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Sustainability Balance

Oanh Thi-Kieu Ho, Usha Iyer-Raniga and James P. C. Wong
School of Property, Construction and Project Management, RMIT University, Melbourne, Australia

Introduction

For many years, the construction industry has increasingly been concerned about environmental impact, usually expressed as greenhouse gas (GHG) emissions, resource consumption, and waste generation. This industry consumes more than 40% of the world's resources, requires 40% of global energy, emits 30% of GHG emissions, and uses 25% of the global water supply (UNEP 2016). To reduce these problems, sustainability goals have been incorporated into the construction industry globally.

Apart from the building and construction industry, the office buildings sector has a significant impact on the environment. It should take responsibility for its energy consumption, waste generation, greenhouse gas emissions, natural resources depletion during project lifecycle from initial stage to demolition stage (Ortiz et al. 2009). Regarding the United States (USA), buildings alone consume 39% of energy use, 72% of electricity resources, emit 39% of carbon dioxide, and consume 13.6% of portable water in the year of 2008 (EIA report 2008). Similarly, in Singapore, the buildings account for 35.9% of energy consumption and 37.8% of electricity consumption (Energy Market Authority 2018). Compared with these countries in the world, Australia is in a similar situation. In this country, buildings generate about 9% of national GHG emissions (Australian Government 2015) and 30–40 of solid wastes (ABS 2016). In addition, these buildings use 21–30% of the total potable water in urban centers (Corr et al. 2008). With such significant consumption and emissions profile, the development of sustainable practices for building projects is necessary for reducing their impacts on the environment.

However, the most critical issue for implementing sustainability in practice is additional cost or cost premium for incorporating sustainable or green features and technologies. As documented in many previous studies, the additional cost is still inconsistent and varied (Issa et al. 2010; Hwang and Tan 2012; Yudelson 2010; Kim et al. 2014). With particular relevance to Leadership in Energy and Environmental Design (LEED) certification, a green rating scheme devised by the United States Green Building Council (USGBC), the additional cost varies from 2% (Kats et al. 2003) to 13.8% (Kats 2010) of total construction cost. Conversely, the additional cost may be insignificant or even nonexistent in office projects (Matthiessen et al. 2007; Rehm and Ade 2013).

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In Australia, the additional cost of using Green Star-rated projects follows a trend similar to the USA. The process of seeking certification from relevant organizations, such as USGBC for LEED and GBCA for Green Star, also involves a cost. For Green Star certification in Australia, this cost ranges from 3% to 5% for 5-Star Green Star projects and 5% for 6-Star Green Star projects where there are no iconic designs (Langdon 2007). Depending on the type of design, in some instances, the cost is insignificant in the Green Star certification as illustrated by research undertaken at Bond University (GBCA 2008a).

Several studies have been undertaken to address and reduce the issue related to the additional cost from different approaches. One of the most popular approaches is to demonstrate the additional cost through different case studies on office projects with actual cost data collected from different countries such as the UK, USA, and Australia (Kats et al. 2003; Steven Winter Associates 2004; Ahn and Pearce 2007). The second approach is to evaluate the additional cost according to participants' perceptions using research surveys (Houghton et al. 2009). Another approach is the suggestion of different models such as the model of selecting material suppliers (Calkins 2008; Akadiri et al. 2013), the assessment model of innovative green technologies (Collier et al. 2013; Sheikh et al. 2011), or Life-cycle cost (LCC) and Life-cycle assessment (LCA) models (Gluch and Baumann 2004; Chen et al. 2011; Kneifel 2010). However, it is evident that a framework for supporting decision-making on sustainable office projects or indeed other types of buildings through the Triple Bottom Line sustainability assessment of green features and technologies is lacking.

Approaching the decision-making process and taking into consideration Triple Bottom Line (TBL) sustainability, this chapter aims to establish a multipillar decision-making (MPDM) framework for assessing green features and technologies (GFTs) for office projects in Australia. In other words, a multipillar decision-making framework provides the underlying rationale and the process for GFTs assessments under the three pillars of sustainability: Economics, Environment, and Society. The framework supports the selection of green features and technologies at the initial stage (or the conceptual design stage) of an office project, which is essential for realizing sustainable development goals (Vyas and Jha 2017; Da Silva and Ruwanpura 2009). Such a framework and understanding of sustainability assessment also contribute to reducing or eliminating the issue related to the additional cost by the efficient selection strategy of GFTs.

This chapter begins by reviewing sustainability, office projects, and Green Star tool used for sustainable or green office projects in Australia. Following this is an explanation of what GFTs are and a shortlist developed from 181 Green Star-rated office projects – new build. An understanding of pillars and subpillars was then undertaken by examining how Green Star uses these in their rating tool. The next section is the research method of Analytic Hierarchy Process (AHP) and the use of an in-depth questionnaire survey. Then, the findings of the weightings of three main pillars and subpillars, the GFTs assessments, and the framework establishment are discussed. The last section is the conclusion of this research Chapter with its main findings and outcomes.

Sustainability and Office Projects in Australia

Sustainability has been defined, and redefined, many times over the last few decades. The most common definition of sustainability used has been put forth by WCED (1987) is "... to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs" (p. 43). Technically, sustainability can be as comprehensive as the relationship between Economic Prosperity, Environmental Quality, and Social Justice; this is known as the Triple Bottom Line (Elkington 1997). Sustainability also encourages the exploration of innovative measures to eliminate problems that can compromise or seriously hinder the TBL. Recent global events, such as the adoption of the Sustainable Development Goals (SDGs) by almost all countries, have focused attention back

on proactive efforts by all levels of society to achieve sustainability outcomes.

Based on these definitions, the use of building features and technologies in sustainable or green office projects are desirable if they generate benefits to TBL sustainability. In this research chapter, green features are defined as structural aspects that improve a building's environmental friendliness in different ways, for instance, energy savings and waste reduction. Green technologies are interpreted as "any well designed technology capable of addressing high energy demands without posing negative effects to the environment" (Dadzie et al. 2017). They are also the technologies that exceed the benchmark of more conventional systems typically used in office buildings.

In Australia, office buildings constitute a substantial proportion of non-residential projects. These buildings make up more than one half of buildings in Australia (GBCA 2015b). Recent building numbers are approximately 4500 buildings across Australia, corresponding with more than 25 million m^2 floor area (Property Council of Australia 2017). Office buildings account for 25% of the total of 19% of energy consumption and 23% of overall greenhouse gas emissions (GBCA 2015b). Accounting for the highest proportion of the building sector and following the need to reduce construction impact on the environment, there is an obvious interest that office projects integrating sustainability should be prioritized in this industry (Butera 2010; Zuo et al. 2016).

Green Star Rating Tool: Office Design

Green Star rating tool is selected for this research because of its brand recognition in sustainability and green office projects in Australia. Green Star is a voluntary tool and the recognized brand for sustainable development in the nonresidential sector of the building and construction industry. It is a reliable proof of sustainable projects being carried out and accepted by consumers and the construction sector in this country. This tool was launched in 2003 as the "second-generation rating tool" of Leadership in Energy and Environmental Design (LEED) and Building Research Establishment Environmental Assessment Method (BREEAM), the "oldest" sustainability rating tools from the USA and the UK, respectively. The Green Star rating tool is managed by the Green Building Council of Australia (GBCA) – a nonprofit organization to assist green building development in this country (GBCA 2015a).

According to GBCA (2015a), Green Star – Office Design benchmarks an office project against the following nine categories:

Management	Indoor environment quality	Energy
Transport	Water	Materials
Land use and ecology	Emissions	Innovation

Green credits are accumulated from nine categories integrated with their weightings. The weightings differ in the states and territories of Australia, particularly in the categories of Water, Land Use, and Ecology (see Table 1). Of the nine categories, the Innovation credit is an additional credit and is not included in the core credits comprising certification. Therefore, the final score is the sum of credits from eight categories plus the credit inherent in the Innovation category. This score decides the rating of Green Star certification based on comparing the credit ranges for Green Star levels.

Green Star certification for office design is determined in three levels: 4-Star, 5-Star, and 6-Star based on the credit total awarded. The three levels are shown below:

From 45 to 59 for 4-Star rating, recognized as "Best Practice"
From 60 to 74 for 5-Star rating, recognized as "Australia Excellence"
From 75 to above for 6-Star rating, recognized as "World Leadership"

Identification of GFTs

Based on their definitions, many GFTs are suitable for sustainable office projects. To select the

Sustainability Balance, Table 1 Credits in eight categories and their weightings

Category weightings	No points	NSW (%)	ACT (%)	NT (%)	QLD (%)	SA (%)	TAS (%)	VIC (%)	WA (%)
Management	12	9	9	9	9	9	9	9	9
Indoor environment quality	27	20	20	20	20	20	20	20	20
Energy	24	25	25	25	25	25	25	25	25
Transport	11	8	8	8	8	8	8	8	8
Water	13	12	12	10	14	15	10	15	14
Materials	23	14	14	14	14	14	14	14	14
Land use and ecology	8	6	6	8	4	4	8	4	5
Emissions	14	6	6	6	6	5	6	5	5
Innovation	No weight. Innovation credits are added								

Source: (GBCA 2008b)

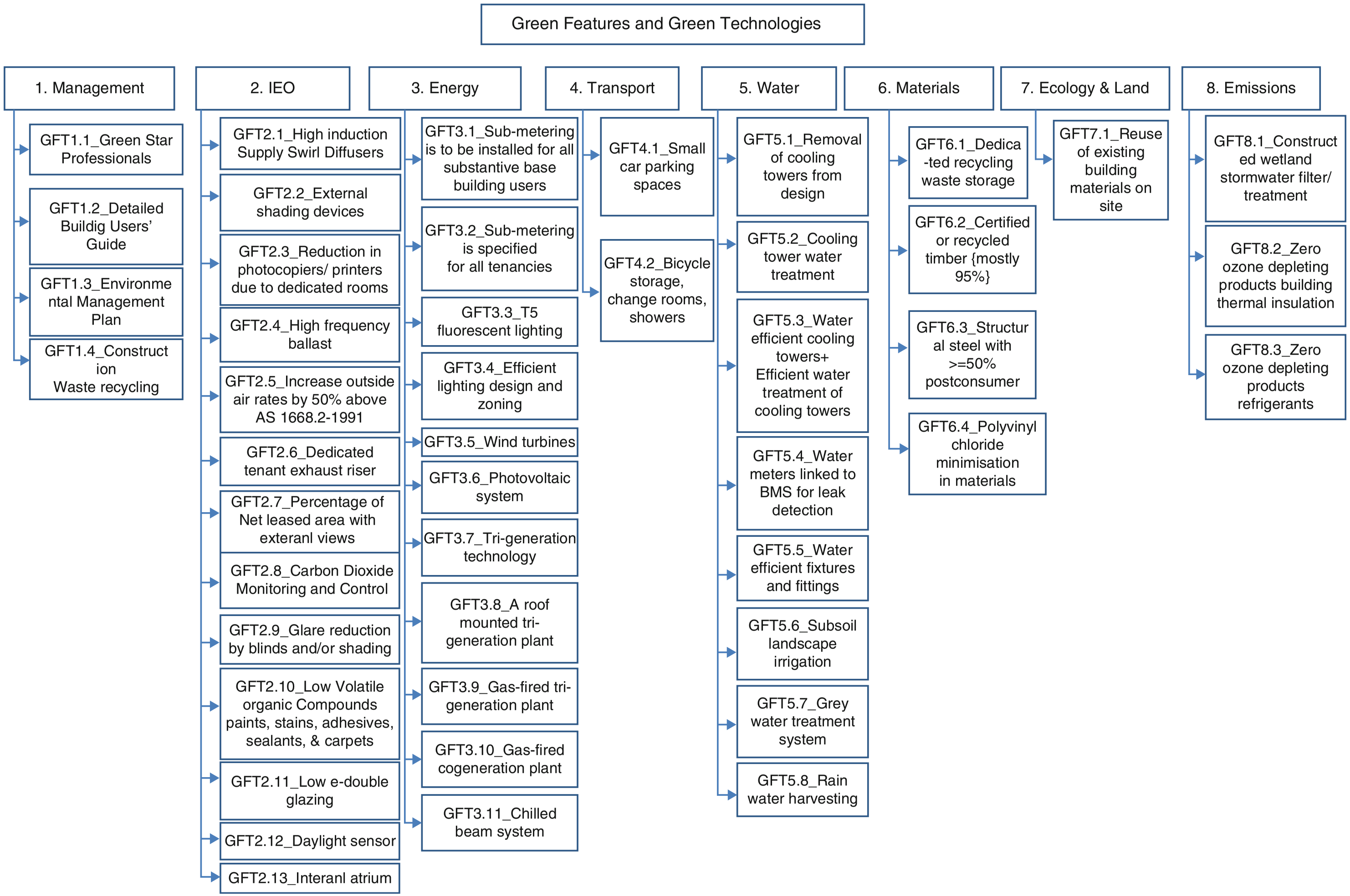
GFTs, a study of 181 Green Star office projects in Australia over 12 years was taken. The most frequently occurring GFTs were then selected, leading to a total of 46 GFTs.

These GFTs were shortlisted based on previous reports of office buildings in Australia, including Green Star rating and Ecological Sustainable Development (ESD) principles. The GFTs selected are the primary elements in office designs for achieving Green Star certification. They have been mainly derived from the categories of Energy, Water, and Indoor Environment Quality, which are highlighted by ESD principles. GFTs have been emphasized in both active and passive systems used in buildings such as lighting systems, passive ventilation, energy technologies, renewable energy systems, water conservation, and transport. While there is a great breadth of use of GFTs, based on their widespread acceptance in previous studies, frequently used ones occurring in reality in Australia have been selected. Based on the study of 181 Green Star – new build projects identified through publications on the GBCA website. A comparison between what was reported in the literature and that shown in reality was then undertaken to provide this short list of 46 GFTs. They are reported in Fig. 1 corresponding to the relevant categories in Green Star.

Pillars and Subpillars of TBL Sustainability

In a decision-making framework, pillars and subpillars need to be developed to aid the decision making process. This two-stage process is essential as a single pillar is unable to significantly consolidate the contributions of all the GFTs to TBL sustainability. It is therefore essential to have multipillar set for the assessment of all GFTs. Multipillars may consist of qualitative and quantitative elements under the three main pillars selected in this research. Doing so helps to evaluate both tangible and intangible contributions of GFTs.

Based on TBL sustainability, the three pillars are Economics, Environment, and Society while subpillars are selected by a systematic approach focusing on five fundamental principles: coherence with project decision (consistency), independence of each criterion, same scale, measurement, and relationship with green features and technologies (Convertino et al. 2013; Si et al. 2016). This selection also relies on what has been included in previous studies. Based on these principles and previous studies, subpillars under each pillar are considered and selected properly. There are in total 7 subpillars for Economics, 7 subpillars for Environment, and 6 pillars for Society (Table 2).



Sustainability Balance, Fig. 1 Green features and technologies resulting from the sample of buildings: 46 in total

Sustainability Balance, Table 2 Rationale supporting the structure of pillars and subpillars

Pillar	Subpillar - Level 1	Subpillar - Level *2*	Reference
Cl. Economics	Cl.1 Cost	Cl.l.a. Initial/capital cost	(Collier et al. 2013; Akadiri et al. 2013; Si et al. 2016)
		Cl.l.b Construction cost premium	(Kats 2010; Langdon 2007)
		Cl.l.c Operational cost	(Collier et al. 2013; Si et al. 2016)
		Cl.l.d Maintenance cost	(Collier et al. 2013; Si et al. 2016)
		Cl.l.e Maintenance complexity	(Akadiri et al. 2013)
		Cl.l.f Payback period	(Collier et al. 2013)
	C1.2. Organizational prior experience		(Akadiri et al. 2013)
C2. Environment	C2.1 Resources sustainability		(Nadoushani et al. 2017)
	C2.2 Energy usage	C2.2.a Heating	(Collier et al. 2013; Nadoushani et al. 2017)
		C2.2.b Cooling	
	C2.3 Water usage		(Collier et al. 2013)
	C2.4 Indoor environmental quality (IEQ)		(Si et al. 2016)
	C2.5 Waste management		(Akadiri et al. 2013)
	C2.6 CO2 Emissions reduction		(Si et al. 2016)
C3. Society	C3.1 Societal benefits	C3.1.a Community engagement	(Si et al. 2016)
		C3.1.b Aesthetics	(Collier et al. 2013; Akadiri et al. 2013)
		C3.1.c Local Infrastructure Development	(Sheikh et al. 2011)
	C3.2 Organizational benefits	C3.2.b Health and Safely	(Akadiri et al. 2013)
		C3.2.b Productivity performance	(Si et al. 2016)
		C3.2.c Social reputation	(Si et al. 2016)

Analytical Hierarchy Process (AHP)

Analytical Hierarchy Process (AHP) is employed as the most suitable multicriteria decision-making method for this research. This is because AHP firstly assists decision-making by allowing the assessment of qualitative and quantitative elements of the multipillar decision making process. It also satisfies certain objectives in the evaluation hierarchy (Zhao et al. 2017) such as achieving sustainable goals. There is a single direction of evaluation structure applicable to all assessments (Zhao et al. 2017). The second step with using AHP is the pairwise comparison of pillars and subpillars to detect the intensity of preference among them (Pohekar and Ramachandran 2004). A scale of 1 to 5 is used in AHP with "1" standing for the equally important level and "5" representing extremely important level. This scale was selected and confirmed by participant's suggestions in the survey pilot. Lastly, AHP uses the principal eigen-vector for aggregating the final vector of different weight coefficients. Eigen-vector is calculated by a matrix $A = (a_{ij})$ with i and j represented pillars and subpillars from 1 to n. The formula is written as $A = a_{11}a_{12}...a_{1n}a_{21}a_{21}...a_{2n}a_{n1}a_{n2}...a_{nn}$. On this basis, the decision is usually made by selecting the highest ranking of GFTs in their assessments.

Questionnaire Survey

AHP assists the establishment of a multicriteria decision-making framework. To accomplish this objective, an in-depth questionnaire survey was used for data collection. This survey received ethics approval from the University Ethics Committee as interacting with people needs to be open and transparent while respecting their rights and privacy as individuals. The survey was designed using Qualtrics, a survey instrument used by the university and available online, making it easier to use. After 4 months spent contacting potential participants throughout Australia, 38 responses were received, but only 13 were fully answered responses and therefore, viable for research analysis. This response rate is 13.48% based on the contact made with 282 institutions, sustainability divisions, construction organizations, and individuals. This low rate can be explained by the 1-h questionnaire length and research requirements for participants to be knowledgeable about and experienced in sustainability issues. The 13 fully answered surveys were completed by different stakeholders, including Developers, ESD consultants, Architects, Building Services Engineers, Quantity Surveyors, Facility Managers, and Researchers. They are also from very senior positions in their organizations such as director, national manager, and principal. Despite the low response rate, the complexity of survey makes the data valuable for analysis and for establishing the framework from different stakeholder assessments of perspectives concerning a green office project.

Findings and Discussion

This section presents the three main research findings, which are discussed as below.

Weightings of Pillars and Subpillars

Based on AHP principles, the weighting of every pillar and subpillar is estimated by a pairwise comparison matrix. Then, weightings were assigned from the highest priority as pillars to the lowest priority as subpillars of the relative importance. Regarding relative importance of the three sustainability pillars, when analyzed as a whole, participants reported Environment as the most important pillar. The next pillar was Economics and this was followed by Society. In the Environment pillar, C2.2 Energy Usage was the most important subpillar, while for the Economics pillar, C1.1 Cost was more important than C1.2 Organizational Prior Experience. In terms of the Society pillar, C3.1 Societal Benefits was more important than C3.2 Organizational Benefits (see Fig. 2).

As can be seen in Fig. 2, the different relative importance of pillars and subpillars illustrates the imbalance that survey participants perceived in the three pillars of TBL sustainability. Technically, sustainability principles of the TBL approach consider the three pillars of Economics, Environment, and Society as ideally having equal relative importance. In other words, these pillars should be balanced when sustainability is being assessed. However, the findings illustrate that Environment is the most important pillar, while the Society is the least important pillar. Similarly, the subpillars have different relative importance in contrast to the balanced relative importance.

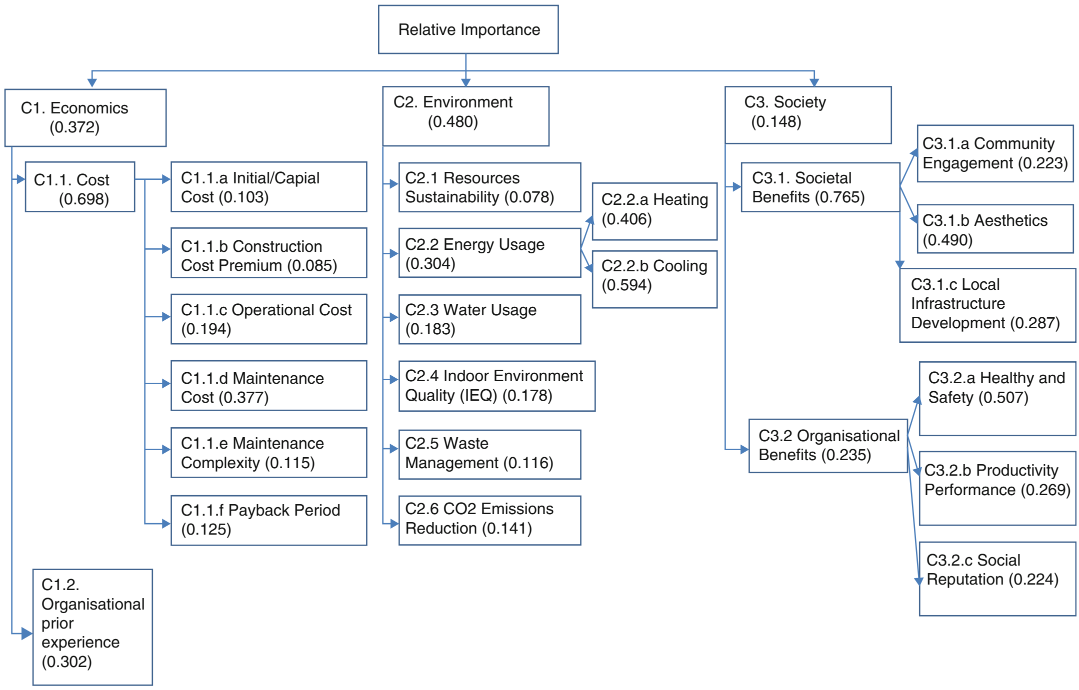
With assigning the relative importance of pillars and subpillars, the weightings of pillars and subpillars are determined based on their priority. For example:

$$\begin{aligned}&\text{The weighting of C1.1.a}\\&\quad = \text{Relative Importance of C1}\\&\qquad \times \text{Relative Importance of C1.1}\\&\qquad \times \text{Relative Importance of C1.1.a.}\end{aligned}$$

By doing so, the weightings of pillars and subpillars undertaken in this research are shown in Table 3.

Assessment of GFTs

For GFTs assessments, their ranking is based on the integration of their pillars' assessments. In every pillar, the assessment is determined by multiplying GFT assessments with their correlative weightings. This calculation follows the principles of the AHP tool. The highest ranking green feature or technology is the one which generates



Sustainability Balance, Fig. 2 Relative importance of subpillars and pillars in pairwise comparison

the most benefits that make TBL sustainability possible. Conversely, the lowest ranking green feature or technology produces the least benefits to the three pillars of sustainability. Based on their rankings, green features and technologies are selected from the highest to the lowest benefits for their suitability in green office projects.

On the one hand, GFTs in the Management category provided the most significant benefits to the TBL sustainability. GFT1.1 – Green Star professionals, GFT1.3 – Environmental management plan, and GFT1.2 – Detailed building users' guide measured at 3.205, 3.026, and 3.006, respectively. The next categories were Energy and IEQ. In the Energy category, GFT3.11 – Chilled beam system (3.070), GFT3.1 – Sub-metering is installed for all substantive base building users (2.947), and GFT3.6 – Photovoltaic system (2.879) were reported as the primary GFTs that created greater benefits. For the IEQ category, GFT2.11 – Low e-glazing or double-glazing (2.980), GFT2.1 – High induction supply swirl diffusers (2.906), GFT2.9 – Glare reduction by blinds and/or shading (2.905), and GFT2.3 – Reduction in photocopies/printers due to dedicated rooms (2.629) generated greater benefits from the TBL perspective. On the other hand, GFTs in the categories of IEQ and Energy provided the least benefits. Particularly, in the IEQ category, GFT2.6 – Dedicated tenant exhaust riser and GFT2.5 – Increase outside fresh air intake rates by 50% took the lowest positions of 2.481 and 2.588, respectively. Similarly, in the Energy category, GFT3.10 – Gas fired co-generation plant and GFT3.3 – T5 fluorescent lighting were the next GFTs that generated less benefits, at 2.591 and 2.629, respectively (see Table 4).

Regarding the GFTs group that were assessed as offering the most benefits to the TBL, the selection of these GFTs for the different Green Star categories can be explained differently. For the Management category, the selection of GFTs is made possible by the achievement of green credits and the cost spent. In research by Zuo et al. (2016), they stated that GFTs in the Management category helped to obtain green credits easily with their frequencies being more than 85%. GFTs in the Energy and IEQ categories are explained by presenting the current trend in sustainable technologies being developed for

Sustainability Balance, Table 3 Relative importance of subpillars and pillars in pairwise comparison

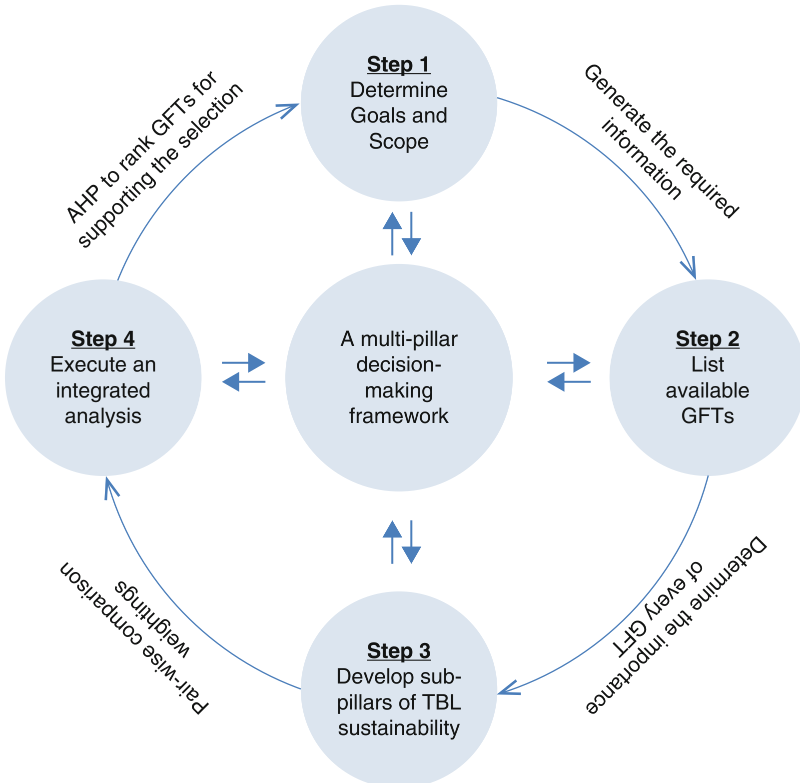
No	Code	Pillar or subpillar	Relative importance	Weighting
	Cl	Economics	0.372	
1	Cl.l	Cost	0.698	
1.1	Cl.l.a	Capital/Initial cost	0.103	0.027
1.2	Cl.l.b	Construction cost premium	0.085	0.022
1.3	Cl.l.c	Operational cost	0.194	0.050
1.4	Cl.l.d	Maintenance cost	0.377	0.098
1.5	Cl.l.e	Maintenance complexity	0.115	0.030
1.6	Cl.l.f	Payback period	0.125	0.032
2	C1.2	Organizational prior experience	0.302	0.112
	C2	Environment	0.480	
1	C2.1	Resources sustainability	0.078	0.037
2	C2.2	Energy usage	0.304	
2.1	C2.2.a	Heating	0.406	0.059
2.2	C2.2.b	Cooling	0.594	0.087
3	C2.3	Water usage	0.183	0.088
4	C2.4	Indoor environment quality (IEQ)	0.178	0.086
5	C2.5	Waste management	0.116	0.056
6	C2.6	CO2 emissions reduction	0.141	0.068
	C3	Society	0.148	
1	C3.1	Societal benefits	0.765	
1.1	C3.1.a	Community engagement	0.223	0.025
1.2	C3.1.b	Aesthetics	0.490	0.055
1.3	C3.1.c	Local infrastructure development	0.287	0.033
2	C3.2	Organizational benefits	0.235	
2.1	C3.2.a	Healthy and safety	0.507	0.018
2.2	C3.2.b	Productivity and performance	0.269	0.009
2.3	C3.2.c	Social reputation	0.224	0.008

achieving green credits. Firstly, the focus of GFTs in the Energy and IEQ categories is on energy efficiency and reduction of environmental impacts (Darko et al. 2017). This focus sets out to eliminate a building's impact on the built environment. GFT3.11 – Chilled beam system, as an example, reveals that GFT3.11 minimizes energy consumption significantly and this in turn leads to environmental protection (Love et al. 2011). Secondly, in achieving Green Star certification, the energy category accounts for the highest green credits of 24 to 25 and then the IEQ category with 20 to 27 green credits, to receive green credits (see Table 1). Therefore, the GFTs assessments primarily concentrate on the energy efficiency and IEQ, which generate the higher benefits of TBL and subsequently higher green credits. It can therefore be stated that GFTs assessments indicate the casual link between the benefits to TBL sustainability and the achievement of green credits.

As can be seen in Table 4, GFTs in Energy and IEQ generate the least benefits to TBL sustainability. This ranking reflects the recent changes of how GFTs are used in the development of sustainability in office projects. For example, GFT3.3 – T5 fluorescent has the lowest ranking because it has been replaced by Lighting Emitting Diodes (LEDs) that reduce energy consumption (Doulos et al. 2017). LEDs save energy and are more efficient than T5 fluorescent in the lighting system. Hence, GFTs assessments from the approach of TBL sustainability reflect the development of green features and technologies in green office projects.

Sustainability Balance, Table 4 Assessments of 46 GFTs based on the TBL sustainability approach

Categories	GFs and GTs	Economics	Environment	Society	Sum	Ranking
1. Management category	GFT1.1	1.045	1.694	0.466	3.205	1
	GFT1.2	1.095	1.493	0.418	3.006	4
	GFT1.3	1.115	1.475	0.436	3.026	3
	GFT1.4	1.170	1.242	0.396	2.808	22
2. Indoor Environmental Quality category	GFT2.1	1.018	1.494	0.394	2.906	9
	GFT2.2	0.978	1.485	0.441	2.904	11
	GFT2.3	0.979	1.286	0.364	2.629	42
	GFT2.4	1.108	1.209	0.369	2.686	39
	GFT2.5	0.975	1.223	0.390	2.588	45
	GFT2.6	0.967	1.163	0.351	2.481	46
	GFT2.7	1.040	1.203	0.455	2.697	38
	GFT2.8	1.101	1.374	0.400	2.875	13
	GFT2.9	1.089	1.400	0.416	2.905	10
	GFT2.10	1.125	1.143	0.362	2.630	40
	GFT2.11	1.084	1.510	0.386	2.980	5
	GFT2.12	1.075	1.256	0.385	2.715	34
	GFT2.13	1.103	1.258	0.489	2.850	18
3. Energy category	GFT3.1	1.167	1.394	0.387	2.947	6
	GFT3.2	1.167	1.336	0.350	2.853	17
	GFT3.3	1.108	1.156	0.364	2.629	41
	GFT3.4	1.165	1.276	0.400	2.841	19
	GFT3.5	1.093	1.201	0.428	2.721	32
	GFT3.6	1.186	1.233	0.460	2.879	12
	GFT3.7	1.044	1.369	0.387	2.801	23
	GFT3.8	1.041	1.357	0.385	2.783	26
	GFT3.9	1.016	1.305	0.378	2.699	36
	GFT3.10	1.010	1.206	0.375	2.591	44
	GFT3.11	1.204	1.465	0.401	3.070	2
4. Transport category	GFT4.1	1.070	1.242	0.414	2.726	30
	GFT4.2	1.085	1.244	0.491	2.820	21
5. Water category	GFT5.1	1.036	1.343	0.449	2.828	20
	GFT5.2	1.046	1.284	0.368	2.699	37
	GFT5.3	1.084	1.403	0.387	2.874	14
	GFT5.4	1.188	1.382	0.370	2.940	7
	GFT5.5	1.150	1.373	0.394	2.917	8
	GFT5.6	1.060	1.274	0.382	2.716	33
	GFT5.7	0.999	1.240	0.376	2.615	43
	GFT5.8	1.132	1.316	0.420	2.868	16
6. Material category	GFT6.1	1.079	1.311	0.404	2.794	24
	GFT6.2	1.112	1.274	0.376	2.762	27
	GFT6.3	1.082	1.249	0.381	2.712	35
	GFT6.4	1.093	1.247	0.384	2.723	31
7. Ecology and Land category	GFT7.1	1.035	1.326	0.427	2.788	25
8. Emission category	GFT8.1	1.068	1.316	0.485	2.869	15
	GFT8.2	1.152	1.223	0.373	2.748	28
	GFT8.3	1.133	1.220	0.379	2.732	29



Sustainability Balance, Fig. 3 The multipillar decision-making framework

A Multipillar Decision-Making Framework

Logically following the process used in this research, a multipillar decision-making framework for the selection of GFTs can now be established with four principal steps. The framework is the most important outcome of this research. They are described in more details below:

Step 1: Determine goals and scope of a green office project. This step generates the required information concerning green features and technologies and may be used to create the pillars and subpillars for assessing green features and technologies, presented in Fig. 3.

Step 2: List all green features and technologies that are available (in this research, it was 46, based on assessment of 181 Green Star projects) to be considered for a particular green office project. It determines which GFTs would be appropriate to be considered for assessments. One may commence with the ones identified in this research and eliminate or add as required.

Step 3: Determine assessments of GFTs based on subpillars for the Economics, Environment and Society pillars. This framework can use the subpillars and pillars of this research as a reference (see Fig. 2). Analytical Hierarchy Process (AHP) has been employed to determine weightings of subpillars and pillars.

Step 4: Execute an integrated analysis of green features and technologies using AHP. The rankings of these green features and technologies can now be developed. This ranking process assists in the selection of green features and technologies where Triple Bottom Line sustainability: Economics, Environment, and Society are a critical consideration either as part of a rating tool or a requirement from other considerations, such as Sustainable Development Goals.

The multipillar decision-making framework can be flexibly modified to meet the context of every green office project. It enhances the understanding of the benefits to Economics, Environment, and Society that are potentially generated by GFTs. This framework will assist decision-makers to identify suitable GFTs at the initial stage of a project and subsequently lead to better outcome of sustainability in an office project.

Conclusion

A multipillar decision-making framework for assisting in the selection of green features and technologies has been developed in this paper. This framework assesses green features and technologies considering Triple Bottom Line sustainability. This framework can be implemented at the initial stage of an office project for aiding the selection of GFTs. It provides GFTs information for supporting decision-makers when they are working with project consultants and other relevant stakeholders. Furthermore, this research indicates that of the three pillars: Economics, Environment, and Society; Environment is the most important pillar in the development of green office projects. These pillars do not have the same relative importance demonstrating the imbalance between the three pillars. There is a causal link in the assessments of GFTs under TBL sustainability and the achievement of green credits in Green Star, or indeed any other tool similar to Green Star. This link leads to special focus on GFTs in the Energy and IEQ categories, as these categories are heavily credited in the Green Star rating tool. Finally, the research shows how to use the framework for selecting GFTs to be applied to an office project. These research findings and outcomes make a substantial contribution to understanding the decision making process for sustainable development in office projects in Australia. This process is not just applicable in the Australian context but may also be applicable to other similar tools and countries adopting such tools.

References

ABS (2016) Construction and the environment [Online]. http://www.abs.gov.au/ausstats/abs@.nsf/featurearticlesbytitle/17A5995C5D55BBBDCA256CAE0015F653?OpenDocument. Accessed 9 Jan 2016

Ahn YH, Pearce AR (2007) Green construction: contractor experiences, expectations, and perceptions. J Green Build 2:106–122

Akadiri PO, Olomolaiye PO, Chinyio EA (2013) Multi-criteria evaluation model for the selection of sustainable materials for building projects. Autom Constr 30:113–125

Australian Government (2015) National Inventory by Economic Sector 2013

Butera FM (2010) Climatic change and the built environment. Adv Build Energy Res 4:45–75

Calkins M (2008) Materials for sustainable sites: a complete guide to the evaluation, selection, and use of sustainable construction materials. Wiley, Hoboken

Chen M, Chen JG, Cheng XX (2011) Life cycle incremental cost-benefit analysis of green building. Appl Mech Mater 71–78:4645

Collier ZA, Wang D, Vogel JT, Tatham EK, Linkov I (2013) Sustainable roofing technology under multiple constraints: a decision-analytical approach. Environ Syst Decis 33:261–271

Convertino M, Baker K, Vogel J, Lu C, Suedel B, Linkov I (2013) Multi-criteria decision analysis to select metrics for design and monitoring of sustainable ecosystem restorations. Ecol Indic 26:76–86

Corr K, Adams I, Boynton D (2008) Water use and sustainable commercial buildings [Online]. Australian Policy Online. http://apo.org.au/resource/water-use-and-sustainable-commercial-buildings2016. Accessed 9 Jan 2016

Da Silva L, Ruwanpura JY (2009) Review of the LEED points obtained by Canadian building projects. J Archit Eng 15:38–54

Dadzie J, Ding G, Runeson G (2017) Relationship between sustainable technology and building age: evidence from Australia. Procedia Eng 180:1131–1138

Darko A, Chan AP, Owusu-Manu D-G, Ameyaw EE (2017) Drivers for implementing green building technologies: an international survey of experts. J Clean Prod 145:386–394

Doulos LT, Tsangrassoulis A, Kontaxis PA, Kontadakis A, Topalis FV (2017) Harvesting daylight with LED or T5 fluorescent lamps? The role of dimming. Energ Buildings 140:336–347

EIA report (2008) Annual energy review [Online]. https://www.eia.gov/totalenergy/data/annual/archive/038408.pdf. Accessed 3 Dec 2018

Elkington JB (1997) Cannibals With Forks: The Triple Bottom Line of 21st Century Business. Oxford: Capstone Publishing

Energy Market Authority (2018) Singapore energy statistics [Online]. https://www.ema.gov.sg/cmsmedia/Publications_and_Statistics/Publications/SES18/Publication_Singapore_Energy_Statistics_2018.pdf. Accessed 3 Dec 2018
GBCA (2008a) The dollars and sense of green buildings: building the business case for green commercial buildings in Australia, Sydney, NSW, Green Building Council of Australia
GBCA (2008b) Technical manual: green star office design & office as built. Green Building Council, Sydney
GBCA (2015a) Green Star-Office v3 [Online]. https://www.gbca.org.au/green-star/rating-tools/green-star-office-design-v3-green-star-office-as-built-v3/1710.htm. Accessed 30 Mar 2017
GBCA (2015b) Mid-tier commercial buildings sector report [Online]. https://www.gbca.org.au/advocacy/mid-tier-commercial-office-buildings-pathway-project/36449.htm. Accessed 30 Mar 2017
Gluch P, Baumann H (2004) The life cycle costing (LCC) approach: a conceptual discussion of its usefulness for environmental decision-making. Build Environ 39:571–580
Houghton A, Vittori G, Guenther R (2009) Demystifying first-cost green building premiums in healthcare. HERD: Health Environ Res Des J 2:10–45
Hwang B-G, Tan JS (2012) Green building project management: obstacles and solutions for sustainable development. Sustain Dev 20:335–349
Issa MH, Rankin JH, Christian AJ (2010) Canadian practitioners' perception of research work investigating the cost premiums, long-term costs and health and productivity benefits of green buildings. Build Environ 45:1698–1711
Kats G (2010) Greening our built world: costs, benefits, and strategies. Island Press, Washington, DC
Kats, G, Alevantis L, Berman A, Mills E, Perlman J (2003) The costs and financial benefits of green buildings: a report to California's sustainable building task force, Washington: Capital E
Kim J-L, Greene M, Kim S (2014) Cost comparative analysis of a new green building code for residential project development. J Constr Eng Manag 140: 05014002
Kneifel J (2010) Life-cycle carbon and cost analysis of energy efficiency measures in new commercial buildings. Energ Buildings 42:333–340
Langdon D (2007) The cost and benefit of achieving green buildings. Second Quarter. Retrieved 2 Aug 2012
Love PE, Niedzweicki M, Bullen PA, Edwards DJ (2011) Achieving the green building council of Australia's world leadership rating in an office building in Perth. J Constr Eng Manag 138:652–660
Matthiessen LF, Morris P, Langdon D, Association, CAB (2007) Cost of green revisited: reexamining the feasibility and cost impact of sustainable design in the light of increased market adoption. Continental Automated Buildings Association, Ottawa
Nadoushani ZSM, Akbarnezhad A, Jornet, JF and Xiao, J (2017) Multi-criteria selection of façade systems based on sustainability criteria. Building and Environment 121:67–78
Ortiz O, Castells F, Sonnemann G (2009) Sustainability in the construction industry: a review of recent developments based on LCA. Constr Build Mater 23:28–39
Pohekar SD, Ramachandran M (2004) Application of multi-criteria decision making to sustainable energy planning – a review. Renew Sust Energ Rev 8:365–381
Property Council of Australia (2017) Office Market report [Online]. Australia. https://www.propertycouncil.com.au/Web/EventsServices/ResearchandData/Office_Market_Report/Web/EventsServices/ResearchServices/Office_market_report.aspx?hkey=7c43b696-cd31-4f6c-8314-4c62a4b0467a. Accessed 28 Mar 2017
Rehm M, Ade R (2013) Construction costs comparison between 'green' and conventional office buildings. Build Res Inf 41:198–208
Sheikh N, Daim T, Kocaoglu DF (2011) Use of multiple perspectives and decision modeling for PV technology assessment. Technology Management in the Energy Smart World (PICMET), 2011 Proceedings of PICMET'11, 2011. IEEE, pp 1–21
Si J, Marjanovic-Halburd L, Nasiri F, Bell S (2016) Assessment of building-integrated green technologies: a review and case study on applications of multi-criteria decision making (MCDM) method. Sustain Cities Soc 27:106–115
Steven Winter Associates, I (2004) GSA LEED cost study: final report. US General Services Administration, Washington, DC
UNEP (2016) Why buildings [Online]. http://www.unep.org/sbci/AboutSBCI/Background.asp. Accessed 9 Jan 2016
Vyas GS, Jha KN (2017) Benchmarking green building attributes to achieve cost effectiveness using a data envelopment analysis. Sustain Cities Soc 28:127–134
WCED (1987) Our common future. Oxford University Press, London
Yudelson J (2010) The green building revolution. Island Press. Washington
Zhao X, Chen L, Pan W, Lu Q (2017) AHP-ANP–fuzzy integral integrated network for evaluating performance of innovative business models for sustainable building. J Constr Eng Manag 143:04017054
Zuo J, Xia B, Chen Q, Pullen S, Skitmore M (2016) Green building rating for office buildings – Lessions learned. J Green Build 11:131–146