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Assessing supplier environmental performance: Applying Analytical Hierarchical Process in the United Arab Emirates healthcare chain

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ABSTRACT

Green sourcing in a supply chain refers to activities that improve the environmental performance of the purchased input enabling businesses to meet the regulatory requirements which helps improve business image but it also has the potential to cut business costs and boost the revenues. This is particularly valid for healthcare organizations with substantial investment in equipment and supplies underscoring the potential for a 'greener' collaboration with the suppliers. This study aims to apply a decision support tool to evaluate the environmental performance of healthcare suppliers in the United Arab Emirates by transforming the qualitative judgments of supply chain professional into a quantitative framework. The use of Analytical Hierarchical Process (AHP) for a consensus decision on supplier's environmental performance ensures a systematic investigation and assessment of the capabilities of suppliers by the industry experts and helps establish a benchmark of environmental considerations relevant to the UAE healthcare setting.

Contents

1. Introduction

Green supply chain management is defined as integrating environmental thinking into supplychain management, including product design, material sourcing and selection, manufacturing processes and the delivery of the final product to the consumers as well as an end-of-life management of the product after its useful life [1]. Initially, the move towards environmental sustainability was largely driven by an ever increasing pressure on businesses from various stakeholders such as the government regulators, community activists, non-governmental organizations (NGOs) and consumers but there is evidence that green supply chain management also has the potential to enable companies to cut cost and boost the revenues. Saving energy and water, material use efficiency and waste reductions are few of the many environmental measures that have the potential to reduce costs. therefore,

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it can be established that green practices allow businesses to meet legal/regulatory requirements, improve public image, gain reputation with the stakeholders and improve financial performance by reducing costs [2,3].

The environmental performance of a supply chain is heavily dependent on the performance of each and every chain link such as the suppliers, sub-suppliers and the downstream customers of each supply chain process [4]. The contribution of the supply management process to the competitive advantage has long been established but the sourcing decisions now have assumed an even greater importance because of its impact on the environmental performance [5,6]. Green sourcing in a supply chain refers to activities that improve the environmental performance of the purchased input enabling a business to meet the regulatory requirements and contributing to an improved business image. Additionally, the environmentally friendly procurement practices also have the potential to improve the economic performance [3]. This is particularly valid for healthcare organizations with substantial investment in equipment and supplies underscoring the potential for a 'greener' collaboration with the suppliers [6].

The contribution of sourcing practices towards environmentally and economically sustainable supply chain warrants a rigorous and carefully structured sourcing program because the choices among environmentally friendly products and services can be extremely complex. Furthermore, what constitutes environmentally friendly or green products and services is also open to interpretations based on the type of industry and environmental pressures faced. The sourcing decisions can also get further complicated if competing suppliers have varied sets of environmental attributes. For example, a particular supplier may be focusing on recycling and remanufacturing activities whereas another supplier may have superior performance on environmental footprint. Handfield et al. [7] highlighted the importance of assessing and resolving such trade-offs to improve the environmental performance of a business.

Analytic Hierarchy Process (AHP) has been a popular tool for helping managers structure the problem of integrating environmental dimensions into supplier evaluation and making decisions that can resolve environmental trade-offs with the help of a structured framework. Despite AHP's frequent use for general supplier selection [8] and for supplier selection with environmental considerations [7], its application in healthcare sector remains considerably untouched. This study aims at filling this gap by implementing AHP framework to assess supplier environmental performance for the healthcare chain in the United Arab Emirates (UAE). To do so, supplier selection criteria in the healthcare sector were researched, a hierarchical structure specific to the sector was proposed, and the criteria within the model were prioritized by considering the evaluations of a group of supply chain/sourcing managers from five hospitals in the Abu Dhabi Emirate of the UAE. Since the environmental considerations for the healthcare suppliers encompass many criteria and sub criteria, therefore, this research is designed by composing a multi-criteria AHP model providing a framework for supplier evaluation on a green criteria. The complexity of multi criteria decision making process is handled by AHP which is known for handling both qualitative and quantitative data [9]. The results of this study have implications for the UAE healthcare sector which is estimated to be worth at $14.6 billion and growing at 16% annually. The consensus opinion of the healthcare supply chain managers could be the first step towards benchmarking the environmental considerations relevant to the UAE healthcare setting.

The remainder of this paper is organized as follows: the next section provides a survey of the relevant literature and Section 3 details the research methodology. The analyses and discussion of the research results is carried out in Section 4 and the paper is concluded with directions for future research in Section 5.

2. Literature review

2.1. Green sourcing

The origins of green sourcing could be traced in the Environmentally Conscious Purchasing (ECP)/Green Purchasing which is defined as the process of formally introducing and integrating environmental issues and concerns into the purchasing process [10]. The growing realization of the importance of the purchasing function for competitive advantage has now given way to a broader perspective known as *Strategic Sourcing* where the emphasis is on the development and management of supplier relationships to acquire goods and services in a way that aids in achieving business sustainability. As discussed earlier, environmental sustainability is no longer just a regulatory burden; it has become a business imperative because of the soaring energy and commodities costs. A host of environmental measures to save energy and water and reduce wastes are being adopted by businesses. However, the amount that organization spends on purchased materials and/or services is typically 50–70% of the value of sales, and therefore, to stay competitive, businesses must ensure the adoption of green practices by its suppliers [11]. Green sourcing is considered to be an augmentation of the strategic sourcing activities with inclusion of environmental sustainable considerations. For traditional sourcing, the decision factors are the economics of a deal and the deal's impact on the customer. Green sourcing starts with the same considerations, but it also takes into account the environmental impact of a particular choice (such as transportation, materials, energy source, or packaging design) on the ecological footprint made by a product or service [6]. However, the challenge is the definition of what constitutes green? Handfield et al. [7] carried out a Delphi study with the Fortune 500 companies to establish a rational framework of the different types of environmental criteria that could help businesses evaluate "greenness". Furthermore, many companies with environmental management programs have established targets knows as the Environmental Performance Indicators (EPIs) to minimize the negative impact of their supply chain, including the impact caused by the suppliers. However, the absence of a structured mechanism to determine the relative importance of different EPIs has hindered the selection of suppliers that can help businesses improve their environmental performance. In the next sub-section, green factors relevant to the environmentally sustainable healthcare chain are identified with the support of literature. These factors were subsequently discussed with the participating healthcare supply chain professionals for relevance to the hospital sourcing activities.

2.1.1. Green criteria applicable to the healthcare sourcing

The purchasing mechanism has been reported to be a promising channel for material selection that can improve the environmental performance of the healthcare chain but the focus has been on the reduction of mercury emissions by purchasing mercury-free products [12]. The emphasis in the healthcare industry seems to be on the 'green' opportunities downstream of the health care facility such as waste treatment [13,14]. Some hospitals have implemented recycling programs to segregate their waste streams for optimal end use such as recycling and materials recovery [15,16]. These downstream measures improve environmental performance but green procurement provides a proactive and substantial opportunity for reducing the carbon foot print of healthcare chains. However, despite the potential, Kumar et al. [17] reported that the environmental friendly suppliers/medical products did not play a role in hospital purchasing decisions.

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To improve environmental performance in collaboration with healthcare suppliers, the identification of critical factors relevant to the dynamics of healthcare practices is the foremost step. The environmentally conscious business practices have been categorized into green design, life cycle analysis, total quality environmental management and environmental certification [18]. This list was expanded to include a comprehensive list of Environmental Performance Indicators (EPI) obtained by a Delphi study conducted by Handfield et al. [7] which aimed to establish a general green sourcing framework that could be applicable to multiple industries. The study also noted that interviewed managers tended to rely largely on perceived measures of environmental performance such as the ISO 14000 standard, environmental footprint, use of hazardous materials, and voluntary environmental certifications. A similar study with Taiwanese supply chain managers identified environmental management system (EMS), use of formal energy conservation practices, publication of environmental reports, recycling, hazardous material management, reverse logistics, resource use minimization, reusable packaging, minimization of environmental emissions, and ease of material re-use/re-cycling as the environmental criteria to be used for supplier evaluation [19]. Awasthi et al. [20] also relied on expert opinions to identify environmental criteria for supplier selection to provide city logistics services. The study documented usage of environment friendly technology, environment friendly materials, green market share, partnership with green organizations, management commitment to green practices, adherence to environmental policies, involvement in green projects, staff 'green' training, lean process planning, design for environment, environmental certifications, and pollution control initiatives as the supplier evaluation criteria. In the case of manufacturing firms, total product life cycle cost, green image, pollution control, environmental management, green product, and green competencies formulated the supplier evaluation criteria, which was expanded by Lee et al. [21] to include product quality and technological capability.

Govindan et al. [22] developed a sustainable framework and used pollution production, resource consumption, eco design and environmental management system to evaluate suppliers on the environmental criteria. In a similar manner, Nikolaou et al. [23] identified materials, energy, water, biodiversity, emissions, effluents and wastes, supplied product/services, compliance and transport as the factors contributing to environmental sustainability. Despite its relevance to environmental sustainability, the hazardous substance management has not been part of the aforementioned suppliers' green evaluation. Hsu et al. [24] presented hazardous substance management (HSM) as a new criteria of supplier selection and emphasized the existence of hazardous waste management systems. Kuo et al. [25] also explicitly used restriction of hazardous substance as a green supplier evaluation criterion along with the eco-design requirements, ozone depleting chemicals, restriction of hazardous substance, ISO 14001 certified requirement of environmental management system and electrical and electronic equipment waste.

The supplier partnerships as part of strategic sourcing entails supplier development. Bai and Sarkis [26] emphasized three broad categories of practices for supplier development comprising green knowledge transfer and communication, investment and resource transfer and management and organizational practices. The category of green knowledge transfer and communication practices included training suppliers on environmental issues, stakeholder expectations and environmental capabilities in addition to giving advice on green manufacturing, green technologies, eco-design, and environmental audits.

2.2. Overview of Analytical Hierarchical Process (AHP)

Analytical Hierarchical Process (AHP) aids managerial decision making in a structured way to generate priorities in the following steps [9]:

- Structure a problem as a hierarchy or as a system with dependence loops,
- Elicit judgments that reflect ideas, feelings, and emotions,
- Represent those judgments with meaningful numbers,
- Synthesize results and
- Analyze sensitivity to changes in judgments.

AHP is a principle of measurement through pair-wise comparisons and relies on the judgment of experts to derive priority scales which measure intangible elements in relative terms. Essentially, AHP methods structure the decision process into a hierarchy and the decision making involves choosing an option from different alternatives. Through a set of pairwise comparisons at each level of the hierarchy, a matrix can be developed, where the entities indicate the strength with which one element dominates another with respect to a given criterion. The comparisons are made using a scale of absolute judgment that represents how much more one element dominates another with respect to a given attribute. The main concern of AHP is dealing with inconsistencies arising with the judgment and improving this judgment [27]. Ultimately, AHP judges and selects the elements/concepts which have a greater influence on a predetermined objective.

Recently, there has been a renewed interest in AHP as an emerging solution approach to complex real world and multi criteria decision making problems [28,29]. The technique has been successfully implemented in various fields, such as logistics management [30–32]; manufacturing [31–33]; health care management [34,35]; environmental management [7,36,37]; marketing [38]; and knowledge management [39–41]. AHP has also been used in various contexts for ranking/prioritizing options, as well as selecting between alternatives (decision making) [42]. Over the years, AHP has become one of the most widely used decision support tools for researchers and decision makers [43].

AHP has also been used to evaluate suppliers on a generic criteria. Ho et al. [8] reviewed various applications of AHP and noted that, despite implementation differences, AHP effectively evaluated the suppliers' abilities to deliver as per the consensus requirements of the decision makers. Similarly, El-Sawalhi et al. [44] maintained that the strength of AHP, as a supplier prequalification framework, stems from its ability to address critical requirements; such as simultaneous consideration of multiple criteria, evaluation of inherent risks from decision maker's viewpoint, careful consideration and post processing of potentially noisy and uncertain data, incorporation of the subjective judgment made by decision makers, and application to qualitative as well as quantitative data. Consequently, AHP is deemed inherently useful for helping managers understand the trade-offs between environmental dimensions and for evaluating the relative importance of these environmental traits while comparing the performance of several suppliers [7].

The cited work in this section describes the suitability of AHP as a decision making framework to facilitate supplier assessment using environmental criteria. However, there is a dearth of academic attention on the application of AHP or any other decision making framework for the healthcare sourcing decisions. This study aims to contribute to the literature by implementing AHP in the UAE healthcare sector for the assessment of suppliers' environmental performance.

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3. Research setting and analysis

A clear and precise statement of the problem encountered by organizations is suggested as the starting point of AHP along with the elements (criteria) and alternatives for decision making [9]. This structured decision making framework is usually used for important and complex issues where many interconnected variables are scattered and await a decision. Fig. 1 presents the outline of AHP method employed in this research. The first step is to identify the problem. The purpose of the research is to refine current theory on the green attributes of the healthcare sourcing practices. Therefore, this research is designed by composing multi criteria sourcing decisions that include environmentally friendly elements.

The development of a hierarchical model is the next step. AHP classifies the goal and all decision criteria and variables into different levels. The highest level of the hierarchy is the overall goal which in our case is the development of a comprehensive framework for sourcing decisions promoting environmental sustainability in the UAE healthcare industry. Level 2 represents the criteria and sub-criteria comprising various environmentally friendly attributes. Level 3 contains the decision alternatives. Fig. 2 depicts the hierarchy of the proposed AHP model. In this research, eight main criteria have been established, namely Supplied Product Attributes (PA), Supplier Environmental Footprint (EF), Supplier Voluntary Certification (VC), Quality Assurance (QA), Supplier Resource Consumption (RC), Supplier Legal Compliance Competency (CC), Supplier Management Systems (MS) and Supplier Management Practices (MP). These criteria have been further divided into 27 sub-criteria (Table 1). The main criteria and sub-criteria have been selected with the support of relevant literature and with the active consultation of the sourcing/supply chain managers of the surveyed UAE hospitals.

The formulation of the AHP hierarchy was followed by the data collection from two public and three private hospitals. As suggested by Saaty [45], the questionnaire was designed on a 9-point scale (Table 2). The questionnaire was pilot tested using industry experts and academics, following which, some of the items were rephrased to make them more representative of the intended constructs. An evaluation team comprising two procurement managers and three supply chain professionals was selected in each hospital. It was made sure that the selected evaluators had sufficient experience and knowledge of the issue being explored here. This, combined with the key designations of the evaluators in their respective hospitals, strengthens the validity of the proposed research framework.

The target respondents comprised the purchasing managers and the supply chain professionals from two public and three private hospitals of Abu Dhabi. According to Cheng and Li [46] and Hussain et al. [47], small sample size is acceptable from AHP's perspective. The AHP solves the survey fatigue problem by only asking participants to compare the importance of two needs at a time. These comparisons are called judgments. A judgment of only two items is much easier for the participants than comparing a list of 20 items simultaneously. The judgments applied in making paired comparisons combine logical thinking with the intuitive

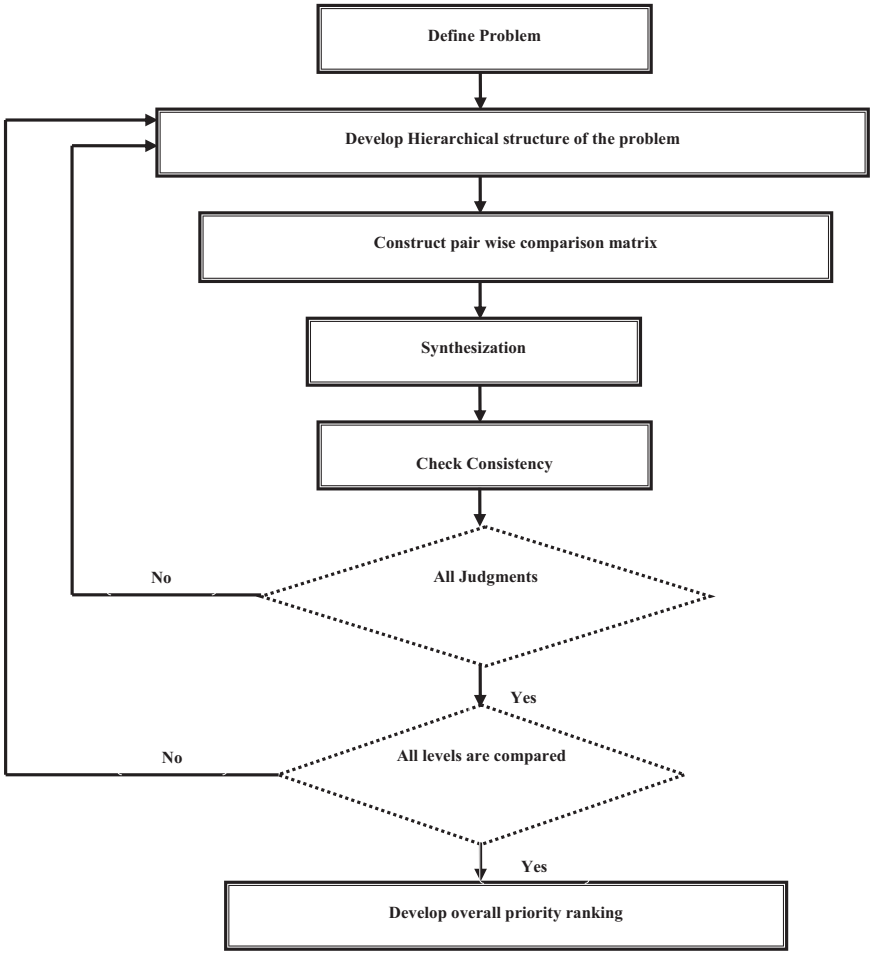

Fig. 1. Flow diagram of AHP method employed.

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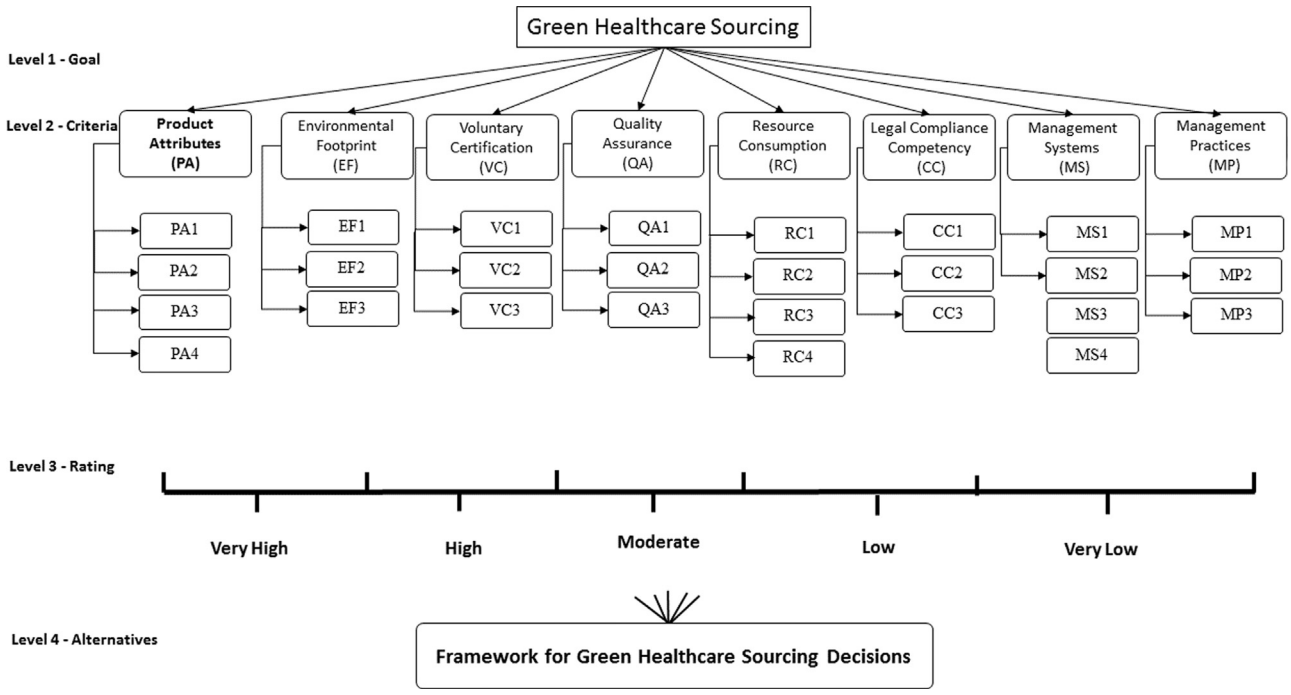

Fig. 2. AHP framework for green healthcare sourcing decisions.

feelings developed from the experience. Pairwise comparisons generate more information and therefore, improve judgment consistency [48]. Therefore, the sample size of 30 experts/respondents is considered to be satisfactory for this research [48,49]. In line with Saaty's [48] suggestion, the geometric mean approach was preferred over the arithmetic mean to combine the individual pair wise comparison judgments to obtain the consensus pair wise comparison judgment matrices for the entire team.

As shown in Fig. 1, the next step in the AHP is to determine pair-wise comparison among the criteria applied. For the pair-wise comparison of the main criteria and sub-criteria, evaluating teams ranked the relative importance of a green attribute against others. The measure of importance is a nine-point scale ranging from the two attributes being equally important to one attribute being absolutely more important over the other (Table 2). For example, if an evaluator identifies that the Supplied Product's Attribute (PA) is moderately more important than the Supplier's Environmental Footprint (EF), then the former is rated '3' and the latter as'1/3' in this comparison and so on [28].

To check the consistency of responses, the Consistency Index (CI) is applied [50]:

$$CI = (\lambda_{max} - n)/(n-1) \quad (1)$$

where, λ_{max} is the Maximum Eigenvalue of the matrix of the importance ratios and n is the number of factors. Then, the Consistency Ratio (CR) is used to assess whether a matrix is sufficiently consistent or not. CR is the ratio of the CI to the Random Index (RI), where RI is the CI of a matrix of comparisons generated randomly:

$$CR = CI/RI \quad (2)$$

Random pair-wise comparisons have been simulated to produce average random indices for different sized matrices. The values of RI are given in Table 3. The acceptable range of inconsistency constitutes CR values smaller than or equal to 0.10. The consensus responses from the 5 evaluation teams for both the main and sub-criteria were within this acceptable range.

4. Analyses of research results and discussion

The geometric mean approach, instead of the arithmetic approach, has been suggested by Saaty [50] to combine the individual pairwise comparison judgment matrices to obtain the consensus pairwise comparison matrices for all evaluators. Table 4 presents the geometric means of pair-wise comparison for main criteria. The next step is to define the relative priorities of criteria (the final column of Table 4) by computing 'Priority Vectors'. Saaty [50] introduced a 'Consistency Principle' for calculating priority vectors. Consistency principle says that $a_{ik} = a_{ij} \cdot a_{jk}$ and subsequent argument for using the special case of the consistency matrix formed by elements $a_{ik} = w_i/w_j$, where w_i and w_j are the elements of the priority weight vector corresponding to criteria i and j.

Table 4 reveals that the respondents considered the criterion of Supplier Environmental Footprint (EF) as the most important element with a priority weight of 17.68%. This was followed by the criterion of Legal Compliance Competency (CC) which received a competitive priority of 14.68%. Supplier Resource Consumption (RC), Quality Assurance (QA) and Voluntary Certification (VC) were ranked 3rd, 4th and 5th at 13.35%, 13.21% and 11.36%, respectively. The element of Supplied Product Attributes (PA) was rated at 10.09% while the criterion of Suppliers Management Practices (MP) and Management Systems (MS) were ranked 7th and 8th at 9.83% and 9.82%, respectively. It is pertinent to note here that the consensus responses fulfill the acceptable CR requirement.

To gain a better understanding of the priorities reported in Table 4, a pairwise comparison of the sub-criteria within each criteria is also carried out based on the consensus responses of the evaluators (Tables 5–12). As shown in Fig. 2, each criterion was further divided into common indicators (sub-criteria) of the main criteria in Level 2. For the criterion Supplied Product Attributes (PA), Green Design (PA1), Recyclable Content (PA2), Total Cost of Ownership (PA3) and Limited/No Pollution Production (PA4) were the four sub-criteria. Table 5 gives the priority listing of the consensus pairwise comparison for the four PA sub-criteria. The Limited/No Pollution Production (PA4) is heavily favoured (39.47%)

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Table 1
Criteria and sub criteria of prequalification of contractors.

Main criteria	Sub criteria
Supplied product attributes **(PA)**	1. Green design **(PA1)** 2. Recyclable content **(PA2)** 3. Lower total cost of ownership **(PA3)** 4. Limited/no pollution production **(PA4)**
Supplier environmental footprint **(EF)**	5. Gaseous pollutants (Green house gas emissions, industrial gas emissions) **(EF1)** 6. Liquid wastes **(EF2)** 7. Sludge/solid wastes **(EF2)**
Supplier voluntary certification **(VC)**	8. Voluntary third party certification such as eco labels, green lights, green label **(VC1).** 9. ISO 14000 certification **(VC1)** 10. Environmental auditing **(VC3)**
Supplier quality assurance **(QA)**	11. Standard for incoming quality assurance **(QA1)** 12. Testing facilities **(QA2)** 13. Product pre-shipment (outgoing) quality assurance **(QA3)**
Supplier resource consumption **(RC)**	14. Remanufacturing/reuse activities **(RC1)** 15. Returnable and reduced packaging **(RC2)** 16. Reverse logistics programs **(RC3)** 17. Energy/resources consumption during their production process **(RC4)**
Supplier's legal compliance competency **(CC)**	18. Current compliance to environmental regulations **(CC1)** 19. Previous violations of environmental permits **(CC2)** 20. Public disclosures of environmental record **(CC3)**
Supplier management systems **(MS)**	21. Quality management system **(MS1)** 22. Environmental management system **(MS2)** 23. Hazardous substance/waste management system (**MS3**) 24. Information systems (**MS4**)
Suppliers management practices **(MP)**	25. Programs to foster employee environmental awareness **(MP1)** 26. Management commitment to sustainability reflected in the mission statement **(MP2)** 27. Requirement of green procurement from the 2nd tier suppliers **(MP3)**

Table 2
1 to 9 Sale for AHP preferences.

Intensity of importance	Definition	Explanation
1	Equal importance	Two criteria contribute equally to the objective
3	Moderate importance	Judgment slightly favor one over another
5	Strong importance	Judgment strongly favor one over another
7	Very strong importance	A criterion is strongly favored and its dominance is demonstrated in practice
9	Absolute importance	Importance of one over another affirmed on the highest possible order
2,4,6,8	Intermediate values	Used to represent compromise between the priorities listed above

while the Green Design (PA2) is rated at 23.16% and the Recyclable Content (PA2) is closely behind at 23.04%. The element Lower Total Cost of Ownership (PA3) is given the lowest rating of 14.34%. Similarly, within the Supplier Environmental Footprint (EF) Criteria, the Liquid Wastes (EF2) are considered very important with a priority score of 45.73% followed by the Solid Wastes (EF3) at 30.12% (Table 6). The Gaseous Pollutants (24.14%) appeared to gather least concern which is surprising as the greenhouse and industrial gas emissions are a major problem worldwide. However, it appears that within the UAE healthcare system, the disposal of liquid and solid wastes is of more concern. Within the Supplier Voluntary Certification (VC) criteria (Table 7), the evaluators rated the Environmental Auditing (VC3) as having the highest priority (41.81%) followed by the Voluntary Third Party Certification (34.01%) such as eco labels, green lights and green labels (VC1). The element of ISO 14000 Certification (VC2) was rated as the least important of the three sub-criteria at 24.19% which is also unexpected given its wide popularity. This anomaly was clarified by industry professionals who revealed that ISO14000 certification is now compulsory and considered as a bare minimum in the industry. For this reason, additional voluntary environmental certifications convey a superior environmental standing of suppliers. Furthermore, VC1 measures such as Eco Labels, Green Lights and Green Label are certifications of the product itself whereas ISO14000 is a more process oriented standard. This explains the prioritization of VC1 over VC2.

For the criterion of Supplier Quality Assurance (QA), the Supplier Testing Facilities (QA2) were rated as the most important at 41.11%, followed by the Standard for Incoming Quality Assurance (QA) at 36.00% (Table 8). The Product Pre-shipment (Outgoing) Quality Assurance (QA) was given the priority of 22.89%. The obtained priority pattern for QA shows the emphasis on quality assurance rather than the quality checks at the end of the production process. Within the Supplier Resource Consumption (RC) category, the Energy/Resources Consumption (RC4) during the production process was evaluated as the most important sub-criteria at 30.39% (Table 9). The presence of a formal Reverse Logistics Program (RC3) and Returnable and Reduced Packaging

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(RC2) were rated closely at 26.66% and 26.80%. The Remanufacturing/Reuse Activities (RC1) were given the lowest priority of 16.15%.

The criterion of Supplier Legal Compliance Competency (CC) was sub-divided into Current Compliance to Environmental Regulations (CC1), Previous Violations of Environmental Permits (CC2), and Public Disclosures of Environmental Record (CC3). The evaluated priorities are intuitive as CC1 is the most important sub-criterion at 53.45% (Table 10). The respondents also thought that a business with public disclosures of its environmental records was more likely to comply with environmental regulations and, therefore, this element was ranked higher (27.50%) than the element of Previous Violations of Environmental Permits (CC2) which received the lowest rating of 19.05%. The Supplier Management Systems criterion was sub-divided into Quality Management System (MS1), Environmental Management System (MS2), Hazardous Substance/Waste Management System (MS3), and Information System (MS4). As was expected, the evaluators considered the presence of a formal environmental management system as the most significant factor contributing towards environmental sustainability. MS2 was given the rating of 30.42% while the elements of Hazardous Substance/Waste (MS3) and quality management (MS1) systems were a close second and third at 27.57% and 26.80%, respectively (Table 11). Supplier Management Practices (MP) of having Programs to Foster Employee Environmental Awareness (MP1), Management Commitment to Sustainability reflected in the Mission Statement (MP2), and Requirement of Green Procurement from the 2nd tier Suppliers (MP3) were also evaluated by the respondents. MP1 was deemed as the most important green factor within this category at 38.65%, with MP2 and MP3 being rated as almost equally important at 30.71% and 30.65%, respectively (Table 12).

Table 3
Random index.

N	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.48

Where: *N* is number of factors.

Table 5
Pair wise comparison matrix for the product attributes sub-criteria.

	PA1	PA2	PA3	PA4	Priority weight (%)
PA1	0.232	0.318	0.130	0.246	23.16
PA2	0.158	0.216	0.318	0.229	23.04
PA3	0.232	0.088	0.130	0.123	14.34
PA4	0.378	0.378	0.422	0.401	39.47
				CR*=*0.0547	< ***0.10*** (Acceptable)

Table 6
Pair wise comparison matrix for the supplier environmental footprint sub-criteria.

	EF1	EF2	EF3	Priority weight (%)
EF1	0.244	0.307	0.173	24.14
EF2	0.365	0.459	0.548	45.73
EF3	0.392	0.233	0.279	30.12
			CR*=*0.0540	< ***0.10*** (Acceptable)

Table 7
Pair wise comparison matrix for the supplier voluntary certification sub-criteria.

	VC1	VC2	VC3	Priority weight (%)
VC1	0.347	0.280	0.393	34.01
VC2	0.292	0.235	0.198	24.19
VC3	0.361	0.485	0.409	41.81
			CR*=*0.025	< ***0.10*** (Acceptable)

Table 8
Pair wise comparison matrix for the supplier quality assurance sub-criteria.

	QA1	QA2	QA3	Priority weight (%)
QA1	0.36	0.34	0.39	36.00
QA2	0.43	0.41	0.39	41.11
QA3	0.21	0.25	0.23	22.89
			CR*=*0.0038	< ***0.10*** (Acceptable)

Table 4
Pair wise comparison matrix for main criteria with priority weight.

	Product attributes (PA)	Environmental footprint (EF)	Voluntary certification (VC)	Quality assurance (QA)	Resource consumption (RC)	Legal compliance competency (CC)	Management systems (MS)	Suppliers management practices (MP)	Priority weight (%)
Product attributes (PA)	0.087	0.043	0.090	0.117	0.183	0.083	0.123	0.082	10.09
Environmental footprint (EF)	0.336	0.165	0.193	0.164	0.129	0.111	0.162	0.154	17.68
Voluntary certification (VC)	0.097	0.086	0.101	0.134	0.050	0.204	0.072	0.165	11.36
Quality assurance (QA)	0.100	0.134	0.101	0.134	0.110	0.171	0.105	0.200	13.21
Resource consumption (RC)	0.058	0.156	0.247	0.148	0.122	0.092	0.162	0.083	13.35
Legal compliance competency (CC)	0.151	0.214	0.071	0.113	0.191	0.144	0.136	0.154	14.68
Management systems (MS)	0.070	0.101	0.140	0.127	0.075	0.105	0.100	0.067	9.82
Suppliers management practices (MP)	0.100	0.101	0.058	0.063	0.140	0.089	0.141	0.095	9.83
						CR*=*0.09	< ***0.10***	(Acceptable)	

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Table 9
Pair wise comparison matrix for the supplier resource consumption sub-criteria.

	RC1	RC2	RC3	RC4	Priority weight (%)
RC1	0.157	0.202	0.097	0.190	16.15
RC2	0.213	0.275	0.224	0.353	26.66
RC3	0.384	0.291	0.237	0.160	26.80
RC4	0.245	0.231	0.442	0.297	30.39
				CR*=*0.025	< ***0.10*** (Acceptable)

Table 10
Pair wise comparison matrix for the supplier's legal compliance competency sub-criteria.

	CC1	CC2	CC3	Priority weight (%)
CC1	0.524	0.613	0.467	53.45
CC2	0.151	0.177	0.244	19.05
CC3	0.325	0.210	0.290	27.50
			CR*=*0.033	< ***0.10*** (Acceptable)

Table 11
Pair wise comparison matrix for the supplier management systems sub-criteria.

	MS1	MS2	MS3	MS4	Priority weight (%)
MS1	0.267	0.264	0.261	0.280	26.80
MS2	0.303	0.300	0.280	0.333	30.42
MS3	0.287	0.300	0.280	0.236	27.57
MS4	0.143	0.136	0.179	0.151	15.21
				CR*=*0.043	< ***0.10*** (Acceptable)

Table 12
Pair wise comparison matrix for the supplier management practices sub-criteria.

	MP1	MP2	MP3	Priority weight (%)
MP1	0.385	0.428	0.346	38.65
MP2	0.272	0.303	0.346	30.71
MP3	0.342	0.269	0.308	30.65
			CR*=*0.011	< ***0.10*** (Acceptable)

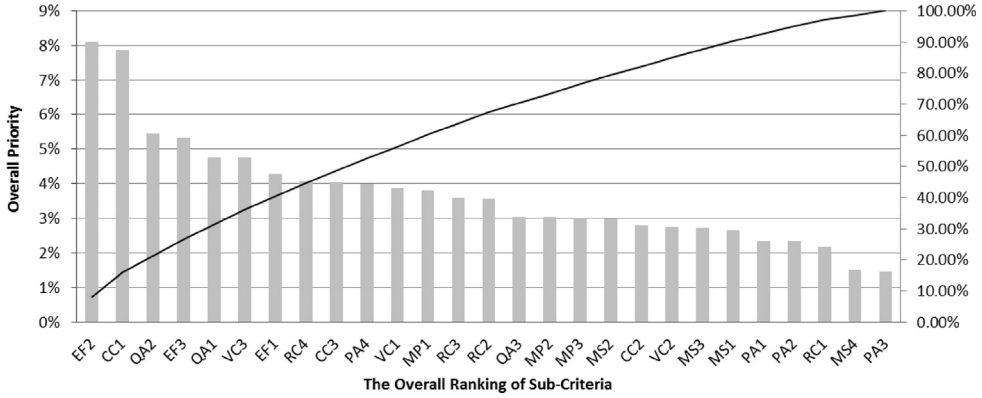

Fig. 3. The overall ranking of the 27 sub-criteria.

The final step in the AHP is to develop the overall priority of the 27 sub-criteria by multiplying the sub-criteria ranking with the criteria priority matrix (Fig. 3). The Liquid Wastes (EF2) is the highest ranked among the 27 sub-criteria at the overall priority of 8.09%. The Current Compliance to Environmental Regulations (CC1) had the second highest overall priority of 7.85% followed by Testing Facilities (QA2) at 5.43% and Sludge/Sold Wastes (EF3) at 5.33%, respectively. The relative overall ranking of the all sub-criteria in Fig. 3 is within a close range because the difference in the overall priority between the highest ranked EF2 and the lowest ranked PA3 is less than 7%.

5. Conclusion and implications

Sustainability and environmental protection practices are getting increasingly more attention in the industry. In order to remain competitive, a supply chain needs to emphasize environment protection and green operations as critical elements of its sustainability measures. Green supplier selection criteria in a dynamic, competitive and regulatory environment can help lessen the environmental and legal risks in addition to increasing the competitiveness of supply chains. Therefore, this study implements a structured transformation of the UAE healthcare chain's environmentally sustainable needs into a multiple criteria for supplier evaluation. The use of AHP for a consensus decision on supplier's environmental performance ensures a systematic investigation and assessment of the capabilities of suppliers by industry experts and helps establish a benchmark of environmental considerations relevant to the country's healthcare setting.

This research makes several contributions to the theoretical debate in this field. First, it introduces a comprehensive criteria and associated sub criteria to access supplier environmental performance in the healthcare industry. Second, the proposed framework has been successfully implemented in the healthcare sector of Abu Dhabi. Third, as opposed to much of the available anecdotal literature on green purchasing, this research has a theoretical basis and uses an empirical analysis to prioritize attributes of supplier environmental performance in the healthcare industry. Additionally, purchasing managers in healthcare sectors can apply this research when evaluating environmental performance of suppliers.

The results from this study demonstrate that the Supplier's Environmental Footprint (EF) criterion is considered as most important by the respondents with a priority weight of 17.68% followed by the Legal Compliance Competency (CC) which had a competitive priority of 14.68%. Environmental footprint is the overall amount of greenhouse gas emissions, consisting primarily of carbon dioxide, associated with an organization, event or production. The environmental footprint concerns by the UAE healthcare procurement and supply chain professionals can be attributed to an energy based economy that accounts for nearly three-quarters of Abu Dhabi's environmental footprint. The UAE government is taking strict measures to deal with the issue of

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environmental footprint as part of the UAE Vision 2021 to achieve sustainable development. Interestingly, it has been found that procurement managers put less emphasis on Supplier Management Practices (MP) and Management Systems (MS). It is recommended that in addition to focusing on the environmental foot print of the suppliers, purchasing managers may also evaluate the management systems and practices of suppliers. This will give them a better understanding of the environmental strategy of the suppliers.

The main limitation of this research is the focus on a small sample of organizations in Abu Dhabi but the lack of empirical research in this region is also one of the main strengths of this paper. The findings cannot be generalized to all organizations in this region or around the world. Future research should empirically test the framework suggested in this paper in different emirates/countries, to enable comparative studies. A more diverse sample would also allow detailed cross-sectorial comparisons (Public and Private Hospitals) which are not possible in the context of this study.

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