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Hierarchy based information requirements for sustainable operations of buildings in Qatar

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ABSTRACT

Information flows in construction projects are generally focused on the needs of the design and construction phases. This creates disruption of workflows across the project stages and in particular with the information handover to the operation stage. The adherence to the clients' requirements for the operation phase of buildings becomes very challenging. A structured information delivery enabled by BIM protocols, established at the project's inception phase, can help: 1) prevent information loss during the project development; 2) ensure the coordinated delivery of the clients' requirements as stated at the pre-design stage, and 3) anticipate the impact of client decisions at early project stages on the operational performance of buildings.

This research presents a methodology and a decision support system to help obtaining, categorizing and trading off sustainability and facility management values using subjective driven priorities from top-level management. The decision support system will assist, within digitally enabled projects, in translating these priorities into objective parameters and information categories. These can be subsequently included within the project tender and bidders' BIM Execution Plans. The tool will also help to monitor the performance of the project design with the national sustainability and the client targets as the project progresses. The proposed tool is presented within the context of Qatar but it could be applied in other countries.

1. Introduction

Information flows in the built environment have traditionally focused on the design and construction phases. This translates into a *drafting centric workflow* as the bulk of information is developed during the construction documentation phase (Gilkinson et al., 2015). Built assets need to optimise their resources taking into consideration the building operation, as this phase constitutes by far the most resource consuming along their lifespan (Jensen & van der Voordt, 2016; Lee, An, & Yu, 2012). Between project stages and disciplines, valuable information is usually dismissed or lost, resulting in significant costs and process disruption (Dodge Data Analytics and Research, 2015; East, 2012; IFMA & Teicholz, 2012; Vukovic & Dawood, 2015).Emerging digital workflows offer new opportunities for organisations to improve the consistency in the information use and the predictability of project outcomes.

A structured information delivery enabled by BIM protocols, established at the project's inception prevents information loss during the project's development (East & Nisbet, 2010). This facilitates the correct and complete set of information given at handover of buildings, and increases their efficient use during operation. To ensure consistency, the UK government has implemented a strategic plan to extent and leverage the benefits from BIM in the construction sector (Digital Built Britain). Furthermore, the Construction Operations Building information exchange (COBie) along with other related documents has been developed to ease the pace for this digital revolution along the different tiers in the supply chain. These documents are the Government Soft Landings (GSL),

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the BS1192 series (2007, 4:2014, PAS (Publicly Available Standard) 1192 (2:2013, 3:2014, and 5:2015), and BS8536:2013. In summary, all of aforementioned standards set the framework to ease the standardised adoption of BIM Protocols. COBie is a standard aimed to assist in the electronic transfer of construction documents and information to facility operators (Nisbet, 2008). It can provide a common structure for the exchange of information and can ensure that information can be prepared and used without the need of expert knowledge for database management. The main aim of COBie is to facilitate a non-proprietary information exchange format at the handover of the building or facility to the asset or facility manager.

In Qatar, though the adoption of BIM technologies and protocols is increasing year on year, there is still a need to improve the methodologies and tools by which the projects are undertaken, and thus far, no strategic policy has been developed in terms of BIM implementation. In particular, due to lack of a strategic approach to BIM adoption, there are inconsistencies in the definition of requirements and the implementation of digital workflows.

Estimates show that if information requirements of facility management are considered at the early project phases, savings up to 13% can be achieved, according to IFMA and Teicholz (2013). It benefits the Operations and Maintenance (O&M) annual costs as well, and more importantly, it sets the pace for ensuring the coordinated delivery of the clients' requirements as stated at the pre-design stage, when the strategic options for the project should be made (Kiviniemi, 2005). If these requirements are hierarchically organised, the clarity and guidance of the brief for the design and construction bidders improve. Establishing the clients' requirements at a pre-tender stage in a structured manner can also contribute to anticipate the impact of client decisions on the building's operation.

This research presents a methodology and a decision support tool to obtain, categorize and trade off the subjective priorities from top-level management. The decision support tool can help to establish and link information and operational requirements at the early project phases (Jansson, Schade, & Olofsson, 2013). The ability of converting client requirements about the operational phase of buildings into tangible values helps to assessing the impact of subjective and organisational-based decisions as the project progresses. Additionally, the tool can be used to establish benchmarks and compare design alternatives during the early project stages hence, enabling alignment with the organisational values since the early design stages.

2. Problem statement

Impact of decisions on operations performance is not easily anticipated at early project stages, though it is well known, that at this stage decisions made on the project definition account for the greatest impact on the building performance and operation. Most of the clients' decisions are reflected usually in the strategic and the initial brief (RIBA, 2013). The high-level requirements and decision process at this stage are commonly based on previous experiences. Hence, subjective criteria and personal or organisational assumptions are commonly found within them. Very often translation of the latter into measurable requirements is not explicit, hampering the adequateness of the design alternatives at initial stages as it is difficult to discern impacts of project brief and design decisions on the operation phase (Hopfe & Hensen, 2011; Kiviniemi, 2005).

Currently, Qatar undertakes a deep transformation of its built environment and its construction industry, underpinned by public and private investment (Qatar National Vision 2030). The Qatar Construction Industry is increasingly adopting BIM (Building Information Modelling) in the majority of publicly procured projects, as a way to adhere to the Qatari 2030 country's vision and to secure the large infrastructure investment ongoing (Vukovic, Hafeez, Kassem, Chahrour, & Dawood, 2015). The Qatari Construction sector contributed 7.2% to the GDP in 2009, and is investing around US$200 billion on construction projects from 2008 to 2022 (Kilani, 2014).

The Employers' Information Requirements (EIR) is part of the documentation to include in the tender, when delivering a project using BIM, and initiate the consistent and structured way to enable efficient and accurate information exchange throughout the project development (UK GOV; BS 8536:2015; PAS 1192-2). This document is part of the digital documentation to be handled when using BIM technologies and methodologies in UK publicly procured projects. In EIR, the Clients set up the list of requirements classified in three main areas; technical, managerial and commercial. It defines the information trade-offs to be delivered across the project development when using BIM Protocols as well (BIM Task Group, 2015). Though this document is crucial to guarantee the correct information exchange, EIR focuses on defining information categories but lacks the analytical approach to justify decisions that have major impact on cost and operation of a building on the early design stages.

For the Qatari Construction Industry (QCI), EIR have yet not been defined, in spite of the increasing use of BIM technologies, tools and protocols. A recent survey within main stakeholders in QCI showed the level of pervasion and maturity of BIM use and adoption (Hafeez, Chahrour, Vukovic, Dawood, & Kassem, 2016). According to the survey, a list of BIM related requirements, which can be included in the aforementioned EIR areas, were commonly found in a big share of contracts (68%). A document review of the content of major project tenders has given detailed information of how the client's priorities are defined in the brief. These contracts mainly used the FIDIC (International Federation of Consulting Engineers) templates.

Understanding the environmental and boundary conditions, as well as client's priorities with respect to those is vital to define the project brief and enhance the communication of project requirements between the stakeholders. Bogers, van Meel, and van der Voordt (2008) highlighted the disruptions found in the brief definition process and content, from the designers' point of view. According to this research the main influencing factors undermining the brief effectiveness are: the lack of consistency in the requirements; unclear and unranked priorities and requirements; and lack of consideration of qualitative, organisational or subjective requirements, limiting most of the times to quantitative and standard based requirements. The increasing importance of the social, environmental and economic values within the main building sustainability rating tools makes the search of key performance indicators (KPIs) and adequate scales selection a cornerstone to define a decision support system for early design stages. Within this paper, a list of factors influencing the FM in QCI is defined, based on analysis of literature and standards values.

An approach that conciliates the difficulty in obtaining clear clients' requirements and a methodology to translate them into measurable factors is needed. This information will be included in the EIR documents using BIM information categories. This approach will ease and clarify the decision making process and the definition of the priorities and goals to pursue for every project or facility focusing on sustainable operation, and it is the objective of this research.

3. Methods

This research is based on the literature research and previous surveys to establish the sustainable facility management KPIs, to be adapted to the Qatari context. Moreover, the analytical hierarchy process theory to establish the specific project priorities gathered from the high management bodies within the client's organisation in Qatar; and the use of open standards to seek for information categories in the translation of priorities and values, is to be included in the employers' requirements documentation.

The starting-point of this research consists of a comprehensive study within existing BIM based QCI projects: the tender documents, the types and definition of contracts, stakeholders, information requirements, and check-points and means of verification of performance compliance. This phase of the research is based on previous literature review, policy documents, and research interviews with major QCI stakeholders, conducted and analysed by Hafeez et al. (2016).

Secondly, the selection of the key performance indicators (KPIs) for sustainable building operation and facility management is done through the study of existing literature and standards. The different values found in EN 15221-7:2012 standard, sustainable facility management approach and other approaches as Jansson et al. (2013), Chen, Yang, and Luet (2015), Zhang and El-Gohary (2016) and the different relevant sustainability assessment schemes.

Several approaches have arisen in recent decades evaluating the built environment considering the whole building lifecycle, based on the principles of sustainable development (*Johannesburg Declaration*, 2002). These principles established three main categories of values to consider, namely: (1) economic values, (2) environmental values, and (3) social values (Hodges, 2005, 2009; Seefeldt, 2010). It has commonly been stated that for each organisation and project, different priorities and values must be defined, as decision-making is often driven by subjective and environmental influences that are not easily identified nor measured (Webster & Wind, 1972; Zhang & El-Gohary, 2016).

Thirdly, the decision support tool is outlined. The decision making process is based on the analytical hierarchy process theory (Saaty, 1980), which has proven useful for prioritising and ranking different options involving objective and subjective criteria making use of expert judgement via controlled interviews and questionnaires.

This third main step in the research describes definition of the decision support approach, which enables consideration of subjective factors in a structured and measured way. Decision making at early design stages faces some barriers, such as uncertainty of data and difficulty to rate subjective criteria (Kometa & Olomolaiye, 1997). Within the existing decision making techniques the analytical hierarchy process (AHP) firstly developed by Thomas L. Saaty in the late 1970s (Saaty, 1980) which allows taking into account heterogeneous sets of factors. The AHP approach, based on the pairwise comparison technique, allows establishing priorities to a set of both subjective and objective based predefined values (KPIs). This allows the benchmarking of design alternatives against a weighted KPIs based report. This section is based on literature and existing approaches to other environments. The outlined approach focuses on the QCI, and the results could generate documentation to be part of the clients' strategic brief in the tender documents. This could be done by translating the KPIs into information categories, with measurable scales, both for subjective and objective criteria.

4. Approach to establish hierarchy based information requirements for sustainable operations of buildings in Qatar

This paper outlines a methodology to set and prioritise clients' values for the QCI project instigation with a twofold objective: (a) to ease the definition of the project brief, enhancing the decision making process with analytical possibilities which can be translated into structured information, and (b) to set high level information requirements aligned to the clients' desired operational performance of the building or facility. The proposed approach consists of the following steps, shown in the flowchart in Fig. 1.

(1) The collection of information related to QCI's contract documents and requirements.
(2) Establishing a framework for EIR in Qatar.
(3) Selecting the KPIs for sustainable building operations in the Qatari context.
(4) Design of an AHP based tool used as a decision support tool for establishing high management level requirements in projects focussing on sustainable operations in Qatar.
(5) Establishing scales for the defined KPIs.
(6) Establishing the information categories for these KPIs found in existing standards (in our case, Omniclass®)
(7) Applying the tool to a hypothetical project use case and validating the tool with focused interviews with experts from the Qatari construction industry
(8) Evaluating the results and
(9) Translating the obtained prioritised values into information to be included within the clients' requirements statement (project brief, EIR or Qatari analogue document)

5. Qatari's contract documentation and clients' requirements

A survey composed of 22 interviewees with a track record of working in the QCI was conducted to infer the main concerns and needs from the expert point of view. The detailed results are shown in Vukovic et al. (2015). According to the survey, the main challenges faced by the QCI relate to quality assurance, and keeping the project within budget and schedule baselines. With regard to information trade-offs and BIM adoption, the respondents highlighted that BIM standards and processes are inconsistently found in the supply chain, mostly due to lack of contractual or regulatory detailed requirements. Therefore, the use of BIM is limited in most of the cases that are bounded to project phases and processes (design coordination mostly), not covering the whole lifecycle information flow. It is generally accepted that a progressive implementation of a standardised BIM approach could enhance working collaboration and solve inefficiencies across project processes (89%). Most of the respondents (82%) consider the Government organisations of Qatar as the appropriate instigators and developers of the standards for the adoption of BIM. Nevertheless, there is still discussion about how to do this. The BIM adoption process needs to be gradually done though, as the effects of ineffective implementation could lead to drawbacks and aggravate current problems by adding complexity to them (Prescott & Olufemi, 2015).

The use content of contracting procedures in the QCI are found in tender documentation which has examined in order to outline the way in which the clients' requirements are expressed, and how BIM related requirements are stated on this documentation. Most of the existing contractual and tender documents are based on the International Federation of Consulting Engineers (FIDIC, 2016; Hewitt, 2014) documentation (68% according to our survey reaching 94% according to other surveys). Other alternative formats are aligned to the American Institute of Architects (AIA) and New Engineering Contract (NEC) (18% and 4% respectively). A further study of the contents and structure of existing tenders and procurement documents has highlighted some worth mentioning features, as they are related to the information, delivery, and scope requirements.

Table 1 shows the different main information categories, their relationship, content, and location along the different information fields. The BIM Task Group highlighted that the "Project Brief" is not explicitly defined as an EIR content (2012). It is partially covered as

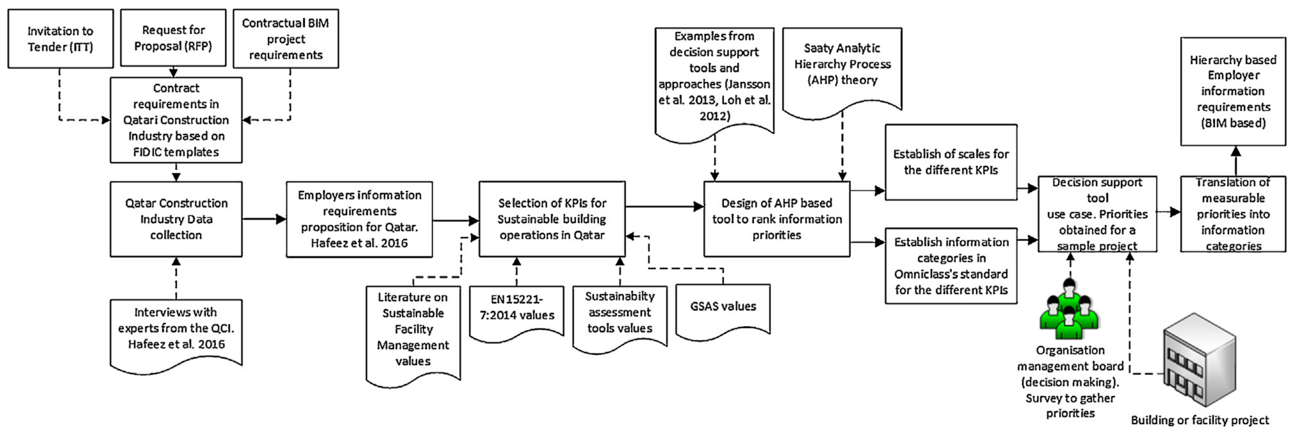

Fig. 1. Flowchart underpinning the approach.

Table 1
Main Information categories trade-off between FIDIC template and EIR.

FIDIC tender documents structure	EIR task group categories		
	Technical	Management	Commercial
Part 1 – Project Brief and Scope of Services	Partially covered	Partially covered	
Part 2 – Authority's Requirements		Partially covered	Covered
Part 3 – Services Implementation		Partially covered	
Part 4 – Project Data – codes, standards, indemnified project data, Stakeholder	Partially covered	Partially covered	

"Clients strategic purpose" on "Commercial" area, and in "Systems performance and Compliance Plan" on "Management" area. The "Technical" area of the EIR is partially covered in FIDIC templates the reference documents within Part 1 and Part 2, establishing the software, the Level of Detail (LoD), Data exchange format and Coordinates. The "Management" area is covered partially in Part 1, Part 2, Part 3, and Part 4. The contents related to the standards, roles and responsibilities, work sequence, systems performance, compliance plan and design management. Commercial area is partially covered in Part 1, and Part 2. Within FIDIC templates, the term 'Data Drops', which means the documentation delivery and decision points for the client is not used. Instead, 'Delivery Points' are specified on the Part 1, as well as the clients' goals and vision.

As the process for adopting EIRs for the QCI is instigating, the opportunity to reflect bounded clients' expectations on an alternative Q*CIR* (*Qatar Clients' Information Requirements*) is promising. Hafeez et al. (2016) showed some of the aspects to cover and how they should be covered. As part of this documentation to include in the alternative QCIR document, we propose to develop preliminary clients' requirements and priority baseline, which improves communication with the design team throughout the tender and project stages. This document will be an output from decision support system. The document aims to ease the decision making process and to add clarity to the outputs based on the clients' priorities and sustainability KPIs. The application of this output will be to serve as benchmark for the different design alternatives and to compare their performance and alignment to the clients' requirements. This represents valuable information to be included in the project brief and EIR.

6. Influencing factors for sustainable facility management in the Qatar construction industry

The next step consists of clearly identifying the most influencing factors of the building's operation, needed by the facilities managers. Those need to be adapted to the environmental boundaries in QCI, to serve as framework for the decision support system. The factors will not just be related to FM processes, but to those, which can be identified as influential in decisions made at the early stages. The research focuses on the existing FM standard processes, the sustainable and energy evaluation tools, the specific Qatari building performance and project rating evaluation system and finally, the latest factors listed in the conceptual approach to sustainable facility management, these three areas will be the main categories to which the categories and subcategories are related.

6.1. European Standards. EN 15221 list of factors

Unlike the sustainability values, which relate to three main areas (economic, environmental and social), according to the European Committee for Standardization, the FM processes within an organisation are found in three main levels, namely Strategic, Tactical and Operational. Strategic processes are conducted at high management level, tactical processes are focused on defining the way to manage the building according to the strategic goals, and the operational processes define the indicators to comply with those goals (EN 15221 series).

These standards define as well the main influencing factors at FM and propose benchmarking approaches, as (1) strategic benchmarking, focusing on evaluating the alignment to the corporate objectives for strategic decision making, (2) process benchmarking, to evaluate the discrete process services, and (3) performance benchmarking, which deals with quantitative and qualitative inputs. The strategic and performance benchmarking are the categories suitable for our purposes. Strategic benchmarking refers to: (1) alignment to corporate objectives, (2) resource allocation decisions and (3) budget review and planning. The main indicators (KPIs) for the performance benchmarking are sorted into indicative benchmarking groups and factors to measure, namely Financial, Spatial, Environmental, Service Quality, Satisfaction and Productivity.

An exhaustive list of performance benchmarking indicators, to be assessed in quantitative, qualitative, or combined approach, is listed in Table 2.

Table 2
EN15221-7:2012. List of performance KPI.

Financial	Space	Environmental	Quality	Satisfaction	Productivity
Primary values	**Primary values**	**Primary values**	**Primary values**	**Primary values**	**Primary values**
Facility Management Costs per FTE (currency per annum)	Net Floor Area per FTE (m^2NFA)	Total CO_2 emissions (tonnes per annum)	Quality of Facility Management	Satisfaction with Facility Management	Core operating hours of facility (facility management related)
Facility Management Costs per workstation (currency per annum)	Net Floor Area per person (m^2NFA)	CO_2 emissions per FTE (tonnes per annum)			Timeliness of service provision (facility management related)
Facility Management Costs per square metre NFA (currency per annum)	Net Floor Area per workstation (m^2NFA)	CO_2emissions per m^2NFA (tonnes per annum)			Uptime facility (business continuity related)
Secondary values	**Secondary values**	**Secondary values**	**Secondary values**	**Secondary values**	Recovery time (business continuity related)
Space & Infrastructure Costs per FTE (or workstation or m^2NFA)	Net Floor Area/Total Level Area (%)	Total energy consumption (kWh per annum)	Quality of Cleaning	Satisfaction with Space	Staff turnover (human resources related)
People & Organisation Costs per FTE (or workstation or m^2NFA)	Internal Area/Total Level Area (%)	Energy consumption per FTE (kWh per annum)	Quality of Workplace	Satisfaction with Outdoors	Absenteeism (human resources related)
Space Costs per FTE (or workstation or m^2NFA)	Gross Floor Area/Total Level Area (%)	Quality of Document Management	Quality of Security	Satisfaction with Cleaning	Absenteeism (human resources related)
Outdoors Costs per FTE (or workstation or m^2NFA)		Energy consumption per m^2NFA (kWh per annum)	Quality Reception and Contact Centre	Satisfaction with Workplace	
Cleaning Costs per FTE (or workstation or m^2NFA)		Total water usage (m^3 per annum)	Quality of Catering and Vending	Satisfaction with HSSE	
Workplace Costs per FTE (or workstation or m^2NFA)		Water usage per FTE (m^3 per annum)	Satisfaction with Hospitality		
Primary activities specific Costs per FTE (or workstation or m^2NFA)		Total waste production (tonnes per annum)		Satisfaction with ICT	
HSSE Costs per FTE (or workstation or m^2NFA)		Waste production per FTE (tonnes per annum)		Satisfaction with Logistics	
Hospitality Costs per FTE (or workstation or m^2NFA)		Waste production per m^2NFA (tonnes per annum)			
ICT Costs per FTE (or workstation or m^2NFA)		Space and Environment			
Logistics Costs per FTE (or workstation or m^2NFA)		Outdoors and Environment			
Business support Costs per FTE (or workstation or m^2NFA)		Workplace and Environment			
		Health & Safety and Environment			
		Mobility and Environment			
		Procurement and Environment			

6.2. Factors found in sustainability assessment tools

Within the plethora of sustainability assessment tools and schemes for buildings, we find implicitly in most of them some common values and categories (i.e. general, energy, water, waste, travel/transportation, pollution, and health). This common structure allows the comparison of the priorities given to the values across the different schemes. The different range of weightings for each criteria and sub-criteria depends on the assessment process. The weightings vary in a noticeable manner one from another. Ameen and Mourshed (2015) evaluated the different weighting structures for four different criteria (Environmental, Economic, Social and Cultural) in the main urban environmental assessment schema, namely CASBEE (JaGBC, 2007), LEED ND (USGBC, 2011), QSAS/GSAS (GORD, 2013a), BREEAM (BRE 2009, BRE, 2011, BRE, 2013a, BRE, 2013b), PEARL (ADUPC, 2010), and SBTool PT UP (iiSBE, 2007). The results showed that 'environmental categories' prevail over the other three in those schemes. Chen et al. (2015) in a similar way, compared the prevalence of passive energy criteria for five different assessment tools (BREEAM, LEED, BEAM plus (HK-BEAM Society, 2004), GBL-ASGB (MOHURD, 2014) and CASBEE, obtaining 24 different KPIs in different categories and evaluating their prevalence. Results showed wide differences of over 30% in category weightings. It is therefore, the different evaluation frameworks allocate different importance to the different values. These priorities are not specifically related to the organisational values and priorities when initiating a project, nor to the expected performance of the building at operation. A closer look at the values adapted to the local conditions has been done by studying the Global Sustainability Assessment System (GSAS) range of values.

6.3. Global Sustainability Assessment System (GSAS)

Gulf Organisation for Research and Development (GORD), developed and implemented the GSAS, a voluntary framework to evaluate the environmental and energy impact of buildings and label them consequently. GSAS is a multi-criteria evaluation system that allows the rating of buildings and infrastructures as well (GORD, 2013b). However, it is not focused on building operation solely. In GSAS, the main factors evaluated relate to the following categories: site, energy, materials, indoor environment, cultural and economic values, management, and operations. The complete list of the factors taken into account for this assessment, widespread in the QCI, is shown in Table 3.

GSAS awards performance based scores (−1, 0, 1, 2, 3) for each category. The scores are weightings that are fixed and are based on AHP (UC 8%, S 9%, E 24%, W 16%, M 16%, IE 8%, CE 13%, MO 6%). After the different items have been assessed for each building project, the evaluations of results are then multiplied by the relative environmental, social or economic impact levels. They are added together to obtain a final (0–3) score. The final score stays within one of six possible certification levels to measure the overall project impact (1–6 stars).

The approach found in GSAS outlines some important KPIs to consider from early project stages in the Qatari and Middle East countries boundary conditions. It is important to note though, that these values reflected in GSAS are just partial and not focused on the building operational stage solely. They serve as a framework to understand the prevailing factors, which differentiate this approach from other evaluation frameworks and therefore should be included as values to include in a KPIs shortlisting.

6.4. KPIs in Sustainable Facility Management

FM has evolved in the last 20 years from being considered just as a maintenance function within the organisations, shifting towards

Table 3
GSAS list of categories and KPI. Relative weighting given to the categories.

Urban Connectivity (8–9%)	Site (9–10%)	Energy (24–25%)	Water (16–17%)	Materials (16–17%)	Indoor Environment (8–9%)	Cultural and Economic values (13%)	Management and Operations (6%)
Proximity to infrastructure	Land preservation	Energy demand performance	Water consumption	Regional materials	Thermal comfort	Heritage & cultural identity	Commissioning plan
Load on Local Traffic Conditions	Water body preservation	Energy delivery performance		Responsible sourcing of materials	Natural ventilation	Support of national economy	Organic waste management
Public Transportation	Habitat preservation	Fossil fuel conservation		Recycled materials	Mechanical ventilation		Recycling management
Private Transportation	Desertification	CO_2 emissions		Materials reuse	Illumination levels		Leak detection
Sewer & Waterway Contamination	Rainwater runoff	NO_x SO_x & particulate matter		Structure reuse	Daylight		Energy & water use sub metering
Acoustic Conditions	Heat island effect			Design for disassembly	Glare control		Automated control system
Proximity to Amenities	Adverse wind conditions			Life cycle assessment (LCA)	Views		Hospitality management plan
Accessibility	Noise pollution				Acoustic quality		Sustainability education & awareness plan
	Shading of adjacent properties				Low-emitting materials		Building legacy
	Parking footprint				Indoor chemical & pollutant source control		
	Shading						
	Illumination						
	Pathways						
	Mixed use						

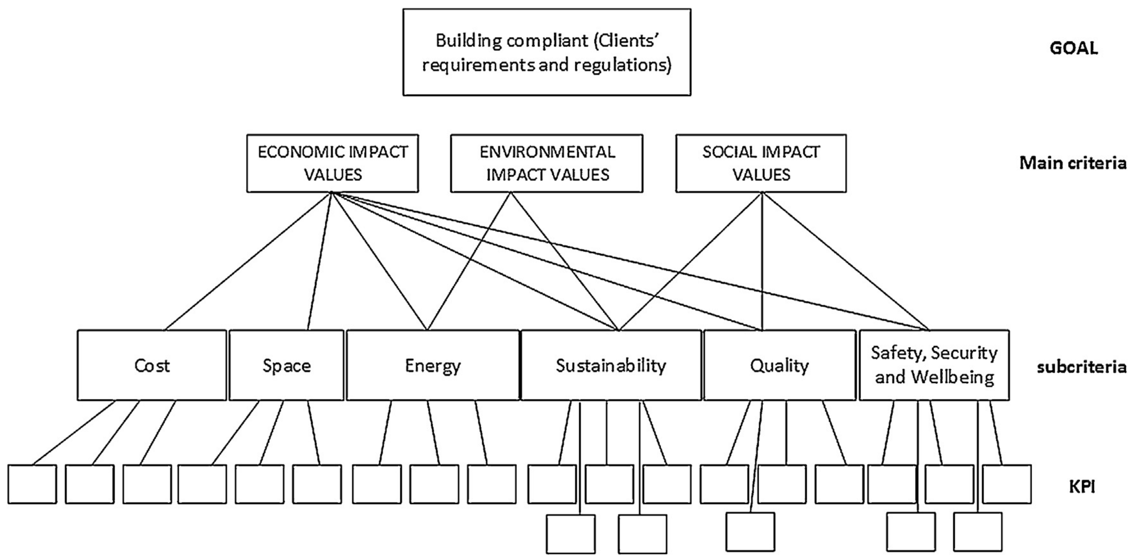

Fig. 2. Scheme of priority hierarchy for the QCI at FM.

a strategic role in bringing together services, assets and to optimise the function and the process of change (Alexander, 2003; Atkin & Brooks, 2009; Tompkins, White, Bozer, & Tanchoco, 2010). This change from a reactive discipline (Barrett, 2000) towards a strategic discipline aligned with the organisational and societal goals needs a different conception of the facilities management processes (Hodges & Sekula, 2013). The concept has been referred to as the Sustainable Facility Management (SFM). The main factors related to the SFM are (1) the societal needs, inside and outside the organisation, (2) the economic needs of the organisation, and (3) its environmental impacts (Wolf et al., 2013). SFM is a life-cycle approach to facility stewardship that integrates people, place, and business of an organisation with the economic, environmental, and social benefits of sustainability (Hodges, 2009).

In relation to this approach, Zhang and El-Gohary (2016) developed an axiology of value considering SFM main values and merging the stakeholders' values from extensive literature review and stakeholder surveys. A list of 50 KPIs was obtained. To check their relevance, they made use of expert judgement, through interviews and statistical analysis, for these values and different building types, namely, residential, commercial, and educational.

The values sorted within this approach take into consideration the project development and the construction stakeholders' values during the project, though it is not centred at the operation stage, in which our approach focuses. The prevalence and variability of the different hierarchy categories across different project types and stakeholders are analysed in Zhang and El-Gohary research. However, a relation within these values and the digital project delivery is not found in the literature and neither research works are adapted to the FM values and the Qatari boundary conditions. Therefore, in this paper we intend to integrate some of the latter values and outline the approach to convert them into structured information categories in the digital construction delivery scheme.

6.5. Selected KPIs for sustainable operation of buildings in Qatar

Based on the preceding approaches, we conclude that the decision making process needs to be tailored to the building types and the context in order to properly consider the boundary conditions. For the QCI we will base our approach on the GSAS criteria, the FM values, and the values found in SFM, selected by the experts and found in literature research and the approaches explained in the previous section, in a KPIs validation process. GSAS framework include relevant KPIs, which are already being used to evaluate and prescribe performance of different building types within the environmental, economic and societal criteria, so it can be a starting point to put together the list of criteria. This list will grow by incorporating values from the FM specific values. The general structure of the hierarchy values found is shown in Fig. 2.

In our approach, the main criteria, validated and obtained from literature and the current building sustainable evaluation rating system are economic, environmental, and social. These are found both in GSAS and in SFM. For the second tier, we based on the FM values found in the standards (EN 15221) with some differences, adapting to the Qatari boundary conditions (reflected in GSAS). These sub-criteria are: (1) Cost, (2) Space, (3) Energy, (4) Sustainability, (5) Quality, and (6) Safety, Security and Wellbeing. At the third level, a set of KPIs are defined taking into consideration the organisational preferences and goals, obtained from expert focus groups for the building type or boundary conditions and so may change depending on each organisation and project type.

7. Outlined solution for the hierarchy based information requirements for the QCI

7.1. Analytical Hierarchy Process and decision support tools

The process of decision-making has been thoroughly analysed during the last decades of the 20th century. One of the problems to tackle refers to the accommodation of subjective criteria along with objective criteria within a weighted decision making structure. Different approaches like decision trees try to reduce the problem by giving predefined alternative answers and options, other, like fuzzy logic, neural networks are strategies that appear to be a black box process, based on previously experimental and expert obtained data.

Other approaches, coming from the marketing and social sciences, have studied the problem of decision making within large organisations, and in construction companies (Kometa & Olomolaiye, 1997; Webster & Wind, 1972) regarding buying processes and deciding to proceed with the construction of a building. These approaches tried to include factors related directly to the objective criteria (task based) with others related to boundary and environmental criteria (non-task based) which were mainly related to psychological, organisational processes and structures, interactions among individuals and organisation goals, and polit-

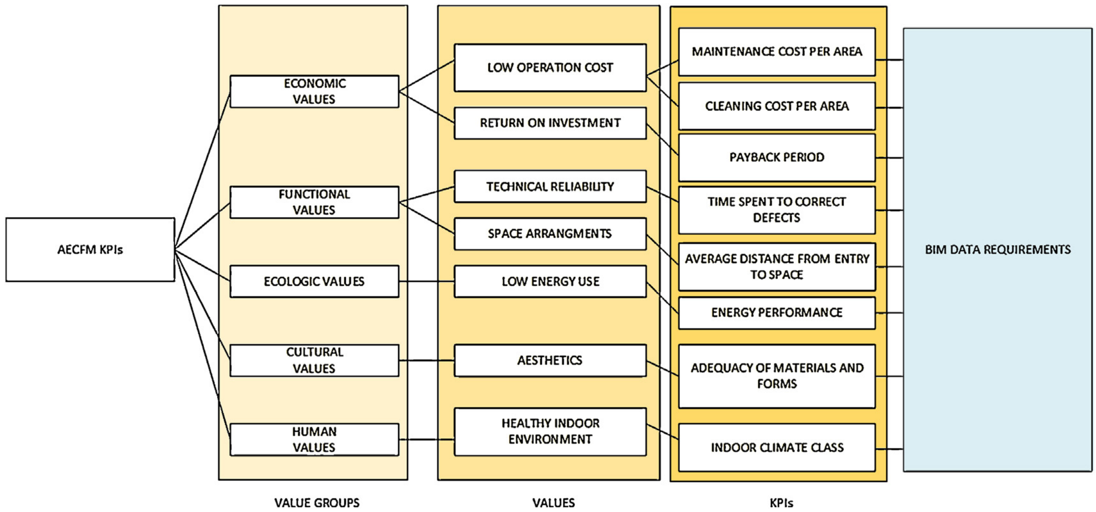

Fig. 3. Hierarchically defined criteria, sub criteria and KPIs related to FM in INPRO project.

ical matters. The categories affecting this process are related to individual interests, organisational procedures, policies, social conventions, and environmental conditioning.

Analytic hierarchy process (AHP) has been used as a feasible approach to combine subjective and objective criteria. AHP was developed by Thomas L. Saaty in the late 1970's, and refined and further studied since then (Saaty, 1980, 1994, 2008). AHP is a mathematical theory for deriving ratio scaled priority vectors from positive reciprocal matrices with entries established by paired comparisons. This approach reduces the complexity of the decision making process, applying the principle of pairwise comparison where it is easier to obtain valid comparisons when evaluating options as pairwise, conducted by expert judgement and rating them in priority scales. AHP is based on expert judgement, in a rational process to rate and value different criteria with one goal. The process establishes the main criteria, sub criteria associated to the higher level, and KPIs defined for these criteria and sub criteria. KPIs are defined as SMART (Specific, Measurable, Achievable, Relevant and Time-bound), so a necessary process is needed to set the valuation framework for each of the KPIs in relation to the environment and the criteria in order to rate them. These rankings lead to a weighted list of factors. A benchmark framework is set, by which the different decision alternatives can be defined and evaluated, including subjective based factors. It is a reliable approach, which has been used for many complex decision making processes, but it needs a proper criteria and KPIs selection and to consider expert judgement to be accurate.

There have been a number of approaches using AHP to improve decision making processes in early design stages of buildings, within the BIM work methodology, e.g. INPRO smart decision making framework (Jansson et al., 2013), Eugene Loh's Environmental Assessment Trade off Tool (Loh, Crosbie, Dawood, & Dean, 2010). These two approaches ground on their capability for establishing early judgement and benchmarking of alternatives applying AHP.

In INPRO (*open INformation environment for collaborative PROcesses throughout the lifecycle of a building*) project, the definition of a decision making process at early design stages of a building project was outlined to define BIM data requirements. It focused on the design process, but had no presence during the pre-tender documentation. The definition of KPIs is structured in five main value groups: economic, functional, ecologic, cultural, and human. Seven sub criteria related to the previous ones and eight KPIs which will be the base to establish the BIM data requirements, namely maintenance cost per m^2, cleaning cost per m^2, payback time for investment, distance from entry to spaces, energy performance rating, adequacy of materials and indoor climate class (shown in Fig. 3). The approach, developed within the Thesis dissertation of Loh (2012), valuated different building alternatives within the sustainability criteria of the materials used, based on objective data and expert opinions based on semi-structured interviewing.

7.2. AHP approach for sustainable building operations in Qatar

In our approach, the selected hierarchy is structured in (1) goal; (2) main criteria, and (3) sub-criteria found in Fig. 2. The different sub categories and KPIs are defined from a wider list, making use of expert opinion for different types of buildings, in the Qatari context following the methodology outlined in Fig. 4. The different KPIs are shown to the stakeholders in different categories to discard and select the most relevant, for each type of building. After validated and defined as relevant, they are valued and ranked using AHP. The approach requires providing specific weightings for every organisation and project, but basic templates for different building types can be provided in advance, easing the process. These templates can be part of the OIR (Organisation Information Requirements). The general approach is shown in Fig. 4. It differs from previous approaches, as it makes possible translation of the goals and KPIs (step 3 in Fig. 4) for the design and construction team in a structured and concise manner (BIM compatible) at pre-tender stages.

Through a compressed list of KPIs selected as template for the specific building (as the one shown in Table 4), the process of prioritisation can be conducted via interviews with the client stakeholders. The latter and the results of the weighting process and translation into information categories will be included in the pretender proposal, as part of the FIDIC, QCIR or EIR. Once the client has stated the priorities for the project, the result will serve as the baseline of the client's expectations. This list, in Table 4, makes use of the expert criteria for the definition of the ratings for the specific building KPI, and will reflect the organisational and High Level requirements aligned to the organisations' vision and mission and specific goals to be met in the building or facility.

7.3. Case study. Approach to categories and subcategories and KPIs to assign priority

Table 4 below shows a list of priorities valued from 1 to 5, for main criteria and KPIs specifically for a hypothetical commercial building project, located in a historic relevant area. The selected

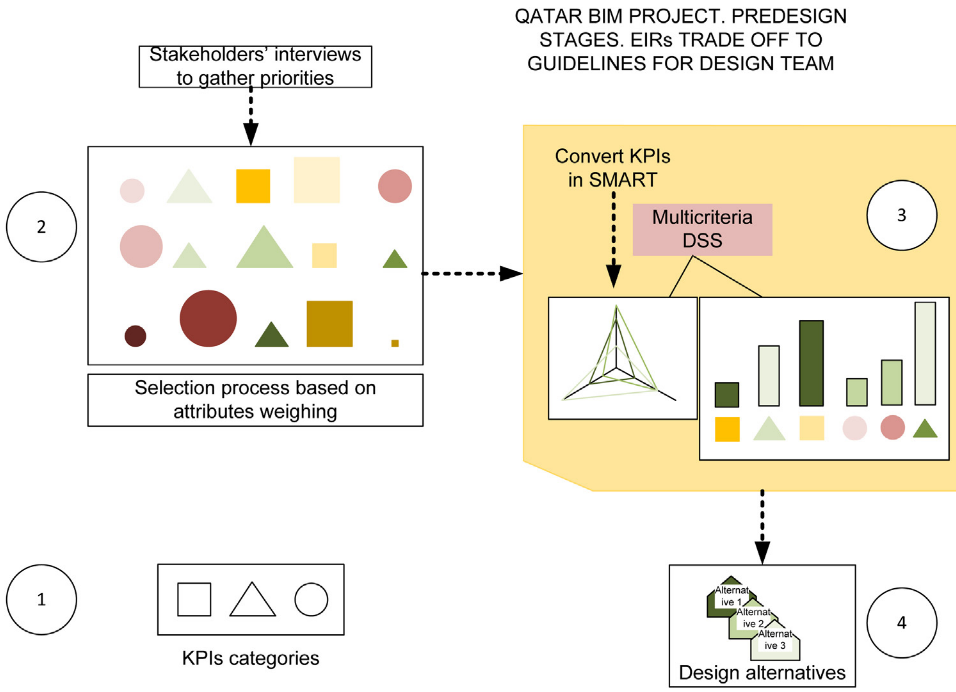

Fig. 4. Approach to perform alternatives benchmarking in QCI.

Table 4
Values obtained from interviews to experts and stakeholders.

	Building type COMMERCIAL	value (1 to 5)	subcategories	value (1 to 5)
ECONOMIC IMPACT VALUES	COST	4	Capital expenditure (CAPEX)	2
			Operation Costs (OPEX)	5
			Productivity	4
	SPACE	2	Occupancy rate (%)	2
			Utilisation rate (%)	2
			Frequency rate (%)	2
ENVIRONMENTAL AND IMPACT VALUES	ENERGY	4	Emissions related to Energy systems	4
			Energy demand performance	5
			Share of renewable energy sources	3
	SUSTAINABILITY	2	Waste	2
			Water	5
			Sustainability of materials	3
			Mobility and Environment	4
			Environmental preservation	2
QUALITY AND WELLBEING IMPACT VALUES	QUALITY	5	Aesthetics	5
			Corporate image and responsibility	5
			Historic preservation	5
			Site quality improvement	1
	SAFETY, SECURITY AND WELLBEING	3	Health And Comfort	3
			Building safety	3
			Users safety	2
			building security	5
			Accessibility	2

subcategories are applied to this specific building type. Through the pairwise comparison, we obtain the relative importance for the main categories in column 3. Moreover, we assign values to the subcategories independently in column 5. The weight of the main categories influences the final value for each subcategory.

The original AHP theory establishes a value range from 1 to 9, in the pairwise comparison. In our case, the range has been limited from 1 to 5, following other previous research (Dawes & Corrigan, 1974; Kallas, Lambarraa, & Gil, 2011; UNEP, 2013). In our approach, the number of KPIs given per category for the traditionally most important categories (Cost, Space, and Energy) is limited to three, to adjust the relative importance of the subcategories. By considering less subcategories, we add relative weight to them in sum. For this validation, we counted on the collaboration of two experts in the QCI at the Qatar University.

To assign the priorities to the values, each subcategory needs to have a specific scale to measure the performance of the related subcategory, e.g. energy performance can be measured in terms

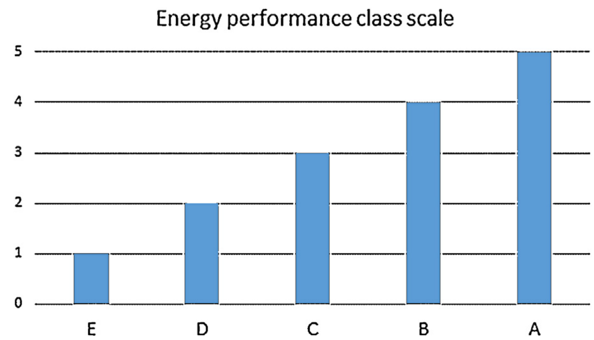

Fig. 5. Scale for Energy Demand Performance subcategory.

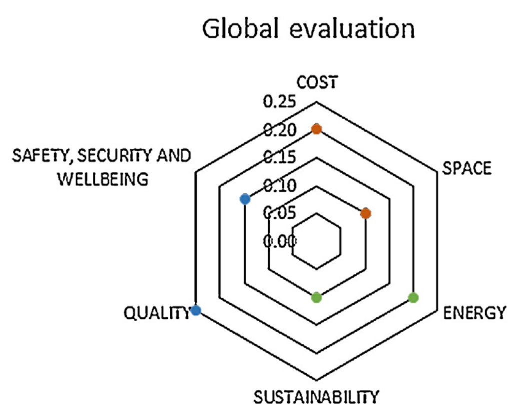

Fig. 6. Graphical baselines for each of the main categories to be measured.

of energy classification label, for the client to consider. "A" class would mean that the client considers it of extreme importance and would be valued with 4 or 5. "E" class would mean the clients just want the minimum requirements for the energy performance of the building, which would be translated in 1 or 2. The scale, which the design team needs to take as reference, is shown in Fig. 5. The scale changes for each type of building and boundary conditions, but needs to be measurable throughout the project development.

Once the values are assigned to the categories and KPIs, the relative weighting is obtained through the matrix calculation, used in the AHP approach. In summary, the relative weightings are balanced. A global view of the importance of the sub criteria is shown in Fig. 6. This high-level value dashboard provides a hierarchical overview of the clients' expectations for the building. The main factors to take into consideration for the project example are related to the quality, cost, and energy, while space, sustainability and safety, security and well-being are kept in a secondary position. The results should then be validated against expert judgement and the clients to check adequateness. Table 6 shows the resulting relative and combined weighting for the categories and subcategories, which is much more detailed and revealing about the clients' expectations.

The different categories have been evaluated independently as it is shown in Fig. 7, as well as it was done in a global evaluation (Fig. 6). For each main category, the detailed relative weightings are shown in Fig. 7 charts. These values will serve as a benchmark framework for the different design alternatives. To do this, the information requirements have to be included in the tender, with individual units and scales. At procurement, the design and construction teams will include this measurable information in their bids to assist in selecting the awarded alternative. During the project, these KPIs will be checked at delivery checkpoints or Data drops, to look for deviations in the project objectives. Therefore, the contracted parties need to provide information, which shows compliance with the values established at early stages.

For each KPI, the measurable indicators and scales are needed. For every subcategory, these indicators can be more easily provided by the contractors (design or construction) than subjective criteria and values, as usually client requirements are found at project initial stages. A sample of the subcategories and KPIs for "Energy" category is shown in Table 6, based on literature and standards. These KPIs (some of them or the most representative) need to be explicitly required by contract as information to be provided by the awarded Design Team and Contractor of the project delivery documentation at different project stages. Scales for each of these measurable indicators will be included as well, for the teams to be able to check the project brief requirements compliance. This information will be included in the EIR.

As regards "Cost" category, we observe in Table 5, as well as graphically in Fig. 7, that "Operational Expenditure" value prevails over the others, followed by "Productivity". For "Space" category, the values seem to be equally important for the clients. This is interpreted as there are no specific requirements for this item, but to comply with the space schedules and program needs. Nonetheless, it is acknowledged that the minimum values in the scales should always comply with either existing minimum conditions found in national, technical and local regulations. With respect to "Energy" the main importance is given to "Energy demand performance" and GHG emissions while renewable energy share is not considered as a priority. Water management, mobility and sustainability of materials prevail in the sustainability category. Historic preservation appears as a paramount factor in the quality category, and building security leads the ranking for the "Safety, Security and Wellbeing" category.

Fig. 8 shows the overall relative weighting for all the subcategories together. This chart shows the overall importance obtained by clients' high management for different subcategories associated with specific building project in operation. Their combined weighting makes possible to prioritise within them, when conflict within categories appear. These conflicts will appear when transforming the priorities into information categories with scaled values. With this global view we can highlight the values which are given the greatest importance by the client, which in the case of the commercial building taken as example are; OPEX, Energy demand performance and Historic preservation. Adequate information categories need to be defined for each of the values to check the evolution during the project development, and be able to keep them adequately in line with the clients' expectations.

Once the Clients' priorities have been established and the scales for the values are determined, each of the bid alternatives can be evaluated and checked against this benchmark. The evaluation will consist of awarding a percentage to each of the values, as for the information provided by the bidders regarding each proposal. This makes it easier for the bidders to understand and to comply with the Brief requirements in terms of both information and performance of the building in operation. Each of the bids will be assessed and compared graphically as well as numerically. Nonetheless, translation of the values into BIM related information categories is needed, in order to facilitate these bidders understanding of the clients' expectations.

7.4. Translation of KPIs into information categories

Within this approach, the added value relies on setting the pace to convert the obtained priorities and values into information categories. Different classification and information structures are currently used in the AECO (Architecture, Engineering, Construction, and Operation) industry, and these have been boosted by the irruption of BIM technologies and processes during the last decades. According to Weygant (2011), standards and formats are what drive the ability of the data to be useful outside of the BIM

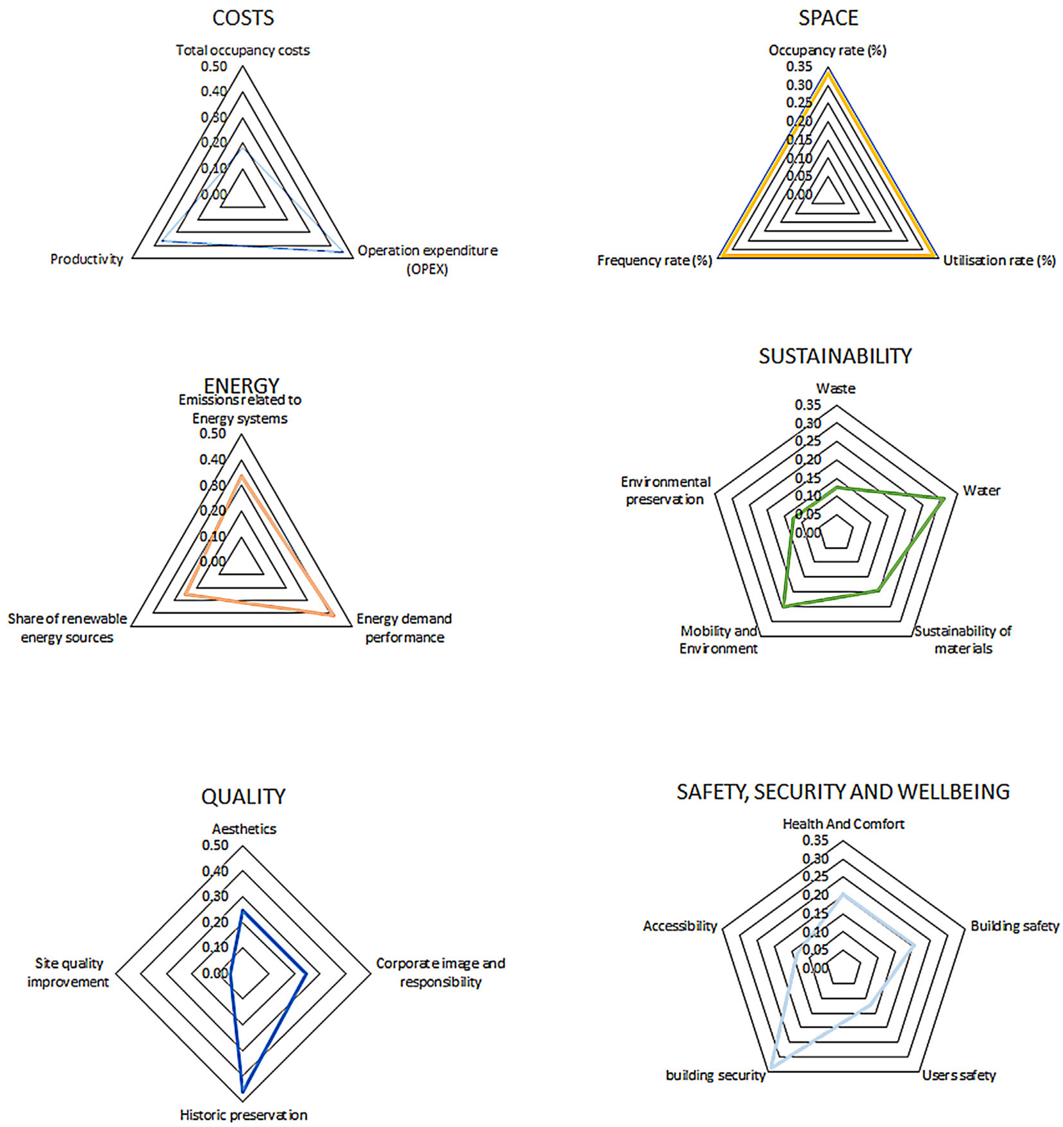

Fig. 7. Graphical baselines for each of the main categories to be measured.

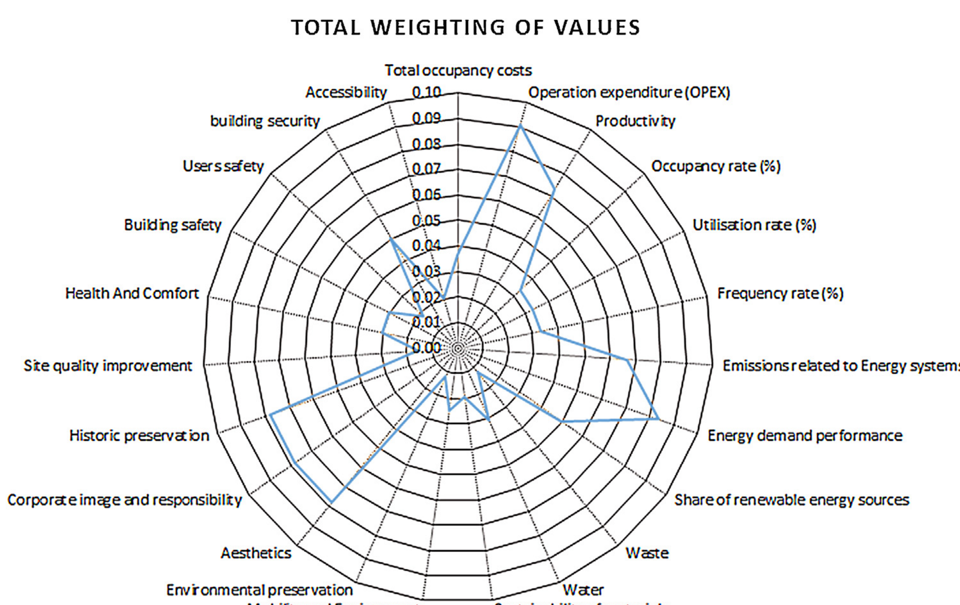

Fig. 8. Graphical global baseline for categories' benchmarking.

Table 5
Relative weighting of priorities based on previously obtained values.

	Building type COMMERCIAL	Relative weighting	subcategories	Relative weighting	Sum weighting
ECONOMIC IMPACT VALUES	COST	20.00%	Capital expenditure (CAPEX)	18.18%	3.64%
			Operation Costs (OPEX)	45.45%	9.09%
			Productivity	36.36%	7.27%
	SPACE	10.00%	Occupancy rate (%)	33.33%	3.33%
			Utilisation rate (%)	33.33%	3.33%
			Frequency rate (%)	33.33%	3.33%
ENVIRONMENTAL IMPACT VALUES	ENERGY	20.00%	Emissions related to Energy systems	33.33%	6.67%
			Energy demand performance	41.67%	8.33%
			Share of renewable energy sources	25.00%	5.00%
	SUSTAINABILITY	10.00%	Waste	12.38%	1.24%
			Water	30.96%	3.10%
			Sustainability of materials	19.50%	1.95%
			Mobility and Environment	24.77%	2.48%
			Environmental preservation	12.38%	1.24%
SOCIAL IMPACT VALUES	QUALITY	25.00%	Aesthetics	31.25%	7.81%
			Corporate image and responsibility	31.25%	7.81%
			Historic preservation	31.25%	7.81%
			Site quality improvement	6.25%	1.56%
	SAFETY, SECURITY AND WELLBEING	15.00%	Health And Comfort	20.22%	3.03%
			Building safety	20.22%	3.03%
			Users safety	12.39%	1.86%
			building security	33.70%	5.05%
			Accessibility	13.48%	2.02%

project file. Likewise, the ability to transform our priorities into measurable information categories within standards will initiate the process for a structured project delivery using BIM. Hence, the KPIs need to be converted into information categories included in the BIM standards, such as COBie, applied in the US and mandated in publicly procured projects in the UK, MasterFormat®, the most common method for organising building information, UniFormat™ groups information in terms of elements used chiefly for cost estimation. OmniClass® is an international standard, which allows the integration of the aforementioned standards adding quantification and qualifying the information (Weygant, 2011). OmniClass®, structured in tables, can be suitable for our approach, due to its quantitative and qualitative features. Uniclass® (Uniclass, 2015) can be an alternative approach for this, and it is indeed the classification scheme adapted to the UK policy. The option that has been primarily selectedfor our purposes is the one shown in the Veteran Association BIM guide, which already establishes information trade-offs making use of UniFormat™/OmniClass® classifications and Level of Development (LoD) (VA guide, 2010). In the guide document and its associated spreadsheets, we find categories appearing in several BIM formats, including COBie, already used as a means to include the information categories needed for facility management. Therefore, translation of information priorities is made easy.

By applying the translation process to the previous example in section 7.3, with respect to the "Energy" category and its values, we find that the information related to the defined KPIs (Table 6) are found in the in the OmniClass® tables related to "Energy Analysis Requirements." That is *Services (Table 32 in the standard), Information (Table 36 in the standard), and Properties (Table 49 in the standard)*. Fig. 9 shows a schematic example of the information categories in different standard formats that can be added as requirements with specific values, once the priorities and scales have been defined.

Once the priorities and values are established and information categories determined, they need to become part of the contractual documentation. According to the FIDIC template of contract, the content of the brief and project scope needs to be located at Part 1, corresponding to the technical and management categories in EIR (see Table 1). There is also a need to establish information requirements as part of the delivery points (data drops), which will include those responding to the priorities established. The document should include a means of evaluating compliance with the values established, to be included in Part 1 as part of the Commercial Management.

8. Discussion and conclusions

This paper describes a structured methodology to obtain, categorize and trade off subjective priorities from top-level management for buildings and facilities. It aims to provide an approach to establish information and operational requirements at the project early phases and to prioritise and assign values to such requirements. The assessment of the impact of subjective decisions can be used to establish benchmarks and compare proposed design alternatives at the early project stages. This aim is achieved by employing the AHP and adapting it to the specific context of QCI. The proposed approach for developing and establishing client priorities can be used to bridge the existing gap between the operational performance and information requirements during the project development. The proposed approach can be best achieved in a whole lifecycle information flow, which is a key target for the digital construction industry. The proposed approach also contribute to aligning project outputs with the organisational values from early design stages.

The first step has consisted of establishing the main criteria and sub-criteria to establish the clients' requirements for a building or facility. This is based on facility management standards, GSAS and SFM existing criteria. For each sub-criteria, a list of measurable indicators (KPI) is established. For each building or project type, scales to measure the performance needed to be defined, based on regulatory framework and actual values, adapted to the boundary conditions. In our case, for Qatar, the different building types will be referred to the GSAS list of buildings.

The AHP is used to obtain priorities about the values from the client and other involved stakeholders from a strategic perspective.

Table 6
Energy values Key performance indicators.

Subcategory and indicators (KPI)	Ranking value		Means of measurement
	Relative	Global	
Emissions related to Energy systems	33.33%	6.67%	
Total CO_2 emissions		(tonnes/year)	
CO_2 emissions per FTE		(tonnes/year*m^2 or tonnes/year*FTE)	
CO_2 emissions per m^2/NFA		(tonnes/year)	
NOx SOx & particulate matter emissions		(Kg/year) or any specific threshold measurement on the standards and good practice guidelines	
Energy demand performance	41.67%	8.33%	
Total energy consumption		(kWh/year)/(%)	
Energy consumption per FTE		(kWh/year*FTE)/(%)	
Energy consumption per m^2/NFA		(kWh/year*m^2)/(%)	
Energy delivery performance		kWh/kWh/Energy performance certificate	
Energy uses disaggregation in conditioned space		(kWh/per use in conditioned space)	
Energy uses disaggregation in not conditioned space		(kWh/per use in not conditioned space)	
Building Air tightness		(1/h). Subjective scale. (1 to 5). Based on standards.	
Systems and HVAC airtightness		(1/h). Subjective scale. (1 to 5). Based on standards.	
Share of energy sources	25.00%	5.00%	
Solid energy fuels		(% of demand covered)	
LNG		(% of demand covered)	
Fuel		(% of demand covered)	
Renewable energy sources		(% of demand covered)	

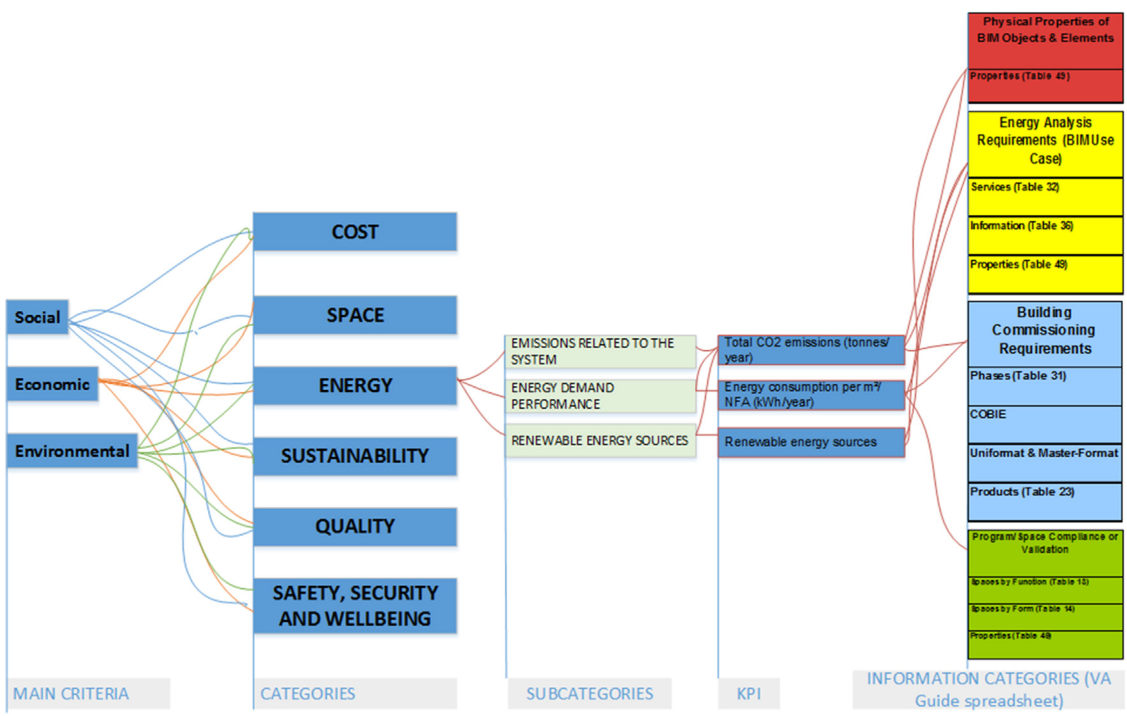

Fig. 9. Graphical process mapping to referable information categories. Energy.

These values represent the baseline for the clients' requirements. A methodology to translate these values and performance indicators into information categories contained in information exchange specifications as COBie, and classification systems as OmniClass®, UniFormat™ and MasterFormat® is outlined. These values and categories are then transferred to the contractual documents, which in our case refer to FIDIC templates.

Consequently, information for the bidders clearly states the clients' priorities in a transparent manner. This allows the bidders to evaluate their proposals against established benchmarks and adjust their proposals to the requirements. They are able to suggest changes or improvements to the values, scales, and hence, to participate in the definition of the way in which the projects are checked for compliance.

8.1. Future research work

Regarding the KPIs and values to be used, future research will study different approaches in gathering priorities from the client, and how the results change depending on the methodology used, in terms of priorities given to the values. It will also show how to solve inconsistencies in rankings, e.g. if several contradictory criteria are given equal importance. The approach taken allows establishing a graphical and numerical benchmark, referring to values, which sets the clients' requirements and goals, in terms of performance for the operational phase. These reference values and benchmarks allow the comparison in a qualitative and quantitative approach, considering both objective and subjective values. This research bridges the existing gap to translate these performance indicators, once prioritised, into information categories associated to them. The feasible way leads to standard classification frameworks for the constructed assets, such as Omniclass® and Uniclass®. Future work will focus on establishing a relation among the different standards of information within the BIM protocols for the Whole Lifecycle Information Flow in the QCI.

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