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Overcoming the limitations of the green pyramid rating system in the Egyptian construction industry: a critical analysis

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ABSTRACT

Despite the tangible contributions of the construction industry to social development and economic growth, it is known for its natural resources overconsumption and solid waste (SW) generation both of which have major negative impacts on the natural environment. In the particular case of materials waste, the construction industry worldwide accounts for about 50% of global annual generated SW. In addition, construction materials may contribute up to 50% of the total project cost. Accordingly, the negative implications of the construction industry have compelled many nations to develop green building rating systems in order to preserve the environment, promote the economic efficiency of using resources, and enhance the quality of citizens' lives which are necessary aspects for achieving the triple bottom line (TBL) of sustainability. Recently, Egypt developed the Green Pyramid Rating System (GPRS) in its first version in 2011. Through investigating the GPRS and especially its Materials and Resources (M&R) category, some shortcomings were identified. Towards improving the GPRS, this paper aims to investigate the GPRS and compare it with its peers BREEAM and LEED with a special focus on M&R category. The investigation and comparison results helped proposing suggestions which may improve the GPRS on the categorical level and the criteria level of M&R category. Moreover, the importance of M&R category is demonstrated by a case study through using palm fronds as a green material for concrete reinforcement to prove the positive impact of this category on the TBL of sustainability.

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Introduction

The construction industry contributes significantly to the Egyptian economy both in terms of employment and gross domestic product (GDP). It is responsible for employing 11% of the total population and accounts for 5% of GDP (Esam & Ehab, 2015). This is hardly surprising given the rapid development and expansion of the construction sector over the past few years to cope with increasing demands for built assets largely driven by public sector's megaprojects (Invest-gate, 2016). The fact that the real growth rate of the construction sector rose from 9.7% in the fiscal year (FY) 2014/2015 (Central Bank of Egypt (CBE), 2015) to 11.2% in the FY 2015/2016 (CBE, 2016) attests to the growth experienced by the construction sector. The growth trends in the construction sector can also be visualised by the amounts of the investment capital which is tripled in the FY 2015/2016 (Barakat et al., 2016) to reach LE 11.7 billion instead of LE 3.7 billion in the FY 2014/2015 (Barakat et al., 2017).

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Despite the aforementioned positive impacts on the Egyptian economy and society, the construction industry's main imperfection lies in its waste generation and environmental pollution (Azis, Memon, Rahman, Nagapan, & Latif, 2012). Construction and demolition waste (CDW) represents a great problem in Egypt (Daoud, Ahmed, Othman, Robinson, & Bayyati, 2020). According to the latest statistics, the Egyptian construction industry generates 5.8 million tonnes of CDW annually (Egyptian Ministry of Environment (EMoE), 2017). In 2016, It was estimated that there are 18 million m^3 of solid waste (SW) dumps throughout Egypt in which most of it is CDW interspersed with domestic waste (EMoE, 2017). The indiscriminate dumping of CDW on residential streets and at uncontrolled dumpsites has become a regular practice amongst Egyptian construction companies (Azmy & El Gohary, 2017; Japanese Ministry of Environment (JMoE), 2004). In Egypt, up to 40% of total construction materials cost is wasted and this is equivalent to 16% of total building cost (i.e. labour and materials cost). It is worth mentioning that the waste in total materials cost must not exceed 4% under any circumstances (Shamseldin, 2003).

Given the fact that the Egyptian government is currently executing a lot of construction megaprojects, it is expected that the amount of CDW will increase based on the high intensity of using materials and resources (Ahmad et al., 2014; Azis et al., 2012). Besides, Elattar and Ahmed (2014) claimed that using more materials and resources unwisely will lead to their depletion and increase of project cost. Moreover, Ajayi et al. (2017) reported that construction materials could contribute up to 50% of the total project cost. Accordingly, in order to mitigate the negative effect of CDW on the triple bottom line (TBL) (i.e. society, environment, and economy) of sustainability, the usage of materials should be rationalised via guidelines and standards indicating how to procure and use materials in a sustainable manner (Abdelhamid, 2014; Daoud et al., 2020; Daoud, Othman, Robinson, & Bayyati, 2018b; Hany & Dulaimi, 2014).

So far, many countries worldwide have developed their own rating standards and guidelines towards green building (GB) practices, named green building rating systems (GBRSs), in quest for sustainable construction industry (Hussin, Rahman, & Memon, 2013). GBRSs emphasise sustainable development of societies on three different levels as follows: (1) human level; (2) country level; and (3) global level (Karmany, 2016). Over the past 15 years, Middle East and North Africa (MENA) countries looked to developing and applying their GBRSs (Attia, 2017). This has taken place after the leading initiatives taken by the UK and US to develop their GBRSs respectively as follows: Building Research Establishment Environmental Assessment Method (BREEAM) in 1990, and Leadership in Energy and Environmental Design (LEED) certification in 1998. Apart from the other sustainable goals of GBRSs, the emphasis on optimising the usage of materials through established guidelines for sustainable procurement of materials is prominent (Attia, 2017; Hussin et al., 2013).

In 2011, the Egyptian Green Building Council (EGGBC) developed the Egyptian GBRS named Green Pyramid Rating System (GPRS) in its first version and it was revised in 2017 based on the third version of the LEED (Ammar, 2012; Ismaeel, Rashed, & Toulibah, 2018). However, the GPRS still needs more development (Ammar, 2012). One of the main weaknesses found in the GPRS is imitating the LEED without adapting to the local context, in which some criteria were adopted without considering local capacity and others were not adopted while being considered as promising solutions for solving the current challenges and needs in Egypt (Attia, 2017). Given a country's specific nature and challenges, a rating system that is developed to suit a certain context or region needs to be tuned and adapted to local contexts (Karmany, 2016). The development of a rating system must reflect local capacity, constraints, opportunities, and above all, the local strategies and needs of the adopting countries. Indeed, the need to develop the structure and rating criteria of the GPRS to address the environmental, economic, and social needs in Egypt is overwhelming (Ammar, 2012; Ismaeel et al., 2018). The GPRS is quite promising but it cannot be considered comprehensive until it attunes to local needs (Daoud, Othman, Robinson, & Bayyati, 2018a; Ismaeel et al., 2018).

Accordingly, this paper focuses on investigating the GPRS and analysing its Materials and Resources (M&R) category to suggest better improvements and developments. The paper starts by comparing the GPRS with BREEAM and LEED quantitatively and qualitatively with a special focus on M&R category. This is for the sake of capturing what suits the Egyptian context in solving aspects of its environmental problems which is CDW. The outcome of the investigation of GPRS and the critical comparison with BREEAM and LEED rating systems, focusing on the M&R category, reveals some of the weaknesses in the GPRS and proposes improvements accordingly as are explained in the research methodology section and investigated in detail later in the paper.

Research methodology

This research adopted a five-sequential step approach, as shown in Figure 1, to investigate the GPRS and analyse its shortcomings especially the Materials and Resources (M&R) category in order to suggest better improvements and developments. *First*, a systematic internet search was conducted

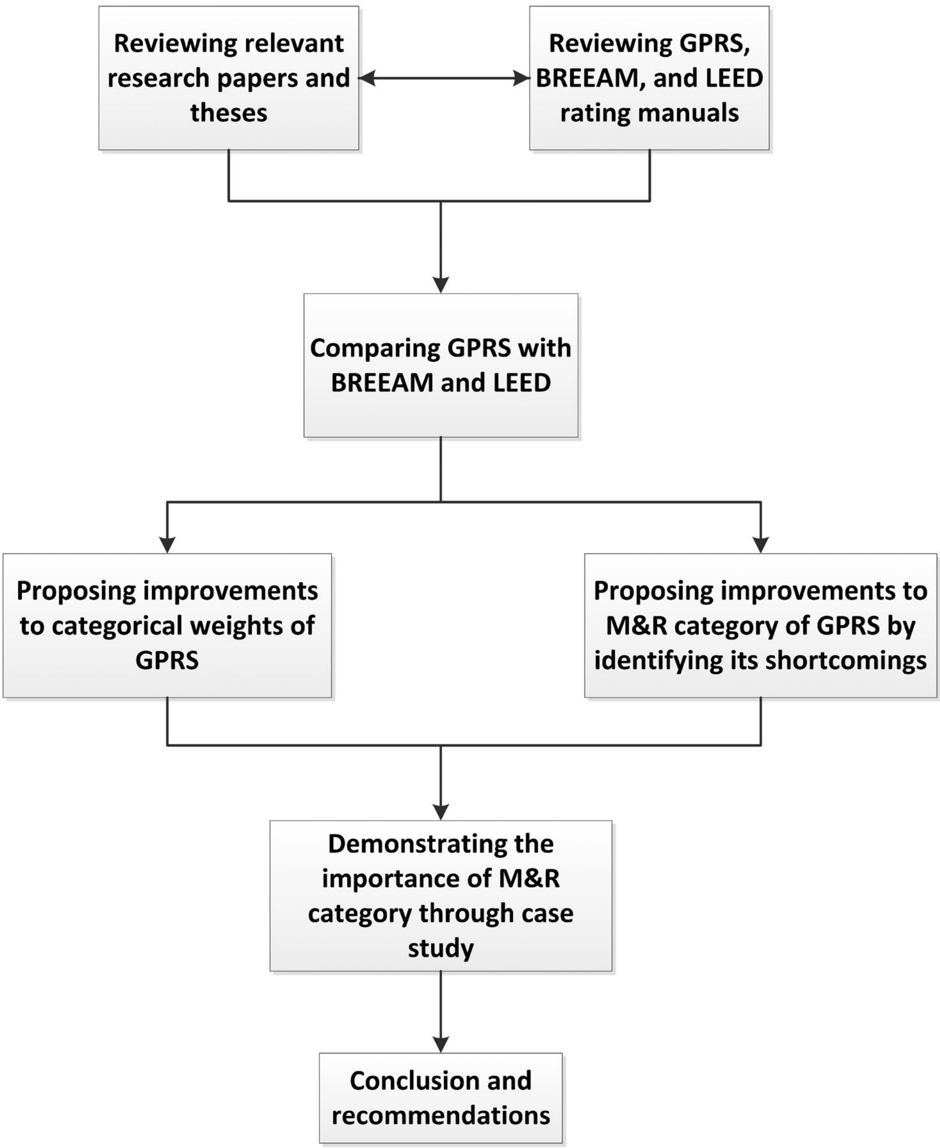

Figure 1. Research flowchart.

via different databases, such as Scopus, Web of Science (WOS), JSTOR, ProQuest, to review different research papers and theses related to the research topic. This was conducted using specific keywords, either separately or in combination, such as 'GPRS', 'BREEAM', 'LEED', 'materials and resources', 'materials waste', 'comparative study', 'waste reduction'. Also, rating manuals of GPRS, BREEAM, and LEED were thoroughly reviewed to capture their components and detailed structure. *Second*, the GPRS was compared with BREEAM and LEED quantitatively and qualitatively in general, on the categorical level, and on the criteria level of M&R category to highlight similarities, differences, and current shortcomings in the GPRS.

Third, improvements to GPRS categorical weights were proposed based on the outcome of the investigation and the critical comparison with BREEAM and LEED rating systems which revealed some of the weaknesses in the GPRS. In addition, an in-depth investigation was carried out on the criteria level of M&R category to identify its shortcomings in the GPRS either by criticising existing criteria or by highlighting missing criteria compared to M&R category of BREEAM and LEED. *Fourth*, a case study, which focuses on using chemically treated palm fronds (PFs) as a reinforcement material for concrete members, was employed to demonstrate the importance of M&R category and its impact on the TBL of sustainability. *Finally*, conclusion and recommendations section are presented to highlight and comprehensively demonstrate the results of this research and propose recommendations for future improvements.

A comparison between GPRS, BREEAM, and LEED

This section presents an overall comparison between GPRS, BREEAM, and LEED. Also, it presents a categorical weights' comparison between the three GBRSs in their most recent versions (i.e. GPRS V2, BREEAM International New Construction 2016, and LEED V4).

An overall comparison between GPRS, BREEAM, and LEED

The main characteristics of GPRS, BREEAM, and LEED are summarised in Table 1. It is noticed that the three rating systems recently released their latest updated versions. This demonstrates that the three GBRSs try to modify and update their contents, either criteria or weightings, to address the changing needs and new challenges towards achieving sustainable construction industry (Doan et al., 2017).

It is obvious from the comparison that the applicability of the GPRS is limited to the Egyptian context only with a limited number of certified buildings. This can be explained by that fact that GPRS has been developed nine years ago and it is still at early stages of development and improvement compared to the well-established BREEAM and LEED (Karmany, 2016). BREEAM and LEED are characterised by large number of certified buildings worldwide. Despite the different contexts, countries other than UK and US are using BREEAM and LEED for certifying green buildings. This is because GBRSs could be classified as international standards or local standards. Based on the comparison, it is obvious that the number of BREEAM certified buildings is almost seven times the number of LEED certified buildings. However, LEED has a higher applicability and popularity in worldwide countries than BREEAM (Doan et al., 2017).

Regarding the number of categories in the three GBRSs, BREEAM has the largest number (i.e. 10 categories), which is higher than those of LEED and GPRS with nine categories and seven categories, respectively. However, the three GBRSs share some common features of categories. This is because the direct influence of BREEAM on LEED (Doan et al., 2017) and the direct influence of LEED on GPRS (Daoud et al., 2018a; Ismaeel et al., 2018), which consequently means that BREEAM has indirect influence on GPRS. Despite the effect of BREEAM and LEED on GPRS, there are some discrepancies in GPRS categories compared to those of BREEAM and LEED. Some categories are missing or named with different terminologies in the GPRS as discussed later in this paper. These discrepancies, between the GPRS on one hand and BREEAM and LEED on the other hand, may have resulted because GPRS was developed by Egyptian governmental bodies and Egyptian and non-Egyptian

Table 1. Comparing GPRS with BREEAM and LEED.

Points of comparison	GPRS V2	BREEAM International New Construction 2016 V2	LEED V4
Country	Egypt	UK	US
Organisations	EGGBC	BRE	USGBC
Flexibility	1 country	77 countries	160 countries
First version	2011	1990	1998
Latest version	2017	2016 (updated in 2017)	2013 (updated in 2019)
Main categories	• Management protocols • Indoor environmental quality • Energy efficiency • Water efficiency • Materials and Resources • Sustainable sites • Innovation and added value	• Management • Health & wellbeing • Energy • Transport • Water • Materials • Waste • Land Use & Ecology • Pollution • Innovation	• Integrative process • Indoor environment quality • Energy & atmosphere • Location & transportation • Water efficiency • Materials & resources • Sustainable sites • Regional priority • Innovation
Rating approach	Additive credits	Pre-weighted categories	Additive credits
Rating levels	• Certified ≥ 40 • Silver pyramid ≥ 50 • Gold pyramid ≥ 60 • Green pyramid ≥ 80	• Pass ≥ 30 • Good ≥ 45 • Very good ≥ 55 • Excellent ≥ 70 • Outstanding ≥ 85	• Certified ≥ 40 • Silver ≥ 50 • Gold ≥ 60 • Platinum ≥ 80
Number of certified buildings	2	561,600	79,100

Source: Housing and Building National Research Center [HBRC] (2017); Building Research Establishment [BRE] (2016), Karmany (2016), Doan et al. (2017), U.S. Green Building Council [USGBC] (2019).

academics. The three GBRSs have common categories, such as *Energy*, *Water*, *Materials*, and *Sustainable Sites*, which are tailored to their local contexts (Ismail, Abo Elela, & Ahmed, 2015; Karmany, 2016). This demonstrates that these categories are attracting global attention and they should be prioritised (Doan et al., 2017). Regarding the rating approach of the three GBRSs, GPRS and LEED sum all credit points to get the final grade while BREEAM pre-weight the categories before summing them to get a final BREEAM score. The rating approach of BREEAM is more complex than LEED and GPRS (Doan et al., 2017; Karmany, 2016).

Categorical weights' comparison between GPRS, BREEAM, and LEED

In this section, the categories of the three GBRSs are compared together to investigate their weights and importance according to each GBRS as shown in Table 2. By examining the three GBRSs, it has been noticed that most of the categories listed in them have same meaning or aim but with different terminology (Ismail et al., 2015). For instance, Land Use & Ecology category in BREEAM is equivalent to Sustainable Sites category in LEED and GPRS. But, the requirements or the criteria of the categories may differ from one rating system to another (Karmany, 2016). Also, the criteria or requirements of a category sometimes are listed under different categories (Menting, 2016).

It is worth mentioning that the weights of GPRS categories are the same for all types of buildings (HBRC, 2017). Conversely, the weights of LEED and BREEAM categories differ according to the building type (BRE, 2016; USGBC, 2019). For instance, the building types in LEED are classified as follows: New Construction, Core and Shell, Schools, Retail, Data Centres, Warehouses and Distribution Centres, Hospitality, and Healthcare. The weight of M&R Category is 12.73% for Core and Shell, 17.27% for Healthcare, and 11.82% for all other types of buildings including new construction. On the other

Table 2. Comparing the categories of GPRS, BREEAM, and LEED.

GPRS categories	BREEAM categories	LEED categories
Management protocols (10%)	Management (11%)	Integrative process (≈0.91%)
Indoor environmental quality (16%)	Health & wellbeing (19%)	Indoor environment quality (≈14.55%)
Energy efficiency (32%)	Energy (20%)	Energy & atmosphere (30%)
	Transport (6%)	Location & transportation (≈14.55%)
Water efficiency (20%)	Water (7%)	Water efficiency (10%)
Materials and resources (12%)	Materials (13%)	Materials & resources (≈11.82%)
	Waste (6%)	
Sustainable sites (10%)	Land use & ecology (8%)	Sustainable sites (≈9.09%)
	Pollution (10%)	Regional priority (≈3.64%)
Innovation and added value (5% bonus)	Innovation (10% bonus)	Innovation (≈5.45%)

Source: BRE (2016), HBRC (2017), USGBC (2019).

hand, the building types in BREEAM are classified as follows: Non-residential (fully fitted, shell only, shell and core), and Single and Multiple Residential Dwellings and Multiple Residential Dwellings (partially fitted, and fully fitted). The weight of Materials category ranges between 12.50 and 18.41% according to the building type. Accordingly, for the sake of thoroughness in this comparison, New Construction and Non-residential Fully Fitted building types are chosen for LEED and BREEAM, respectively. This is because the chosen LEED and BREEAM building types are fitting most of the construction projects which makes it a fair comparison with the GPRS as shown in Table 2.

It can be noticed that Energy Efficiency (EE) category has the highest weight in the three GBRSs. In the case of the GPRS, this demonstrates the growing energy crisis in Egypt mirrored by electricity supply interruptions in the country (Ismail et al., 2015). Also, the Water Efficiency (WE) category is accorded the second highest weight in the GPRS which reflects the growing water poverty owing to the construction of the Renaissance Dam leading to a reduction in Egypt's share of the Nile River (Ismail et al., 2015). It is noticed that the weight of M&R category in the three GBRSs is almost the same. However, in the case of the GPRS, M&R category should be accorded a higher weight compared to BREEAM and LEED. This is because Egypt still relies heavily on traditional methods of construction, which is not the case in advanced construction industries of the UK and US This has implications for material use, which is not as efficient as in modern construction, leading to increased materials wastage which consequently results in escalations of total project cost and depletion of natural resources (Elattar & Ahmed, 2014; Ismail et al., 2015). Indeed, Say and Wood (2008) highlighted the fact that although some categories within rating systems have a greater positive impact on sustainability, yet they are assigned lower weights. Furthermore, Dev (2017) argued that optimising materials consumption of the construction sector should be the priority of the GPRS given that it was developed to promote GBs in Egypt, minimise ecological footprints of the built environment, and boost the economic development by constructing complete societies in the deserts to meet the life needs of accelerating population growth. Accordingly, in the specific case and local context of the GPRS, the weighting allocated to M&R category need to be revised as investigated in the next section of this paper.

In particular, GPRS and LEED have no specific Waste category unlike BREEAM. In the Waste category of BREEAM, the management of both operational waste (i.e. waste resulting from the operation of the building by its occupants) and construction materials waste (i.e. waste of materials resulting from construction operations) is addressed (BRE, 2016). Although there is no specific category addressing issues of waste in LEED, it nevertheless addresses the management of both operational and construction materials waste through defined pre-requisites and requirements in its M&R category (USGBC, 2019). In the case of GPRS, only the management of operational waste has been addressed through defined criteria in the Management Protocols category (HBRC, 2017). In other words, GPRS paid no attention to the escalating problem of CDW generated by the Egyptian construction sector (Elattar & Ahmed, 2014; Hassan, 2012). Accordingly, CDW management has to be incorporated in the GPRS as investigated later in this paper.

A proposal for improving the categorical weights of GPRS

This section presents modified categorical weights as shown in Table 3, which are proposed by this study, for GPRS based on the current challenges faced by the Egyptian construction industry as previously investigated. Based on the aforementioned challenges in Egypt regards electricity supply shortage, water scarcity, and CDW, new categorical weights of the GPRS are proposed to address the current problems. Accordingly, EE, WE, and M&R categories are given the highest priorities to reflect their importance. Categorical weights are carefully modified to make sure that the rest of modified categories are assigned reasonable new weights compared to their old ones in GPRS V1 and their current ones in GPRS V2. The summation of all newly proposed categorical weights, without the bonus category, has to be 100. Accordingly, the process of weights modification started by proposing new weights to the aforementioned three critical categories, then modifying other categorical weights.

It is worth mentioning that WE category is accorded a new higher weight similar to its old one in GPRS V1 given the expected negative impacts of Renaissance Dam on Egypt. On the other hand, the electric power supply problem has been improved since the election of H.E. President Abdel Fattah El Sisi as a president. Total capacity in Egypt's power sector increased by 80% between June 2013 and June 2018 to 55.5 gigawatts (GWs), and there is a power surplus over demand in Egypt (Castlereagh Associates, 2019). Accordingly, the EE category is accorded a bit lower weight to match its old one in GPRS V1 given the importance of this category and the current improvements in the Egyptian power sector. M&R category is accorded a higher weight than its old one in GPRS V1 and current one in GPRS V2 given the growing challenge of CDW problem in Egypt. The new proposed weight is accorded to

Table 3. New proposed weights for GPRS categories.

Categories	Old weights in GPRS V1	Current weights in GPRS V2	New proposed weights	Comment
Management protocols (MP)	10%	10%	5%	The weight was modified as most of the elements in this category are included in other categories (Ismail et al., 2015).
Indoor environmental quality (IEQ)	10%	16%	10%	This category is important as much as Sustainable Sites (SS) category given the importance of enhancing the TBL of sustainability. Accordingly, they were assigned similar weights.
Energy efficiency (EE)	25%	32%	25%	This category is important given the current electricity supply interruptions in Egypt. A careful attention has to be paid for reducing and optimising energy consumption. Accordingly, it is assigned an average weight between the new proposed weights of both WE category and M&R category.
Water efficiency (WE)	30%	20%	30%	A higher weight is proposed to overcome the water crisis resulting from the construction of Renaissance Dam on the Nile River. A careful attention has to be paid to save water resources and optimise their usage.
Materials and resources (M&R)	10%	12%	20%	A higher weight is proposed to save raw materials from depletion, avoid high project cost, and reduce CDW given the current boom of construction in Egypt. This new proposed weight takes into consideration the integration of the missing criteria, discussed in the previous section, in the future version of the GPRS.
Sustainable sites (SS)	15%	10%	10%	This category demonstrates the importance of protecting the agricultural land from urban sprawl (Ismail et al., 2015).
Innovation and added value (IN)	5% (bonus)	5% (bonus)	5% (bonus)	

M&R category while paying attention to other remaining categorical weights. For instance, the IEQ category is accorded the same weight as its old one in GPRS V1. Also, the weight of SS category is kept as its current weight in GPRS V2 without changes. Finally, the weight of MP category is reduced by 5% compared to its current weight in GPRS V2 given the fact that most of its criteria are listed under other categories and to make sure that the summation of all proposed categorical weights is 100%.

Towards improving materials and resources (M&R) category of the GPRS

In this section, the shortcomings in the criteria of the M&R category are considered. This has been achieved based on an in-depth investigation of the criteria of the M&R category in the three GBRSs. The shortcomings either in the existing criteria or the criteria which are missing in the GPRS, compared to those of BREEAM and LEED, are listed in Table 4 together with corresponding analysis.

Case study: Palmocrete© – replacement of steel rebars by chemically treated palm fronds as concrete reinforcement

The main goal of this case study is to prove the importance of M&R category and its impact on the TBL of sustainability and support the rationale behind proposing a higher weight to it as investigated in this paper. This case study adopted only one criterion of the M&R category, which is 'using renewable materials', by using PFs as concrete reinforcing material. Due to the relatively high mechanical properties of palm PFs, PFs are considered attractive replacement to steel rebars in concrete members. PFs can improve the ductility, strength, and resistance to cracking of composite material, and they are responsible for converting the sudden brittle failure of concrete in tension into more gradual and ductile failure. PFs can be used in concrete medium after being coated with polyester chemical compound to preserve its mechanical and physical properties from deterioration and preserve its durability (Daoud, 2013). This technique of using PFs as concrete reinforcement is intended to produce lightweight concrete members for a low income one-story housing and it is named by Daoud (2013) as Palmocrete©. Accordingly, this section demonstrates in detail the benefits of using chemically treated PFs, a green material, as replacement of steel rebars in concrete members.

Availability of palm fronds in Egypt and their positive impacts on sustainability

As reported in (Daoud, 2013), palm trees are widespread in the Arab countries with over a 100 million trees. Egypt owns more than 10% of the palm trees in Arab countries, in which it has 11 million palm trees distributed among its governorates. Studies on Egyptian palm trees showed that every palm tree yields 15–20 PFs as a result of annual healthy pruning process. This means that Egypt has a rich availability of PFs which ranges between 165 million to 220 million PFs annually (Daoud, 2013).

Palmocrete© has great impacts on the TBL of sustainability in Egypt. Based on research and field pilot experiments carried out by Daoud (2013), the impacts can be summarised as follows:

- *Economic impact*: PFs can be used instead of steel rebars in concrete reinforcement leading to reduction in the building cost. PFs may reduce the cost of reinforcement (materials and placement) by 80–90%. One ton of steel costs about 10,000 LE according to the Egyptian market in 2019. On the other hand, PFs reinforcement costs 10-20% of steel rebars reinforcement cost, in which most of the cost goes to the coating compounds of the chemical treatment. It is worth mentioning that PFs possess high ultimate tensile strength (UTS) which may reach 70% of the steel rebars' UTS.
- *Environmental impact*: PFs produced from healthy pruning process of palm trees are rarely used in construction despite their huge potentials as a replacement of steel reinforcement. They can be

Table 4. Shortcomings in M&R category of the GPRS V2.

Criteria	Status	Comment	References
Renewable materials and materials manufactured using renewable energy.	Existing	• Lack of database for the available green materials in Egypt and their suppliers. • Lack of green materials certification in Egypt using national or international standards. • Lack of specification which ensures that the renewable materials should be obtained from a source which is rapidly renewable by specifying a time frame. • For materials manufactured using renewable energy, it is not effectively applied due to high initial costs of renewable energy.	Eldeeb (2013), Ismail et al. (2015), HBRC (2017), Khalifa et al. (2018), Ismaeel et al. (2018), Daoud et al. (2018a)
Regionally procured materials and products.	Existing	• The maximum distance between the construction site and the suppliers needs to be minimised below the specified distance 500 km. This distance is specified as 160 km in the LEED. This is necessary to minimise the negative impacts of materials' transportation on the environment.	Eldeeb (2013), HBRC (2017), USGBC (2019)
Reduction of overall material use.	Existing	• Not effectively applied due to lack of contractor's awareness.	HBRC (2017), Khalifa et al. (2018)
Alternative building prefabricated elements.	Existing	• Not effectively applied due to high initial costs of prefabricated elements and lack of highly qualified contractors.	HBRC (2017), Khalifa et al. (2018)
Environment – friendly, sound and thermal insulation materials.	Existing	• Lack of data about life cycle costs and information of these materials. • Not effectively applied due to lack of contractor's awareness.	BRE (2016), HBRC (2017), Khalifa et al. (2018), USGBC (2019)
Construction waste management	Missing	• Lack of requirements and instructions regarding the diversion of materials waste from landfills by applying reducing, reusing, and recovering techniques. The GPRS requires only presentation of a schedule for principal project materials. Also, it is worth mentioning that recycling industry lacks in Egypt. Accordingly, recycling is not mentioned here as a solution for CDW management.	BRE (2016), Elattar and Ahmed (2014), Hassan (2012), HBRC (2017), Ismail et al. (2015), USGBC (2019)
Building and material reuse	Missing	• Lack of requirements and instructions to indicate the reuse of an existing building structural elements (e.g. floors, roof decking), enclosure materials (e.g. skin, framing), and permanently installed interior elements (e.g. walls, doors, floor coverings, ceiling systems). This should help in reducing CDW.	Elattar and Ahmed (2014), BRE (2016), HBRC (2017), USGBC (2019)
Material efficiency	Missing	• Lack of requirements and instructions to help in reducing the amount of materials used in building design without compromising on the structural stability and other performance factors.	BRE (2016), HBRC (2017)

buried in concrete medium, and as a result, the indiscriminate disposal as SW on the streets and dumpsites can be mediated to ameliorate the environmental pollution resulting from current means of disposal, which is open incineration. Above all, and unlike the finite resources used in steel manufacture, palm trees are renewable materials.

- *Social impact*: Palmocrete© has huge social impact through the boost to self-esteem associated with employment and income generating opportunities in Egypt. The affordability of Palmocrete© technique can provide tremendous employment and income generating opportunities due to the reduction in construction costs. It has the potential to stimulate and sustain rural income and wealth by developing desert and remote areas in Egypt.

Pilot experiment: constructing a small house in Egypt using Palmocrete© technique

Palmocrete© technique is used for reinforcing one-way and two-way solid slabs and beams. These concrete members are reinforced using chemically treated PFs as aforementioned. The design of these concrete members using Palmocrete© technique is carried out via using the Egyptian code of practice for concrete structures and Response-2000 programme, in which the UTS of steel rebars is replaced by the UTS of PFs. Slabs and beams rest on bearing walls constructed according to the Egyptian code of practice for concrete structures. These bearing walls rest on ground beams which act as foundations for the building (Daoud, 2013).

In June 2011, a one-story building was built in Aswan governorate with dimensions of 8 m length by 6 m width. The construction of the building was funded by the British University in Egypt (BUE) and executed through ENACTUS-BUE as a part of community development programme. The ground beams were reinforced using chemically treated PFs as a flexural reinforcement, while shear reinforcement were steel stirrups. After concrete casting of ground beams, bearing walls were built over them. After the construction of bearing walls, wooden formwork was installed for slab construction. The two-way solid slab was reinforced using chemically treated PFs in the two directions as shown in Figure 2. The slab's beams were reinforced using chemically treated PFs for flexural reinforcement and steel stirrups of 6 mm diameter as shear reinforcement as shown in Figure 3. In addition of the four beams of the slab, there was an intermediate beam in midway of the slab dividing the long direction into two halves, as shown in Figure 4, because the length of PFs was ranging between 4 and 5 m while the long direction was 8 m (Daoud, 2013).

The final stage was concrete casting of the slab and its curing for 28 days. Local people and builders were transferred the knowledge of applying the Palmocrete© to help them in constructing or adding value to their low-income houses. Palmocrete© is cost effective, uses available locally produced PFs treated with available and affordable chemical compounds, and may prolong the active lifetime span for such slabs dramatically. The constructed building, as shown in Figure 5, is being used till now for 9 years without any cracks in the slab or settlement in the ground beams (Daoud, 2013).

Conclusion and recommendations

This paper thoroughly investigated the GPRS, as a part of an on-going PhD research project, and compared it with the well-established BREEAM and LEED in general, on the categorical level, and on the criteria level of M&R category. It was found that most of the categorical weights of the GPRS are imitating those of BREEAM and LEED without being tailored to the local context to address the current challenges in Egypt. For instance, the weight of M&R category is imitating its peers in BREEAM and LEED without considering the escalating problem of CDW in Egypt. Accordingly, this study proposed newly modified categorical weights, as investigated in Table 3, which may be considered for tackling the current challenges in Egypt regarding CDW, energy conservation, and water scarcity. These three categories (i.e. M&R, EE, and WE) were assigned the highest weights in the newly proposed categorical weights to demonstrate their criticality and importance.

Figure 2. Slab reinforcement. Source: Daoud (2013).

Based on an in-depth comparison of M&R category in three GBRSs as investigated in Table 4, shortcomings and limitations in this category of the GPRS were discussed. it was found that three important criteria are missing in the M&R category of the GPRS, compared to BREEAM and LEED, which are: construction waste management, building and material reuse, and material efficiency. It is recommended to integrate these criteria in the next version of the GPRS as they may help greatly in reducing and properly managing CDW in Egypt. In addition, it was found that existing criteria lacks critical elements. For instance, 'Renewable Materials and Materials Manufactured Using Renewable Energy' criterion lacks critical elements such as database for green materials in Egypt and their suppliers, green materials certifications, and standards needed to ensure that renewable materials are obtained from a source which is rapidly renewable. It is recommended to address the absence of the critical elements needed for the rigour and effective application of the criteria. Furthermore, it was

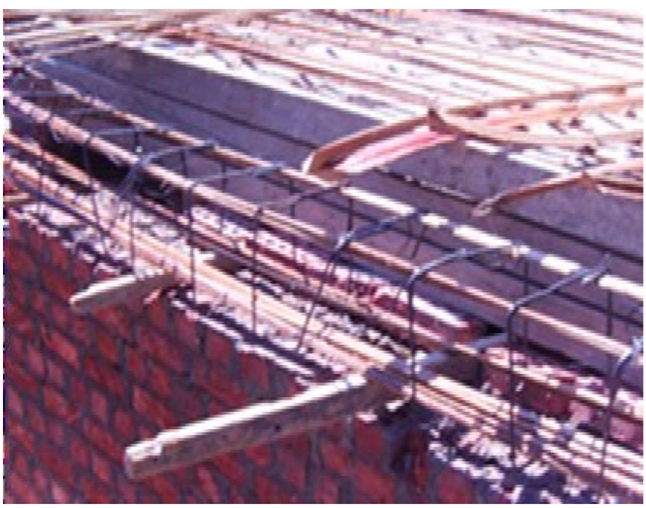

Figure 3. Beam reinforcement. Source: Daoud (2013).

Figure 4. Intermediate beam. Source: Daoud (2013).

found that some of the existing criteria are suffering from ineffective application due to low awareness of contractors, absence of qualified contractors, and high initial costs of its application. The Egyptian government is recommended to increase the awareness and capabilities towards the application of these high-tech methods and provide incentives for their application.

A case study of using PFs as a green material for concrete reinforcement was investigated. Through the application of this case study, it was proved that the efficient adoption of one criterion (i.e. using renewable materials) of M&R category can positively impact the TBL of sustainability. The main aim of the case study was to demonstrate the impact of M&R category on sustainability, and to reinforce the argument of according it a higher weight than its current weight in the recent version of

Figure 5. Final constructed building. Source: Daoud (2013).

the GPRS. In summary, the next version of the GPRS has to revise the weights of the different categories based on the current challenges in the Egyptian context. Also, it has to ensure that the M&R category is rigours enough by addressing the current shortcomings and limitations in its criteria to help in solving CDW problem in Egypt.

Disclosure statement

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