Electrical management and building automation were of mid-level importance. Software analytic and green building concepts were ranked as a mid-level importance. Despite respondents recognised the need to integrate green technology with building design, only 30% of them claimed this as important.

5. Stage-2 Interviews Findings and Analysis

5.1. Practitioner's Ranking of SB Strategies

Interviews with nine (9) facilities managers, building owners and operators were conducted parallel to the distribution of the surveys. All interviewees had substantial work experience (20 years and more) in building designs and management. Findings showed that HVAC systems, access control and fire alarms (safety and security systems) were amongst the common SB strategies, either as a stand-alone or as an integrated system. Other strategies (such as smart grids, usage of green materials, solar power, water management systems, and electrical power management) did not receive much attention (see Table 2).

5.2 Comments on 'Smart' Status of Buildings

While asking interviewees to comment on the 'smart' status of buildings in T&T, the answers varied with opinions. Four interviewees (some 45%) advocated that investments into SB have been made as it related to the use of the technology and modern features (such as HVAC or access control). However, other respondents argued that it would be unwise and difficult to regulate technology with respect to the current level of technology status and building intelligence in T&T. For them, technology such as solar panels, energy efficient grids, HVAC or water drainage systems was not seen as an integrated part of SB designs. Some further stated that the adoption of these system(s) would be attributable to the concern of corporate and social responsibility

Table 1: A Breakdown of the Ranking of Elements for SB Strategies

Elements for SB Strategies	**Ranking**										
	0	10	20	30	40	50	60	70	80	90	100
Data Network /| Information and Communication System	55%	25%				5%					
Structured Cable	70%	10%		5%							
Grounding System	75%			5%		5%					
Solar Power Technology	75%	10%									
Voice Over Internet (VoIP)	70%	5%			5%			5%			
Uninterruptible Power Supply System	65%	10%				5%		5%			
Video Distribution System	70%	5%	5%			5%					
Audio Visual System	60%	20%				5%					
Access Control System	25%	15%		15%	10%	5%	5%	5%			5%
Video Surveillance System	55%	5%			5%	5%	5%		5%	5%	
Intrusion Detections System	40%	10%			5%	10%	10%		5%	5%	
Wireless System	55%	15%	5%			5%		5%			
HVAC Management Control System	30%	10%		15%		10%	10%	5%		5%	
Electric Power Management Control	55%	5%			5%		5%	5%	5%	5%	
Programmable Lighting Control System	70%	15%									
Fire Alarm System	35%	5%	5%		20%			5%	5%		10%
Elevator Systems Controls	75%	5%						5%			
Facility Management System / CMS	45%	10%	5%	5%		10%	5%			5%	
Integration of Business System	70%		5%			10%					
Green Building Technology (e.g. Green roofing, facades)	70%	10%	5%								
Building Automation System (BAS)	75%				5%				5%		
Drainage System	75%		5%		5%						
Building Interior Layout	70%		10%			5%					
Water Management System	75%			5%				5%			

Table 2: Adoption of SB Strategies

Types/Options of SB Strategies	**Adopted**	**Percent**
Safety and Security Management System	**13**	65%
Fire Protection System	**12**	60%
HAVC System	**13**	65%
Electrical Management System	**9**	45%
Lighting Management System	**2**	10%
Drainage Management System	**4**	20%
Transportation Systems	**2**	10%
Building Automation System (BAS)	**9**	45%
Building Façade	**1**	5%
Building Interior Layout	**2**	10%
Computerised Management System (CMS)	**10**	50%
Software Analytic	**6**	30%
Green Building Concept with Building Design	**6**	30%
Integration of Building Automation and Software Analytic	**3**	15%
Not Sure	**1**	5%
Other	**0**	0%

rather than any effectiveness measures in T&T. Moreover, many building owners and operators argued that it would be more difficult to standardise technology than to have governance over it.

5.3 Contrasting Interview versus Survey Findings

Queries on building intelligence received some mixed responses, leading to the different understating of SB in T&T (see Table 3). From the survey findings, there were not many SB solutions. Similar findings were shared in the interviews, with the top four (4) solutions being: 1) safety and security, 2) fire protection, 3) HAVC, and 4) CMS. Besides, the survey showed that funds have been distributed into the area of building manintenace, but most would still be seen as an expenditure to businesses and not a cost-saving entity. The interview findings however reflected that lacking of incentives had been hindering the SB projects execitions. Many building practitioners were not supportive towards SB adoption. For instance, energy saving strategies would always not be the first priority in T&T. Employing technology solutions as being a SB strategy concept were in an infant stage in T&T. These solutions have been considering as an expense rather than a financial saving to building owners. Even if a SB strategy is utilised, it would largely be classified as stand-alone SB solution.

6. Development of a SB Assessment Approach

An examination into the SB designs in T&T revealed the following gaps:

- Selection of technology is based on owners' discretion;
- No benchmarks are set to verify any benefits derived from strategy;
- Minimal usage of SB materials at designing phase;
- Misconception of SB implementation; and
- Stand-alone technology is considered best practice.

In order to address the gaps identified, a five-step SB Assessment approach was developed, incorporating the analysis of empirical findings from the study. This approach addressed the fundamental issues and weighed the impacts of current building strategies in T&T. Figure 3 depicts the skeleton and process flow amongst these five (5) steps of the approach.

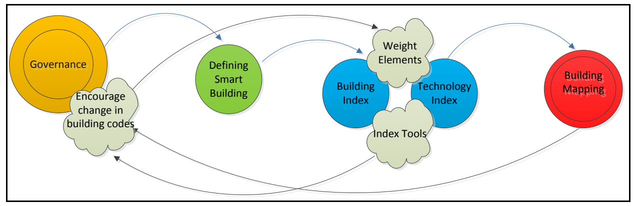

Figure 3: Process Flow of a Five-Step SB Assessment Approach

6.1 Step I: Building Governance

Governance is needed in the form of legislation which would incorporate SBs, and a regulator body or institution is needed (Finch and Clements-Croome, 1997). The legislation would address concerns for a SB governing body, penalties, minimal requirements for SB classification, identify standardise technology for use with SB and the design of a new building code for T&T. This first stage aims to assist with multiple user requirements, working patterns and ambiguity within SB industry. It is envisaged that the governing body would be responsible for building management and foster good building practices to be adopted in T&T. Encouragement towards legislation would increase stakeholders' participation across many business sectors.

6.2 Step II: Defining Smart Building

A SB integrates various systems to effectively manage resources in a co-ordinated mode to maximise technical performance, investment and operating cost savings and flexibility (Wong et al., 2005). There is a need of having a nomenclature definition for SBs for T&T. Once a definition is identified, it should be integrated into the new building code and be supported by the governing body.

Table 3. Comparison of Interview and Survey Findings

	Question	Interview	Survey
1	Knowledge of SB	Experience in SB with Qualification. Ranking 7-10	Ranking 5-6
2	Obstacles Preventing SBs	Lack of Incentives Low Energy Cost	Budget Cost 40%, Stakeholders Interest 70 %
3	Ranking Building Intelligence	Mixed response based on technology used either it is addressing needs or unable to measure intelligence	65% View building as low Ranking, 30% each either satisfied or not with Ranking
4	Current SB Strategy Used	Either stand-alone systems or Limited Integration to Safety and Security, Fire Protection, HAVC and CMS	Safety and Security, Fire Protection, HAVC and CMS
5	Building Codes Consideration	Mixed response but a need to have change in Industry developing technology adaptation	40% Yes, 50% Not Sure 10% No Comment
6	Baseline for SB Strategy	Safety and Security, Fire Protection and HAVC	Safety and Security 65%, Fire Protection 60% and HAVC 13%

Table 4: Priority of Modules Assigned to Buildings

Type of building	P1	P2	P3	P4	P5	P6	P7	P8	P9
Hospitals	M1	M7	M3	M4	M9	M2	M5	M8	M6
Weight	9	8	7	6	5.5	5	2	1.5	1
Residential buildings	M3	M5	M7	M1	M4	M9	M2	M8	M6
Weight	9	8	7	6.5	6.5	3	2	1.5	1
Commercial (office) buildings	M4	M2	M9	M3	M1	M7	M6	M5	M8
Weight	9	8.5	8	7.5	7	6.5	6	6	3
Transportation terminals	M7	M3	M1	M6	M4	M9	M8	M2	M5
Weight	9	8.8	8	7	6	6	4	3	2
Educational Institutions	M4	M7	M2	M5	M9	M1	M3	M8	M6
Weight	9	8.8	8.5	8.2	8	7	6.5	6	5

Source: Adopted from Wong and So (2002)

6.3 Step III: Deriving Smart Building Index

The need to measure the intended building performance should be conducted, in compliance with the nine Quality Environment Modules (QEM) that were advocated by AIIB (Ho et al. 2005). These QEM are listed below:

- M1: Environmental friendliness – health and energy conservation;
- M2: Space utilisation and flexibility;
- M3: Cost effectiveness – operation and maintenance with emphasis on effectiveness;
- M4: Human comfort;
- M5: Working efficiency;
- M6: Safety and security measures - fire, earthquake, disaster and structural damages, etc.
- M7: Culture;
- M8: Image of high technology;
- M9: Construction process and structure; and

Different types of buildings would have different design criteria (such as residential, commercial, educational and religious). In order to promote proper building maintenance and management through the use of market forces, a need to develop a Building Quality Index (BQI) is needed (Ho et al., 2005). This is to assign different modules in priorities. Table 4 shows an example of assigned modules of five (5) different buildings, assigning P1 for the highest rating and P9 for the lowest rating for each type of building (Wong and So, 2002; Wong et al., 2005).

For the purpose of mapping the ranking to individual scores and obtaining their weights, AIIB utilised Cobb-Douglas production function. The overall IBI is defined as:

$$I = M_1^{\frac{w_1}{w_1+\ldots+w_9}} \quad \ldots \quad M_9^{\frac{w_9}{w_1+\ldots+w_9}}$$

$$1 \le I \le 100; \quad 1 \le M_i \le 100; \quad \text{and} \quad 9 \ge w_i \ge 1 \quad \text{for } i = 1\ldots9$$

where,

M_i is the score of the ith module (e.g. M 1 = the Green Index); and w_i is the ith module's weight (or importance) relative to other modules, and preferably a positive integer.

From the formula, it can be seen that *I* is a weighted geometric mean of the individual scores, which is weighted exponentially by their relative importance. The following shows a similar formula used to assess the individual modules score, M_i:

$$M_i = x_1^{\frac{w_1}{w_1+\ldots+w_n}} \quad \ldots \quad x_n^{\frac{w_n}{w_1+\ldots+w_n}}$$

where,

x_i is the score of the ith element and there are n elements; and w_i is the ith module's weight (or importance) relative to other modules.

There are basically three (3) types of conversion formula (So et al., 1999; Barsatie, 2015). The first type is of the form: [*a*, *b*] to (*x*, *y*) where "*a*" and "*b*" are descriptions bearing clear meaning of the elements. "*x*" and "*y*" are scores which are real numbers within the range between 1 and 100. The formula means that a score of *x* will be awarded to the element if the value of it is equal to "*a*" and a score of *y* will be awarded to the element if it is equal to "*b*".

The second type is of the form: [*a*…*b*] to (*x*…*y*). This means that the score calculated based on a linear projection or mapping from the raw value of the element within range from "*a*" to "*b*" to the range of score from "*x*" to "*y*" where "*x*" and "*y*" are scores within the range 1 to 100. The third type is of the form: (excellent, good, fair, and worst) to (*x*1, *x*2, *x*3, and *x4*) where the four *x*s are real numbers within the range from 1 to 100. The overall index obtained will enable the building to be awarded a grade as advocated in Table 5.

Table 5. Ranking of overall performance of the IB

Score	Ranking	Description
80-100	A	Distinction building
60-79.99	B	Credit building
50-59.99	C	Satisfactory building
35-49.99	D	Fair building
1-34.99	E	To be improved

Source: Adopted from Wong and So (2002)

By relating the IBI ranking to the current situation of T&T, a four-ranking index is proposed (as illustrated in Table 6) for the SB Assessment.

Table 6. A Conceptual Ranking Index for SB Assessment

Score	Ranking	Description
80 +	A	Distinction Building
50 - 79.99	B	Credit Building
20 - 49.99	C	Fair Building
0 - 19.99	D	Need for Improvement

6.4 Step IV: Developing Component/Attributes Index

In this step, the types of components are to be identified, and their criticality for use in buildings be examined. This included an identification of several factors concerning the evaluation of the 'intelligent level' of buildings (Wong and Li, 2006). These factors would be classified into nine (9) criteria groups, for example, green, space, comfort, work efficiency, culture, high-tech image, safety and security, construction process and structure, and cost-effectiveness. Table 7 shows a summary of factors affecting the selection of SB systems and components.

Table 7: Factors Affecting the Selection of SB Systems and Components

Selection of intelligent building systems and components
Selection attributes Reference
Safety and security system
Work efficiency
Time needed for public announcement of disasters (second/minute)
Time needed to report a disastrous event to the building management (second/minute)
Time for total egress (minute)
Connectivity of CCTV system to security control system
Number (or percent) of monitored exits and entrances
Earthquake monitoring devices
Wind load monitoring devices
Structural monitoring devices
Maintainability of installation
Comprehensive scheme of preventive maintenance AIIB
Life span (year)
Allow for further upgrade
Compatibility with other building systems
Integrated with BAS
Technological related
Existence of artificial intelligent (AI) based supervisory control
Modernisation of system
Area monitored by CCTV
Cost effectiveness
First cost
Life cycle cost

These factors would be rated according to the importance of the numerous building systems. A Likert five-point scale could be used to measure and rank the attributes according to their mean score ratings (Wong and Li, 2006). The mean score rating could be calculated using the following formula:

$$\text{Mean} = \frac{1(n_1) + 2(n_2) + 3(n_3) + 4(n_4) + 5(n_5)}{(n_1| + n_2 + n_3 + n_4 + n_5)},$$

where, n_1, n_2, n_3, n_4, and n_5 represent the total number of responses for attributes as 1 to 5, respectively.

Secondly a t-test analysis should be employed to identify the "important" and "most important". The null hypothesis (H_0), $\mu_1 < \mu_0$, against the alternative hypothesis (H_1), $\mu_1 > \mu_0$, were tested, where μ_1 represents the population mean, and μ_0 represents the critical rating above which the attribute considered is most important. The value of m_0 should be a fixed number as to represent "importance" and "extremely importance" attribute according to the scale in the questionnaire (Wong and Li, 2006). A decision rule can be to reject null hypothesis (H_0) when the calculation of the observed t-values (t_0) (Equation (2)) was greater than the critical t-value (t_c) (Equation (3)), as follows.

$$t_O = \frac{\overline{\chi} - \mu_0}{\widehat{s}_D/\sqrt{n}} \quad \text{Equation 1}$$

$$t_C = t_{(n-1,\alpha)} \quad \text{Equation 2}$$

$$t_O > t_C \quad \text{Equation 3}$$

where χ is the sample mean, $\widehat{s}_D/\sqrt{n}$ is the estimated standard error of the mean of different score

6.5 Step V: Mapping the Building Design

The selection attributes identified from Step VI would be used to judge the impact of the building components. Once the ranking has been identified, a certificate would be awarded to the building. To accomplish the mapping process, the awarded rank buildings would be categorised either as (1) performance-based building (2) serviced-based building (3) system-based building as advocated by Wang (2010). Once the building is ranked, the benefits being achieved could be evaluated.

7. A Case of SB Assessment Implementation

The importance of encouraging governance would allow for stakeholders to buy-in the industry (i.e., Step I). Once this governance is implemented, the building owners and operators can realise the pay-outs of SBs not only as a financial gain, but also the potential of leading towards a smart city design. Step II looks at addressing this issue of an adaptable SB definition. This is an area for continual research and acceptance by the governing body.

The methodologies outlined at Steps III and IV follow a practitioners-oriented approach from leading countries within the SB or IB industry. These methods are geared towards ensuring that the building infrastructure and components are optimal, and reassure that the building has an approved structure. Step III requires a building to be classified by purpose of design. Safety-structure and environmental friendliness would be considered. Once a building has met the minimal requirements for a ranking, it would be considered as SB (Step IV). The weights for various SB components would be identified. The building would then be mapped, ensuring satisfaction and convenience of persons residing and working inside (Step V).

For illustrating SB assessment implementation, the respondents' answers to the "Ranking a Building" (see Table 8) are used to assist with the application of the proposed SB assessment approach. Assuming that there is minimal assessment of 10 points for each weight element, the response from one invited building practitioner was used. This assists with applying Cobb-Douglas utility function tool and the formula, as follows:

$$I = M_1 \frac{W1}{W1+W2+W3+W4+W5+W6+W7+W8+W9} \ldots\ldots$$

$$M_9 \frac{W9}{W1+W2+W3+W4+W5+W6+W7+W8+W9}$$

Table 9 shows the computation of the SB assessment of the respondent's building. The overall SB ranking based on the respondent's assessment is computed as: $I = 10.01$. The ranking versus the overall SB ranking could then be mapped. The computed index of the building is 10.01 that falls into Grade D being described as a need for improvement. This method shows a conceptual adaption for a building index which allows for expansion in identifying a greater number of weight assessments per M_i count. The expansion would be the responsibility of the governing body to identify additional weights when designing a Likert-scale Questionnaire. However, the foundation shows benefits if adapting for evaluating a building's overall impacts and functionality, thus enabling building practitioners (owners, managers and operators) to define the building purpose and ensure that a ranked status is maintained for the building life-span.

The overall functional requirements could be suited for relatively new structures. This practitioners-oriented approach would be effective if there is a classification of buildings based on their respective design purpose. Allowance is needed for a standardise designing for a base number of weight assessment. Once classification of buildings is implemented, there would be a difference in weighted assessment for each building. For example, a hospital weight assessment would vary from that of an office building. In order to ensure buildings of a similar type are assessed appropriately, the number of weighted assessments should be evenly distributed for each type of building (for example, an office building should have no less than 50 weighted assessments per M_i).

Table 8. Respondents' Answers to the Ranking of SB Attributes

Respon-dents	SB Attributes*								
	M1	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**	**M8**	**M9**
1	1	1	1	1	1	3	1	1	3
2	1	1	1	1	1	1	1	1	1
3	2	1	4	1	1	2	3	1	3
4	3	3	5	5	3	7	5	3	5
5	3	3	3	3	3	5	3	3	3
6	4	4	5	4	2	5	5	3	5
7	4	4	4	2	3	5	4	2	5
8	5	5	5	3	2	5	5	2	5
9	5	4	5	2	2	5	2	2	7

* - The 9 Quality Environment Modules (QEM) as advocated by AIIB (Ho et al. 2005)

Table 9. Computation of a Sample Assessment of SB Attributes

SB Attributes*	Assessment		Weights
M1	10	W_1= Weight of M1	4
M2	10	W_2= Weight of M2	4
M3	10	W_3= Weight of M3	4
M4	10	W_4= Weight of M4	2
M5	10	W_5= Weight of M5	3
M6	10	W_6= Weight of M6	5
M7	10	W_7= Weight of M7	4
M8	10	W_8= Weight of M8	2
M9	10	W_9= Weight of M9	5
		W_1+….+W_9	33

* - As advocated by AIIB (Ho et al. 2005)

Table 10. Likert-Scale Attribute Component for Buildings A, B and C

	BAS	**Infosys**	**Fire**	**HVAC**	**Electrical**	**Lighting**	**Drainage**	**Building Façade**	**Building layout**	**Mean**	**Variance**	**Standard Deviation**
Building A	4	4	5	4	3	4	4	3	5	4.0	0.5	0.7
Building B	5	5	5	5	5	5	4	1	1	4.0	3.0	1.7
Building C	2	3	1	4	2	3	1	4	4	2.7	1.5	1.2
Benchmark Standard	5	5	5	5	5	5	5	5	5	5.0	0.0	0.0

One methodology would be to utilise a Likert-scale approach, awarding points for more benefits derived. From this data, obtaining an average for each attribute can be found using the formula for deriving a specific baseline number:

Mean =

$$\frac{1(n1) + 2(n2) + 3(n3) + 4(n4) + 5(n5)}{(n1 + n2 + n3 + n4 + n5)}$$

This would assist with categorising the building as a performance-based, or service-based, or system-based building. This methodology would allow respondents to measure each element on an interval basis using the five-point scale, and rank the attributes in descending order where "1" represents not important and "5" represents importance. Once a mean is derived, then a value can be assumed as an accepted benchmark of a selected SB technology area. A building whose attributes are scored above the benchmark value per element is eligible for awarding a certificate for SB compliance.

Moreover, the individual levels of technological capabilities of buildings could be compared, using the hypothetical data that were obtained from the attribute component questionnaire (see Table 10). The relative technological ranks of buildings could then be derived. Figure 4 shows a diagrammatic representation of benchmark standard amongst Buildings A, B and C. The levels of consistency per buildings could be ascertained. For example, the drainage-capacity of Building B significantly exceeds the status of its façade and layout characteristics. Building B is in close proximity to the benchmark standard due to its relatively high mean rank of 4.0.

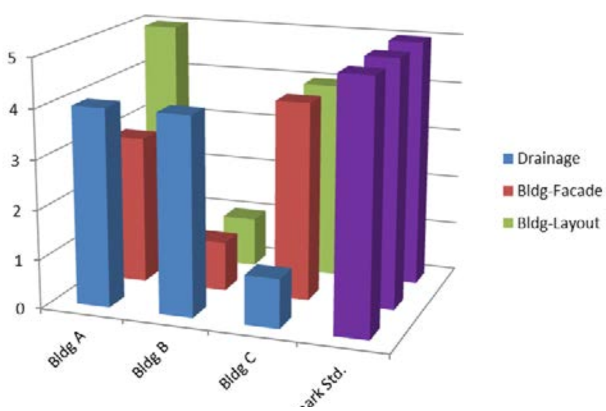

Figure 4: Diagrammatic Representation of the Benchmarks amongst Buildings

7. Conclusion

The construction booms in T&T during the 1970s and then in the 2000s saw the birth of many high-rise buildings, both by private and government entities. The development raised many questions about the afterlife care of these buildings. This paper discussed the problems associated with the adoption of SB concepts in T&T. The results showed that the architects, facility managers and building owners in T&T had perceived the importance of Smart buildings such as HVAC, fire protection and security systems in a working environment. For facilitating stakeholders to promote the SB concepts towards design and performance, this study contributed to the development of a proposed 5-steps SB assessment approach.

The SB approach built upon the AIIB's nine Quality Environment Modules (QEM) (Ho et al. 2005; AIIB, 2017), and incorporated factors concerning the evaluation of the 'intelligent level' of buildings advocated by Wong and Li (2006). The approach is more practitioners-oriented, comprising 1) building governance, 2) defining SB, 3) deriving SB index, 4) developing component/attributes index, and 5) mapping building design. A Likert-scale and calculations for Cobb-Douglas / t-Test are instrumented for standardising the variance of buildings. The SB elements are to be captured and then calculated. The utilisation of an index is to evaluate building strategies. The approach is geared towards enabling building practitioners (owners, developers, operators, and managers) who become conscious of ensuring their building is certified for human occupation and that consistency is adopted in selection of SB solutions in T&T.

It is anticipated that the adaption of a building index and assessment would ensure that SBs become the main building strategies in moving forward in T&T. Future study could validate the key elements identified for SB design and strategies of varied residential purposes and commercial/operations nature. Comparative evaluations and case studies are suggested to examine critical processes and individual steps for conducting SB assessments in T&T.

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