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Abstract: Extant literature on sustainability in procurement and supplier selection suffers from a number of deficiencies. First, studies pertaining to the dynamic nature of stakeholders' expectations of sustainability and its impact on determining a supply portfolio have not been studied before. Second, there is a genuine lack of study linking the stakeholders' sustainability requirements, firm procurement strategies, and eventual supplier selection. Third, most of the existing studies address sustainability issues in procurement and supplier selection but fall short of determining an optimal portfolio of suppliers and corresponding optimal order quantities. This study addresses the above research gaps by developing a sustainability-focused multi-criteria decision model for supplier evaluation and determining optimal order allocation among the suppliers linking the stakeholders' sustainability requirements and firm procurement strategies. Based on dynamic capability theory, we develop a decision support framework integrating multi-phased quality function deployment and dynamic optimization. We apply the decision support framework to a European apparel company which sources apparel from Bangladesh: a country that is a low cost sourcing destination. First, this study identifies the stakeholders' sustainability requirements. It then explicates the company's procurement strategies in terms of stakeholders' requirements followed by translating the procurement strategies to relevant supplier assessment criteria. Finally, a linear optimization model is developed to maximize the suppliers' sustainability performance in order to determine the optimal supply portfolio. The results identify two distinct groups of suppliers satisfying the overall sustainability performance. However the optimal order quantities among the suppliers vary randomly depending on the variations in demand and priority weights of the suppliers. The paper concludes with a detailed discussion of the results and implications.

Keywords: Sustainability; Supplier selection; Stakeholders; Multi-criteria, Fuzzy Analytical Hierarchy Process; Quality Function Deployment; Dynamic optimization.

1. Introduction

The call for sustainability-focused procurement has greatly increased in recent years due to stakeholders' growing concerns regarding the poor sustainability performance of suppliers from emerging countries (de Brito et al., 2008, Carter and Rogers, 2008, Carter, 2004, Islam and Deegan, 2008). As a result, the introduction of sustainability criteria in purchasing decisions has produced a new set of trade-offs (Dai and Blackhurst, 2012). Regarding procurement from emerging countries, the demand for a sustainability-focused, multi-criteria supplier assessment model has escalated even more due to several high profile industrial accidents (e.g. Rana Plaza and Tazreen Fashion tragedy in Dhaka, Bangladesh) and scandals (e.g. the Nike sweatshop scandal) (CIPS 2019). Further, the poor social and environmental performance of supply firms is often the cause of consumer boycotts and negative media exposure (Hossan et al., 2012, Vugrin et al., 2011). This is a major reputational risk when sourcing from emerging countries. To offset the challenges of sustainability risks arising from suppliers' performance, companies have started to concentrate on sustainability issues when making procurement decisions. However, the social and environmental expectations of stakeholders are dynamic. With changes in the environment, stakeholders' focus on sustainability requirements is also changing, which leads to changes in supplier selection criteria and their importance weight. A number of studies (Vahidi et al., 2018, Prosman and Sacchi 2018, Luthra et al., 2017, Demirtas and Üstün 2008, Bevilacqua, Ciarapica, and Giacchetta 2006 and others) have been conducted on supplier assessment. Similarly, many studies (e.g. Bevilacqua et al., 2006, Kahraman et al., 2003, Dulmin and Mininno, 2003, Demirtas and Üstün, 2008, Narasimhan et al., 2006, Ng, 2008) have examined multi-criteria decision modelling (MCDM) for supplier evaluation. However, most of the existing studies suffer from a number of deficiencies. For example, Vahidi et al. (2018) propose a sustainability-resilience bi-objective model for sustainable supplier selection and order allocation. Although their modelling approach is quite comprehensive in nature it, however, does not consider the dynamic nature of sustainability requirements in the framework. Prosman and Sacchi (2018) consider the case of circular supply chain (a combination of forward and reverse supply chains). Their research uses the life cycle modelling approach, deals with three dominant environmental supplier-selection criteria, and hence neglects the economic and social dimensions of sustainability. Luthra et al. (2017) develop a framework for the efficient ranking of suppliers based on three dimensions of sustainability (economic, environmental and social). While the authors use an integrated modelling approach (combining AHP and an MCDM approach), they do not deal with dynamic nature of sustainability requirements and do not determine the optimal order quantities for the efficient suppliers. Hence, gaps in the extant studies can be summarized as follows: (i) most studies do not consider all three dimensions of sustainability (economic, environmental and social) in supplier assessment, (ii) most studies fall short of considering the dynamic changes in the sustainability requirements of stakeholders in supplier assessment, (iii) most studies do not determine the optimal supplier portfolio and corresponding optimal order quantities concurrently, (iv) most studies do not link stakeholders' sustainability requirements, firm procurement strategies, and eventual supplier selection in an integrated framework. Further, sustainability issues in supplier selection in the case of sourcing from emerging countries have not yet been explored.

Considering the above research gaps, the research questions investigated in this study are as follows:

(1) What are the stakeholders' expectations of the focal firm regarding sustainability in the supply chain and how do they relate to the procurement strategies of the firm?

(2) What are the supplier assessment criteria and how are they related to the firm's procurement strategies and the sustainability requirements of the stakeholders?

(3) How to determine the optimal supplier portfolio with corresponding optimal order quantities?

(4) What are the impacts of the dynamic nature of stakeholders' sustainability requirements on supplier portfolio and order quantities?

In investigating the above research questions, we develop a sustainability-focused multi-criteria decision-making framework considering the dynamic changes in stakeholders' sustainability expectations during supplier assessment and the selection of optimal supplier portfolio and order quantities. To efficiently address the existing gaps in the research, we rely on the dynamic capability view (DCV) (Teece et al., 1997) as theoretical underpinning. Teece et al. (1997) state that *dynamic capability* is "the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments". We surmise that sustainability requirements of the stakeholders are dynamic in nature. They change depending on the changing environmental conditions. For example, the industrial accidents and various scandals mentioned previously (CIPS 2019) are likely to refocus stakeholders' attention to address these incidents in sourcing from emerging countries. Firms hence need to develop the micro-foundations of dynamic capabilities (various skills, processes, procedures etc.) (Teece 2007) to cope with changing sustainability requirements. We argue that the optimization-based Fuzzy-AHP-QFD approach developed in this paper is a micro-foundation (a specific tool, framework, process) of DCV which adequately addresses the dynamic changes in stakeholders' sustainability expectations in supplier assessment and the selection of an optimal supplier portfolio and order quantities. This contributes to the "how" aspect of the DCV, as discussed by Whetten (1989).

The optimization-based Fuzzy-AHP-QFD method is a multi-phased integrated approach which combines the QFD method (Akao 1990, Hauser and Clausing 1988) where the weighting process for QFD is done using a fuzzy calibration process(Kamvysi et al. 2014) and an analytical hierarchy process (AHP) (Saaty 1980). We use the interlinked QFD process proposed by Hauser and Clausing (1988; pp.73) which translates the sustainability requirements of the stakeholders through firm's procurement strategies, and the supplier assessment criteria to ranking of the suppliers. The final phase of the multi-phased process uses an optimization method to determine the optimal portfolio of suppliers and corresponding optimal order quantities for each supplier. To investigate the dynamic nature of the stakeholders' requirements, a simulation study is undertaken which we term dynamic optimization. It is noted that the simulated dynamic optimization unearths some interesting findings which we discuss later in appropriate section. As the Fuzzy-AHP-QFD method addresses all the research questions in a systematic way, we argue that this is best suited for this study.

With respect to the research questions presented earlier, we use a mixed-methods (Creswell and Clark, 2007) research approach to develop a holistic understanding (Boyer and Swink, 2008). A field study technique followed by a multi-phased Fuzzy-AHP-QFD approach is implemented to capture stakeholder demand and to assess the suppliers. Finally, a dynamic optimization model is developed to determine the optimal order allocation i.e. optimal portfolio of supply. The decision support approach developed in this study is unique in the supplier selection literature as the previous studies determined only the ranking of suppliers, while the dynamic nature of stakeholders' sustainability requirements in evaluating suppliers and determining their order quantity was largely ignored. It also contributes to research on dynamic capability theory and supply chain sustainability by integrating the two previously unlinked topics (Hong et al. 2017). The approach developed in this study has significant managerial value as well, as managers will be able to change the criteria weight of suppliers and their order quantities based on the changes in stakeholders' sustainability expectations. Further, managers who face challenges when sourcing from low-cost countries will benefit greatly from this study.

The literature review and the research methodology are presented in the sections below followed by the results and discussion (including implications). This paper concludes with a discussion of the contributions made by this study, and an acknowledgement of the limitations, which point to avenues for further research.

2. Literature review

The next sections include a review of the literature on supply chain sustainability, its implications for procurement and supplier selection and, finally, a description of the methods currently being used for supplier selection.

2.1 Sustainability in the supply chain

A sustainable supply chain (SSC) has been explained as a chain of organizations capable of managing the flow of material, information and capital by ensuring cooperation and collaboration among all supply chain stakeholders in order to achieve environmental, social, and economic goals without compromising the stakeholders' requirements (Seuring and Muller, 2008). In recent times, sustainability has become a corporate strategy, as customers are highly concerned about the sustainability of organizations and their supply chains (Lewis et al., 2005; Bendul et al. 2017). Further, sustainability in supply chain is the key challenging issue if the requirements of stakeholders are to be met (Darnall et al., 2008). To achieve sustainability in supply chains and to meet the stakeholders' requirements, a balance needs to be maintained among environmental, economic and social goals (Carter and Rogers, 2008, Carter and Easton, 2011). Extant literature suggests various ways and means in order to achieve sustainability in the supply chain. Moktadir et al. (2018a) use a fuzzy analytical hierarchy process (FAHP) to evaluate the drivers of CSR (corporate social responsibility)-based sourcing in the context of the footwear industry in Bangladesh. The authors consider all three (economic, social and environmental) dimensions of sustainability and identify twenty drivers of CSR-based sourcing. Their analysis shows financial drivers are the most important followed by environmental drivers. Koberg and Longoni (2019) conducted a systematic review of sustainable supply chain (SSC) management in the context of the global supply chain. The authors reviewed the relevant articles of the past fifteen years and concentrated mostly on the management aspect of SSC. Their results indicate that firms which have a "greater connection with multi-tier suppliers and are managed directly or through third parties" demonstrate better sustainability in the supply chain. Using graph theory and a matrix approach, Moktadir et al. (2018b) study the drivers of sustainable manufacturing practices and the circular economy in the context of the leather industry in Bangladesh. The authors find that the adoption of sustainable manufacturing practices helps improve the sustainability of the supply chain. However, it is noted that the concept of the circular economy primarily addresses waste minimization via the increased reuse and recycling of products, enhancing environmental and economic sustainability. Hence, the social aspect of sustainability is undermined. Seuring et al. (2019) study the linkages between the sustainable supply chain management (SSCM) theory of Seuring and Muller (2008) with the bottom of pyramid (BoP) project supply chains in Kenya and Uganda. The authors use qualitative interviews as their methodology. Their research reveals two important findings: (i) strong linkages exist between SSCM theory and BoP project supply chains, and (ii) third party (NGOs etc.) involvement in auditing and monitoring suppliers ensures minimum standards for environmental and social sustainability issues in supply chains are met. Moktadir et al. (2018c) study the barriers to sustainable supply chains in the leather industry of Bangladesh. The authors use the decision making trial and evaluation laboratory (DEMATEL) tool to investigate the interrelationships among the barriers. Local customers' lack of awareness of green products, a lack of commitment from top management, a lack of reverse logistics practices and outdated machinery were identified as the highest priority barriers to a sustainable supply chain.

Satisfying stakeholders' requirements is also an important element of stakeholder theory (Freeman, 1984). According to Perrini and Tencati (2006), a sustainable organization seeks to optimize its environmental and social goals along with its economic goals for a sustainable and value-based stakeholder relationship. The crucial point is that a sustainable supply chain is now viewed as a must-have by customers, governments and other stakeholders (Seuring and Muller, 2008); hence, organizations as well as their supply chains try to incorporate sustainability in their strategies (Aragón-Correa and Sharma, 2003). However, the above literature review did not reveal any study to translate the stakeholders' sustainability requirements into optimal supplier selection and optimal order quantities from the suppliers.

2.2 Sustainability in procurement and stakeholders' requirements

Sustainability in the supply chain depends largely on sustainable procurement (Dai and Blackhurst, 2012, Carter, 2004) as the poor sustainability performance of suppliers is a threat to the whole supply chain. For example, in October 2001, Dutch authorities stopped the shipment of more than 130,000 game consoles as they failed to meet the minimum cadmium levels as specified in the Dutch standards (Carlton, 2006). Moreover, companies are often accused of purchasing from factories with poor sustainability standards in low-cost countries where working conditions and compliance with regulations are notoriously lax (Naeem and Welford, 2009, Vugrin et al., 2011, Ahmed and Peerlings, 2009). As a result, buyers have come to realize that the environmental and social problems associated with the various stages of production need to be acknowledged, irrespective of their position in the SC. Central supply chain firms are increasingly being held responsible for the performance of their supply network members. Previous studies have identified a number of sustainability issues such as fair wages, a good working environment and safety, abolition of child labour and forced labour, health hazard-free products, pollution control, and others (Vugrin et al., 2011, Belal and Owen, 2007, Nuruzzaman, 2007, Emmelhainz and Adams, 1999, Kabeer and Mahmud, 2003) which are demanded by the stakeholders. Sonnichsen and Clement (2020) undertook a comprehensive literature review on green and sustainable public procurement. The authors highlight the need for circular public procurement and found three high-level factors, organizational, individual behaviour and operational tools, as the main influencers of sustainable public procurement. It is noted that among the operational tools, prioritisation and evaluations tools and supplier selection tools are the main contributors of sustainable public procurement. In another review paper, Yu et al. (2020) develop an integrated framework for electronic procurement and sustainable procurement in the construction industry, finding sixteen strategies to promote sustainable procurement (SP) with mandatory government regulations, policies and guidelines, education and training of industry stakeholders, and organisational leadership support and commitment being the dominant ones. The study also reveals that 34% of SP articles deal with all three dimensions of sustainability. Fayezi et al. (2018) discuss a concept called procurement sustainability tensions (PSTs) which arise in most organizations. The PSTs arise due to the multidimensional (sometimes conflicting) nature of sustainability dimensions (economic, social and environmental) and the multi-stakeholder environment which most companies face. The study also discusses various legitimacy contexts, which manifest the development of PSTs. This study justifies our approach of focusing upfront on stakeholders' sustainability requirements to ultimately find the optimal supply portfolio. Appendix 3 presents a summary of the factors and variables for procurement sustainability from the extant literature.

Companies' moves toward sustainability are motivated by stakeholders' requirements (Bai and Sarkis, 2010). The unification of the sustainability criteria in the field of procurement to meet stakeholders' requirements can be explained by stakeholder theory, which advocates that organizations are responsible for their actions to the shareholders and the stakeholders (Freeman, 1984). Managers are expected to satisfy the requirements of stakeholders; otherwise, an organization's sustainability will be questioned. Further, companies are experiencing changes in the internal and external environment arising from buyers, suppliers, shareholders, employees, government, competitors, pressure groups and others (Freeman, 1984). Thus, organizations must change their strategies to successfully meet the increasing number of stakeholder sustainability requirements (Freeman, 1984). In parallel, it can also be argued that management must be able to identify the sustainability requirements demanded by the stakeholders and establish broader business strategies and specific procurement strategies in response to stakeholder expectations and demands.

2.3 Sustainability in supplier selection

To ensure sustainability in the supply chain, it is essential that the basics of sustainability are maintained in supplier selection. The literature reveals various methodologies to ensure sustainability in supplier selection. For example, Liu et al. (2019) use a fuzzy three-stage integrated multi-criteria decision-making (MCDM) approach to ensure sustainability for new energy vehicle battery supplier selection. Khan et al. (2018) propose an integrated model based on the fuzzy-Shannon entropy method for sustainable supplier evaluation and selection. The authors apply the model in a manufacturing company in Pakistan. Li et al. (2019) propose a novel framework for sustainable supplier selection, which uses an extended TOPSIS (Technique for Order Performance by Similarity to Ideal Solution) method that also integrates the advantages of cloud model theory. The authors apply their framework to sustainable photovoltaic module supplier selection. Jain and Singh (2019) develop a fuzzy inference system with fuzzy Kano philosophy for sustainable supplier selection. The authors apply the method to the iron and steel industry of India.

To adequately meet the sustainability expectations of stakeholders, buyers also have started to measure the sustainability performance of suppliers, generally through certifications, such as ISO 14001, which are provided by regulatory bodies (Adams and Narayanan, 2007). In the dynamic business arena, organisations pay attention to environmental and social issues, conducive working conditions and health and safety issues to meet the expectations of stakeholders (Islam and Deegan, 2008). Similarly, Hossain et al. (2012) and Chowdhury and Hossain (2015) argue that employee and management training can also help the organization achieve its sustainability objectives. Internal stakeholders require more training and education regarding a sustainable supply chain, which fulfils management's desire of increased sustainability standards (Seuring et al., 2008). In accordance with the sustainability standard, technological advancement, particularly in terms of efficiency, is very important as it helps reduce costs, harmful emissions, and the amount of input required (Dewulf et al., 2000).

As previously mentioned, stakeholders' call to consider sustainability issues in procurement decisions is intensifying with the suppliers' concern with sustainability being reflected in company practices. As an example, during 2009, Walmart publicized the creation of a sustainability index, which included a sustainability index for suppliers (Dai and Blackhurst, 2012). Realizing their importance, a growing number of researchers have addressed supplier selection issues in relation to social and environmental concerns (Lu et al., 2007, Dai and Blackhurst, 2012, Bai and Sarkis, 2010, Tsai and Hung, 2009). Apart from Dai and Blackhurst (2012), most of the studies consider social and environmental issues separately rather than treating them as integrated issues. Moreover, the voices of multiple stakeholders have not been captured in most of the studies although it is essential that companies heed these voices when making procurement decisions. The study of Dai and Blackhurst (2012) incorporates both social and environmental issues; however, the ill-defined subjective judgement of quantifying the qualitative aspects of sustainability issues can be better explained by means of fuzzy numbers. Further, we argue that the procedure of ranking the suppliers based on sustainability criteria (Dai and Blackhurst, 2012) may not be adequate when the managers need more information. For example, stakeholders' sustainability requirements and the weight given to their importance may change over time, and managers may be interested in maintaining multiple suppliers and their order allocation etc. Therefore, it is important to develop a method that can address the evolving nature of stakeholders' sustainability needs by ranking suppliers based on predetermined criteria while also determining the optimal quantity of supply.

2.4 Multi-phased Fuzzy-AHP-QFD for supplier selection

Supplier evaluation requires qualitative as well as quantitative criteria (Bevilacqua et al., 2006, Ho et al., 2010) and as a result, the integration of qualitative and quantitative approaches in supplier selection is salient. Therefore, the Fuzzy-AHP-QFD approach is suitable for supplier selection as it uses both qualitative and quantitative methods.

The aforementioned approach is in line with the multi-stage AHP-QFD approach of Dai and Blackhurst (2012). However, we added fuzzy modelling to effectively quantify the qualitative judgments in various phases of the process. Triangular fuzzy sets are used to express ill-defined subjective judgments quantitatively and precisely (Delice and Güngör, 2011, Bottani and Rizzi, 2006). Fuzzy-QFD approaches have been applied in previous studies on supply chain management (e.g. Ho et al. 2012; Dao et al., 2011, Kuo et al., 2009, Dai and Blackhurst, 2012, Chowdhury et al., 2019) to address qualitative and ill-defined subjective judgements. Therefore, the Fuzzy-AHP-QFD approach is appropriate for translating the voice of stakeholders on sustainability requirements to the supplier assessment process as applied in this research.

In addition to highlighting the research gaps in the introduction, we expound them further in this section. For this, we critically review the closely related papers from the literature. Table 1 presents a summary of the analysis. We observe that none of the previous studies considers the dynamic requirements of stakeholders in determining the sustainability-focused supplier selection criteria. Moreover, extant studies fall short of considering the theory behind the dynamic requirements of stakeholders in supplier selection and order allocation. To address these gaps in the literature, we extend the literature on supplier selection by considering the dynamic requirements of stakeholders, which is also justified by the theoretical lens of the dynamic capability view.

(Insert Table 1 about here)

In this study, we develop a sustainability-focused (optimization integrated) multi-phase Fuzzy AHP-QFD framework (see Figure 1) that comprises three hierarchical interrelated QFD matrices. In interlinked QFD matrices, the columns of one phase are converted into the rows of the next phase (see arrows in Figure 1) (Hauser and Clasusing 1988). As shown in Figure 1, phase 1 of the framework relates the stakeholders' sustainability expectations/requirements (ie. CR_i in rows) to the company's sustainable procurement strategies (DR_j in columns). The R_{ij} in this QFD matrix represents how well the procurement strategies (DR_j) realize the stakeholder requirements (CR_i). In phase 2, the columns of phase 1 are taken as the rows (see Figure 1). Hence, CR_i in phase 2 are the procurement strategies and the columns (DR_j) are the supplier assessment criteria. (CR_i). The R_{ij} in this QFD matrix represents how well the procurement strategies (CR_i) are met by the supplier assessment criteria (DR_j). Again, in phase 3, the rows (CR_i) become the supplier assessment criteria of phase 2 and the columns (DR_j) of phase 3 are taken as the suppliers for which ranking is sought. The R_{ij} in this QFD matrix represents how effectively the suppliers (DR_j) meet the supplier assessment criteria (CR_i), which assists in developing the suppliers' ranking. It is observed that through these interlinked QFD matrices, the stakeholders' sustainability requirements of phase 1 are translated into the ranking of suppliers in phase 3. Finally, in phase 4, the framework develops a multi-objective optimization model to determine the optimal portfolio of supplies from the suppliers. The details of the multi-phase Fuzzy-AHP–QFD approach are explained in the following section with respect to a real-world case application.

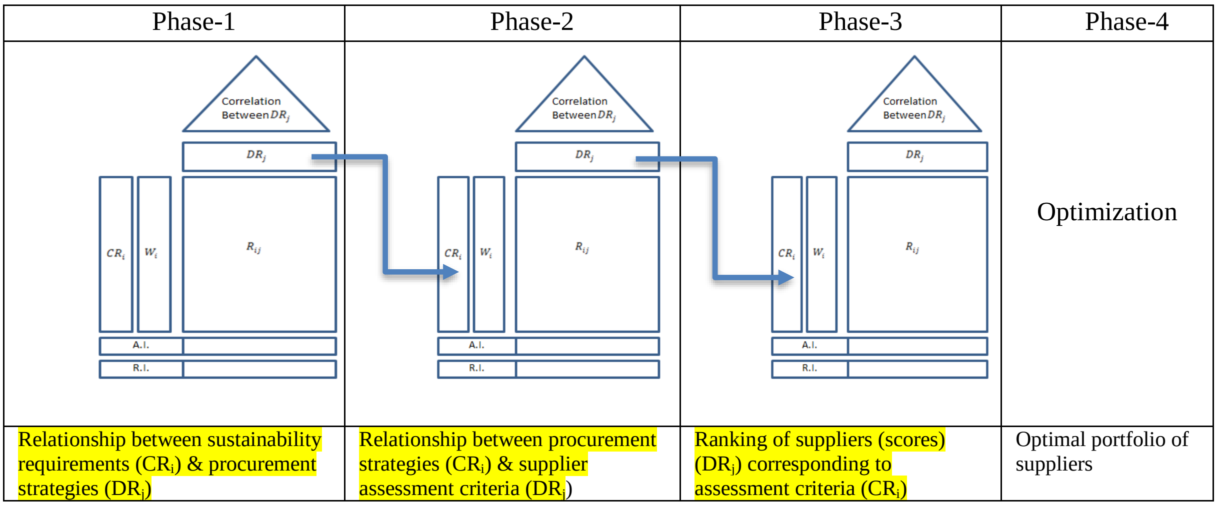

Figure 1: Sustainability-focused Multi-phased Fuzzy AHP-QFD Framework

Note: CR_i = Customer requirements; W_i = Degree of importance of CR_i's; DR_j = Design Requirements; R_{ij} = Relationship Matrix (i.e. degree to which CR_i is met by DR_j) A.I.= Absolute importance of DR_j's ; R.I.= Relative importance of DR_j's.

3. Research method

To address the research questions, we implemented an optimization-based multi-phased QFD process as the primary methodology. It is noted that the WHATs (CR_i) and HOWs (DR_j) of the QFD matrix (see Figure

1) need to be contextualized for our case application. As previously discussed in the first phase, WHATs represent the sustainability requirements of the stakeholders (mainly, the consumers, consumer association, NGOs and government agencies) during procurement from low-cost countries. HOWs represent the related sustainable procurement strategies of the buying firm. In the 2nd phase, the WHATs represent the sustainable procurement strategies of the company (i.e. HOWs from the 1st phase) and the HOWs are replaced by the company's supplier assessment criteria. In the third phase, the WHATs represent supplier assessment criteria. HOWs indicate the suppliers to be ranked. The fourth phase of the research involves optimization as a means of determining the optimal supply portfolio of suppliers. Table 2 summarizes the four phases of the research design along with other relevant information. Because the research problem is context-specific, we need to conduct a field study along with the quantitative study using the fuzzy QFD and optimization technique. Therefore, the mixed-methods technique is used in this research to ensure the quality, accuracy, validity and reliability of the collected data (Creswell and Clark 2007).

(Insert Table 2 about here)

Phase 1

In the first phase, we selected a case company to identify their sustainability concerns as well as relevant procurement strategies. This phase includes both qualitative and quantitative techniques in collecting and analysing data. For the qualitative part, we primarily used the literature review and interviews for data collection. A field study was conducted to identify the sustainability requirements of the stakeholders when sourcing from low-cost countries. Relevant themes from the literature were used to identify the sustainability requirements of the stakeholders. A semi-structured questionnaire was used to collect the data from the three decision makers (included in the QFD work group) of a large buying firm operating in Bangladesh. The respondents were asked to describe the sustainability requirements of the stakeholders. After determining the sustainability requirements (WHATs), the respondents were asked about the sustainable procurement strategies (HOWs) used by the company to meet the requirements. With the quantitative approach, a structured questionnaire was used to determine the importance weight of the WHATs and to measure the relationships between the WHATs and HOWs. The Fuzzy-QFD tool was used in this regard. The data collected from the respondents were averaged using the weighted average method.

The qualitative data analysis involved extracting the sustainability requirements (WHATs) from the content analysis, which were then compared with the literature for necessary amendments. Once the WHATs were finalized, our respondents were asked about the sustainable procurement strategies (HOWs) used by the company to meet the requirements. Six sustainability requirements and nine relevant procurement strategies were identified by the respondents (see Tables 3 and 4 in the results section). The extracted sustainability requirements and corresponding strategies were compared with the findings the from literature to ensure validity.

For the quantitative analysis, the sustainability requirements were rated based on the importance score calculated using the Fuzzy-AHP method. We used a triangular fuzzy number (TFN) in AHP scaling as presented in Appendix 1 (Kamvysi et al., 2014).

Since different fuzzy numbers can be used based on the requirements and the analysis, we deploy the use of TFNs known as triplets. TFNs are helpful in quantifying linguistic data since they are easy to calculate and interpret (Bevilacqua et al., 2006). The triplets are presented in the form of A= (x^L, x^α, x^R). Here x^L, x^α, and x^R are in the membership group A where x^L and x^R are the lower and upper triplet numbers. On the other hand, x^α is the modal value. The fuzzy membership function is shown in equation 1.

$$\mu_x(x) = \begin{cases} \frac{x}{x^\alpha - x^L} - \frac{x^L}{x^\alpha - x^L}, & x \epsilon\ (x^L, x^\alpha) \\ \frac{x}{x^\alpha - x^R} - \frac{x^R}{x^\alpha - x^R}, & x \epsilon\ (x^R, x^\alpha) \\ 0, & \text{otherwise.} \end{cases} \quad (1)$$

The spread of a fuzzy number is δ where δ $= x^\alpha - x^L = x^R - x^\alpha$. The values of δ can be adopted based on the fuzziness of judgments. Aligned with Zhu et al., (1999), $0.5 \leq \delta \leq 1$ is a suitable range. For this study the value of δ is chosen as 1. Considering the modal value x^α, the fuzzy number for representing the fuzzy judgment is denoted as $\{(x^\alpha - \delta), (x^\alpha), (x^\alpha + \delta)\}$ while the reciprocal fuzzy numbers are presented as $\{1/(x^\alpha + \delta),\ \frac{1}{x^\alpha},\ and\ 1/(x^\alpha - \delta)\}$. Considering the degree of fuzziness δ=1, and the confidence interval α=0.5, the fuzzification of AHP's nine-point scale is depicted in Appendix 2.

The weights of the sustainability expectations (WHATs) of the stakeholders were ranked on a nine-point scale and then used for QFD-based analysis (Akao, 1990). It is important to note that the weights assigned by the decision makers for a pairwise comparison of the stakeholders' sustainability requirements are TFNs ($w_{i\propto}$, $w_{i\beta}$, $w_{i\gamma}$). The TFNs were de-fuzzified using the formula suggested by Yager (1981). The TFNs ($w_{i\propto}$, $w_{i\beta}$, $w_{i\gamma}$) were defuzzified using the formula ($w_{i\propto}$+2 $w_{i\beta}$+ $w_{i\gamma}$)/4.

When the weights of WHATs were established, we determined the relationship between the stakeholders' sustainability expectations and the corresponding procurement strategies. The WHATs/HOWs relationship score was obtained by R_{ij}, *where* $i = 1, \ldots \ldots k$ *and* $j = 1 \ldots \ldots m$; m=number of the HOWs and k= number of the WHATs. In our case, k=6, m =9. The R_{ij} elements represent an aggregate relation score between the *i*th WHAT and the *j*th HOW. R_{ij} elements are also presented as TFNs, $R_{ij} = (R_{ij\propto} , R_{ij\beta} , R_{ij\gamma})$.

The absolute and relative importance score of HOWs is determined by equations (2) and (3).

$$\text{Absolute importance,} \quad AI_j = \sum_{i=1}^{n} \left(W_i R_{ij}\right) \tag{2}$$

$$\text{Relative importance,} \quad RI_j = \frac{AI_j}{\sum_{j=1}^{m} AI_j} \tag{3}$$

By taking the weighted sum of the R_{ij} elements corresponding to each HOW, we can derive the AI_j values. The AI_j values are presented as TFNs $AI_j = (AI_{j\propto} , AI_{j\beta} , AI_{j\gamma})$, which are de-fuzzified using the formula of Yager (1981) (($AI_{j\propto}$+2 $AI_{j\beta}$+ $AI_{j\gamma}$)/4). Similarly, the relative importance scores can be determined using equation (3).

Phase 2

The purpose of the second phase is to determine the supplier assessment criteria to operationalize the procurement strategies derived from the first phase of the research. This phase includes both the qualitative and quantitative approaches for data collection and analysis. The collection of qualitative data comprised a literature review and interviews. Factors/variables from the existing literature were used to establish the supplier assessment criteria. A field study was undertaken to identify the supplier assessment criteria of the buying firm while sourcing from low-cost countries. A semi-structured questionnaire was developed to collect the data from the decision makers. For the quantitative data, a structured questionnaire was used to determine the importance of each sustainable procurement strategy (WHATs) and its relation to the assessment criteria (HOWs), which represents the extent to which the procurement strategies (WHATs) will be achieved by the supplier assessment criteria (HOWs). The data collected from the respondents were averaged using the weighted average method.

For the data analysis, the decision-makers' opinions on the relationship between the sustainable procurement strategies (WHATs) and each of the assessment criteria (HOWs) were analysed using the fuzzy-QFD method. Then the absolute and relative importance score of the HOWs were calculated by applying equations (2) and (3). The absolute importance scores derived in this phase were also in fuzzy triplets and needed to be de-fuzzified using the formula suggested by Yager (1981). Then, relative importance score was determined using equation (3) and crisp value.

Phase 3

The aim of the third phase is to rank the suppliers based on the impact of each supplier on the sustainability assessment criteria of the suppliers. This phase of the research uses the quantitative method for data collection and analysis. The decision makers were asked to list their suppliers, and then a structured questionnaire was used to rate the contribution of each supplier (HOWs) on the attributes/assessment criteria (WHATs).

For the data analysis, decision-makers' opinions on the various suppliers corresponding to each assessment criteria were analysed by means of the fuzzy-QFD method once again, following equation (2). The absolute and relative importance score of each supplier was obtained by applying equations (2) and (3). The absolute importance scores derived in this phase were also in fuzzy triplets and needed to be simplified using the formula suggested by Yager (1981). Then, the relative importance was determined using crisp values.

Phase 4

In this phase, we develop a dynamic optimization model to allocate orders to the selected suppliers. Using this dynamic optimization model, we conducted an experiment taking into account the random weights of the suppliers' sustainability evaluation criteria. Dynamic optimization was used to reflect the dynamic changes in the sustainability requirements of stakeholders and reconfigure organizational decisions and strategies according to the changes (Teece et al. 1997). Aligned with the DCV, we argue that the weights of the suppliers' sustainability evaluation criteria can change over time due to the changing requirements of the stakeholders. For example, over the past few decades, the child labour issue was the most important issue of focus of the apparel supply stakeholders of Bangladesh but after several high-profile industrial accidents, such as the Tazreen Fashion factory fire and Rana Plaza Building collapse, building safety has become a highly prioritized issue to stakeholders. Further, environmental sustainability requirements such as water treatment and waste recycling are gradually becoming issues of focus although they were not as important to stakeholders during the 1990s.

To design the optimization model, the QFD group members provided the necessary information about the company's procurement process, total quantity of products to be purchased, the budget for procurement and the unit price of the products from each supplier. The work group members also provided some important information about the procurement policy of the company. For example, the company prefers the strategy of maintaining multiple suppliers rather than depending on single suppliers, thereby maintaining a portfolio of suppliers. The company also has an upper limit and a lower limit of supplies from the suppliers. After collecting the relevant data, we find the optimal order allocations among the suppliers. Our optimization problem is presented by equations (4) to (10).

Maximize sustainability performance $(Z) = \sum_{i=1}^{n} R_i x_i$ (4)

Subject to the following constraints

$\sum_{i=1}^{n} x_i = N$ [demand constraint] (5)

$\sum_{i=1}^{n} p_i x_i \leq B$ [budget constraint] (6)

$x_i \leq U\,;\ \forall i$ [maximum order allocation constraint] (7)

$x_i \geq L;\ \forall i$ [minimum order allocation constraint] (8)

$x_i \leq C_i;\ \forall i$ [supplier capacity constraint] (9)

$x_i \geq 0;\ \forall i$ [non-negativity constraint] (10) where R_i= weight of supplier i on the basis of the sustainability assessment criteria, x_i = decision variables which refer the quantity of products to be procured from supplier i, N= demand in a planning period, p_i is the unit price from supplier i, B = total budget for each period, U= upper limit of purchase quantity from each supplier and L= lower limit of purchase quantity from each supplier, C_i = capacity of supplier i

4. Random Experiment

As previously mentioned, a random experiment is performed to change the weights assigned to the supplier assessment criteria to reflect the dynamic changes in the sustainability requirements of the stakeholders. We design an experiment to randomly generate data in order to analyse the changes in the result. The steps of the experiment are as follows:

Step 1: Generate a random number for each criteria weight of each supplier

Step 2: Determine the weight of each supplier

Step 3: Record weights in the model

Step 4: Decide order allocation and sustainability performance

Step 5: Repeat steps 1 to 4 100 times

Step 6: Document and analyse findings

We develop a decision support system in Excel to determine supplier weight and to carry out the experiment for order allocation to different suppliers.

5. Case Study Data Analysis

Our case study company is a major European buyer. It has operations in 21 countries and has 900 suppliers in 40 countries. It employs more than 37,500 staff dispersed throughout many overseas countries, including Bangladesh. It buys different types of jeans from Bangladesh, Vietnam, India and some other low-cost countries. Each year, it procures a huge volume of clothes from Bangladesh, worth over half a billion USD. At present, it has five listed suppliers in Bangladesh. As the multi-national buyers are under close scrutiny when sourcing from low-cost countries, the case study company faces a dilemma when evaluating and selecting suppliers and determining optimal order allocations based on sustainability performance. The application of a sustainability-focused, multi-criteria fuzzy AHP-QFD approach is quite suitable in this case. Notably, the approach proposed in our research has been affirmed by the decision makers of the case company as a useful tool for overcoming its dilemma. To apply the methodology, a workgroup consisting of four members (three decision makers of the case company working in Bangladesh and an academic specialising in procurement and supply chains) was set up. Decision-maker one is a merchandising manager with 14 years of experience in the industry. Decision-maker two (with seventeen years of experience) deals with procurement and decision-maker three (with nine years of experience) deals with compliance issues. The academic member in the working group is a lecturer in operations and supply chain management having expertise in procurement and sustainable supply chain management.

The data analysis followed the research method described previously and the results are reported as follows.

5.1 Phase 1 results

The content analysis reveals that buyers need to consider several stakeholders' expectations with regard to sustainability concerns. The significant concerns of the case company are listed in Table 3.

(Insert Table 3 about here)

The decision makers expressed their opinions and experiences regarding the sustainability-related compliance of the stakeholders. As an example, one of the decision makers stated: "…*We need to confirm that our suppliers ensure there is a good working environment and the health and safety issues of the workers are addressed*". He also added: "*We monitor our suppliers' plant and check the records to ensure they pay a minimum standard wage to the workers*" and "*We also ask them for child care facilities, good sanitation systems, a medical facility and maternity leave for the workers*…".

The decision makers of the case study company are highly concerned about the sustainability requirements and the consequences of violating sustainability standards.

In this regard, one of the participants stated: "*After the tragic incidents of the factory fire and the building collapse of two garments factories in Bangladesh, we faced serious pressure from consumer groups when importing products from Bangladesh*". He also added that "*Though we do not have any link* *with the supplier responsible for the building collapse, we are under pressure from consumer groups as we source from Bangladesh.*"

The company also undertakes a number of sustainability strategies during procurement. According to the decision maker, these strategies are effective for socially and environmentally responsible procurement. For example, the decision maker said: *"... All suppliers and manufacturers need to show a test report to ensure that goods are lead free, azo free and free from other environmental hazards*…". This expresses the strategic actions of the company during procurement.

This statement affirms the company's strategy of engaging in environmentally responsible purchasing. Similarly, the respondent mentioned other strategies with respect to the sustainable procurement of the company. It was noted that failure to execute the strategies could jeopardize the reputation of the company. Negative reporting about one or two companies could affect the whole industry. Companies, therefore, are conscious of adopting sustainability strategies when procuring from low-cost countries. The decision makers of the case study company reported a number of sustainable procurement strategies which are listed in Table 4.

(Insert Table 4 about here)

Once the stakeholder concerns regarding sustainability and the corresponding sustainable procurement strategies were identified, the next step was undertaken to decide the importance weight of the sustainability requirements. This was performed by asking the decision makers to compare the sustainability requirements in a matrix by adopting the fuzzy AHP scale (as mentioned in Appendix 1). The results from the comparison of the sustainability requirements are shown in Table 5.

(Insert Table 5 here)

Once the AHP comparison of the stakeholders' sustainability requirements was obtained from the Fuzzy-AHP matrices, the crisp values were completed as shown in Table 6. From the crisp values, the final AHP weight of the sustainability requirements was obtained which is shown in the last column of Table 6.

(Insert Table 6 here)

It is observed that the decision makers assigned the highest weight (0.325) to AP (affordable price), followed by a weight of 0.236 to WE (safe working environment). Hence, the economic and social dimensions of sustainability received the highest weights. Interestingly, the lowest weights were assigned to EUR (efficient use of resources) and EI (reducing environmental impact), which is the environmental sustainability dimension.

The next step in the first phase of this research is to understand how stakeholders' sustainability concerns (WHATs) and the sustainable procurement strategies are linked. The opinions of the respondents relating to the WHAT-HOW relationship values are presented in Table 7. The rows of Table 7 indicate the sustainability requirements (WHATs) from Table 3, and the columns indicate the procurement strategies (HOWs) from Table 4. The matrix elements in Table 7 present the WHAT/HOW relationship values in the fuzzy triplet form. As an example, the triplet (6, 7, 8) (intersection of WP and DR1 in Table 6) presents the fuzzy relationship "very strongly" (see Appendix 2), i.e. WP is "very strongly" supported by DR1. Table 7 also shows the relative importance (RI_j) of the procurement strategies (DR_j). It is observed that DR_1 (sourcing products at a competitive price; see table 4), DR_2 (product with a high quality and safety standard) and DR_3 (ensuring socially responsible purchasing) have the highest relative importance. Hence, the economic and social dimensions of the procurement strategies received the highest relative importance in realizing the sustainability requirements of the stakeholders.

(Insert Table 7 here)

5.2 Phase 2 results

In this phase, the decision makers reported the criteria for supplier assessment based on the sustainability perspective, which are shown in Table 8. It is noted that the criteria cover all three dimensions of sustainability (economic, social and environmental). They were then asked to assess the relationships between the procurement strategies and the assessment criteria, i.e. to what extent were the procurement strategies met by the assessment criteria. Table 9 depicts this relationship matrix. It is notable that the rows of Table 9 indicate the procurement strategies (WHATs) derived from Table 4, while the columns present the suppliers' sustainability assessment criteria (HOWs) derived from Table 8. It is also notable that the matrix elements depict the WHAT/HOWs relationship values expressed in the fuzzy triplet form. As an example, the triplet (2, 3, 4) (value corresponding to CP and DR1 in Table 9) presents the fuzzy relationship of “moderately” (see appendix 2), i.e. CP is “moderately” supported by DR1. Note that the first column of Table 9 are the weights of WHATs from Table 7. The RI_j row presents the relative importance scores of the DRs, which is taken as the weights of the WHATs in Table 10. From the RI_j row of Table 9, it is observed that DR3 (safe and hazard-free working environment; see table 8), DR5 (control of banned chemicals, Azo, Amo, lead etc.), DR6 (pollution controlling measures, recycling, water treatment), and DR 9 (price) have the highest importance weights. These cover the social, environmental and economic dimensions of sustainability. It is interesting to note that DR8 (delivery reliability and low lead-time) and DR10 (experience) have the lowest importance weights (see table 9). This is because this international buyer has five suppliers in Bangladesh from which they have sourced before and they are all highly reliable and experienced suppliers of apparel.

(Insert Table 8 and 9 about here)

5.3 Phase 3 results

In phase 3, we determine the score of each supplier in light of the assessment criteria based on the decision makers’ opinion. The performance of the five suppliers in relation to each assessment criterion (relationships between WHATs and HOWs) was analysed (shown in Table 10). The rows in Table 10 show the suppliers’ sustainability assessment criteria (WHATs) derived from Table 8, and the columns show the suppliers of the company (HOWs). The matrix elements depict the WHATs/HOWs relationship in the fuzzy triplet form. As an example, the triplet (2, 3, 4) (value corresponding to SP and S1 in Table 10) shows the fuzzy relationship of “moderately” (see Appendix 2), i.e. SP is “moderately” supported by S1. Note that the first column of Table 10 are the weights of WHATs derived from the previous table. The RIj row presents the relative importance of the suppliers, which is used to prioritise the suppliers.

(Insert Table 10 about here)

The results show that supplier 2 has the highest ranking, followed by supplier 5. They form one group, while suppliers 1, 3 and 4 form another group with similar rankings. Suppliers 2 and 5 seem to be the clear choices for sourcing apparel. However, a careful look into Table 10 reveals strengths and weaknesses for all suppliers. For example, it is noted that supplier 2 scores "very strongly" or above on the criteria SP (standard payments and benefits), HS (health and sanitation), HR (human rights (restricting child labour, forced labour in organization), BC (control of banned chemicals), CQ (conformance quality), EX (experience) and RED (readiness for responding to disaster), i.e. in seven of the twelve criteria (see Tables 8 and 11 and Appendix 2). These criteria cover the economic, social and environmental dimensions of sustainability. Supplier 5 also scores "very strongly" or above in BC, DR, PR, EX, FS and RED, i.e. in six of the twelve criteria (see Tables 8 and 11 and Appendix 2). On the other hand, supplier 1 scores "very strongly" or above in two criteria and suppliers 3 and 4 score "very strongly" or above on one criterion each. Hence, it is plausible that, to maximize sustainability performance, an optimal mix of supplies from different suppliers will be needed. This is revealed in the next phase.

5.4 Phase 4 Results

As previously discussed, the company decision makers provided the necessary information on the procurement policy of the company. They reported that men's jeans are the most widely sourced item from Bangladeshi suppliers. Depending on demand, the company sources from 1,200,000 to 2,200,000 jeans (of specific designs) in a particular planning period. They also reported that the unit prices of the product from the five suppliers are 12, 11, 13, 10 and 12 USD respectively and last year their sourcing from Bangladesh was altogether 27,500,000 USD. They assume next year's budget will also be around 27,500,000 USD. The decision makers also confirmed that they do not want to place orders over 500,000 pieces with one particular supplier to avoid any risk associated with a single supplier and the minimum quantity ordered from any supplier is 100,000 as a part of the contractual agreement. The five suppliers have the following capacity limits: 3,500,000, 3,000,000, 5,000,000, 3,000,000 and 4,000,000for suppliers 1, 2, 3, 4 and 5, respectively. Once the data necessary for optimisation is gathered, a final attempt to find the optimal order allocation by solving a dynamic optimization problem is undertaken. The objective function here is to maximize the contribution of each supplier in terms of sustainability performance which depends on the supplier weight (R_i), which is again dependent on the criteria weight of each supplier and the quantity of supplies (x_i). The optimization problem is formulated as follows:

$$\text{Maximize sustainability performance } (Z) = \sum_{i=1}^{n} R_i x_i \tag{11}$$

Subject to

$$x_1 + x_2 + x_3 + x_4 + x_5 = N \qquad (12)$$

$$12\,x_1 + 11\,x_2 + 13\,x_3 + 10\,x_4 + 12\,x_5 \leq 275{,}00000 \qquad (13)$$

$$x_i \leq 50,0000;\ i = 1,2,\ldots,5 \qquad (14)$$

$$x_i \geq 10,0000;\ i = 1,2,\ldots,5 \qquad (15)$$

$$x_1 \leq 350,0000 \qquad (16)$$

$$x_2 \leq 300,0000 \qquad (17)$$

$$x_3 \leq 500,0000 \qquad (18)$$

$$x_4 \leq 300,0000 \qquad (19)$$

$$x_5 \leq 400,0000 \qquad (20)$$

$$x_i \geq 0;\ i = 1,2,\ldots,5 \qquad (21)$$

Note that to solve the above optimization problem, the R_i's are taken as the relative importance RI's from Table 10 (the last row). However, as can be observed from phases 1 to 3, when the sustainability requirements of the stakeholders change, the R_i's will change. We hence conducted an experiment by randomly changing the R_i's and the demand for apparel (between 1200000 to 2200000 pieces). The following section presents the results.

5.5 Random experiment and analysis

In real time, criteria weights and demand can change from period to period based on the stakeholders' expectations. To address this issue, we generated 100 random cases by changing the criteria weight of each supplier and the demand per period. To illustrate, we present five examples in Table 11. The detailed results can be found in Appendix 4. We observe from Table 11 that, in general, allocation to the suppliers varies in accordance with the supplier weights to maximize the sustainability performance, but not in the linear proportion of the suppliers' weights. The optimization model allocates the quantities to various suppliers to maximize the sustainability performance subject to various constraints. We also observe that a higher demand leads to an eventual higher sustainability performance.

It is noted that demand plays a significant role in allocating quantities to various suppliers. For example, consider instances 53 and 72 in Appendix 4. The supplier weights (R_i values) of these two instances are similar to the supplier weights in Table 11, i.e. suppliers 2 and 5 have the highest weights, forming one group and suppliers 1, 3 and 4 have similar weights, forming another group. The optimal allocation for instance 53 is 100000, 500000, 100000, 409670 and 500000 respectively for suppliers 1, 2, 3, 4 and 5 for a demand of 1609670 pieces. However, for instance 72, the optimal allocation becomes 100000, 500000, 489642, 500000 and 500000 respectively for suppliers 1, 2, 3, 4 and 5 for a demand of 2089642 pieces. It is observed that the allocation to supplier 3 drastically changes when demand increases substantially.

(Insert Table 11 here)

To produce Appendix 4, we generated a random number for the weight of each criterion for each supplier. Then, we determined the supplier weight based on the random number generated for 100 instances. We observed that the maximum and minimum values of the sustainability performance are 452,482.3 and 247,925.9 respectively with an average of 351,512.1 and a standard deviation of 57,097.2. We also observed the random variation of demand, which is shown in Figure 2. From the experiment, the maximum and minimum values of demand are 2,198,649 and 1,205,462 respectively with an average of 1683,001.9 and a standard deviation of 289,941.9.

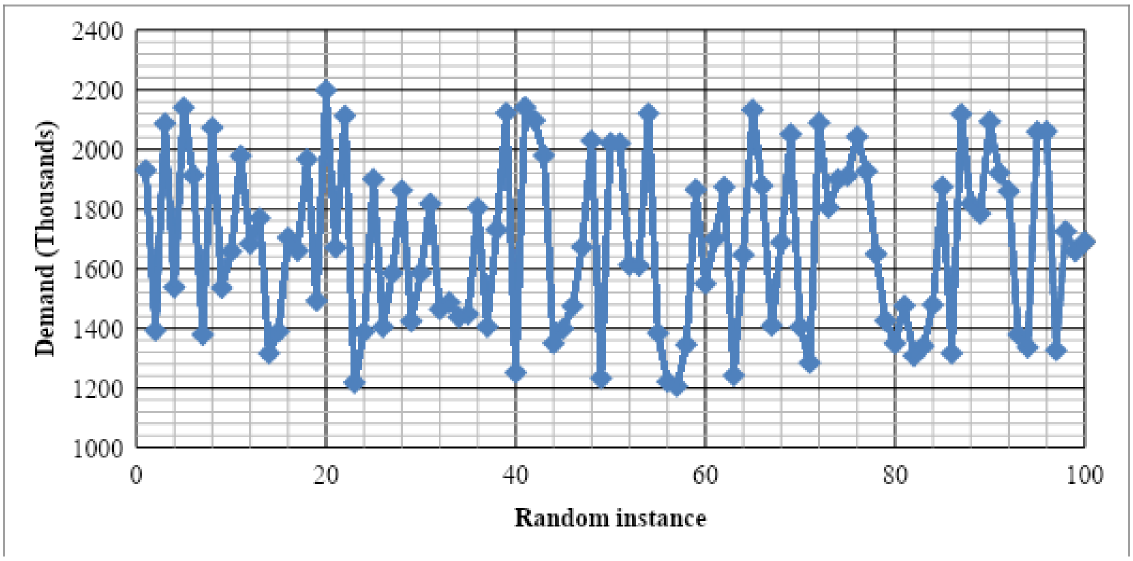

Fig. 2: Demand for different random instances

Figure 3 shows how order allocation against each supplier and sustainability performance change with a change in demand. We observed that order allocation is always at the maximum level (500,000 units) for supplier 1, as this supplier has the highest weight. Then, with increasing demand, order allocation increases for suppliers 5, 3, 2 and 4 according to the higher value of supplier weight. Hence, the bottom line is supplier allocation is sensitive to both supplier weights and product demand.

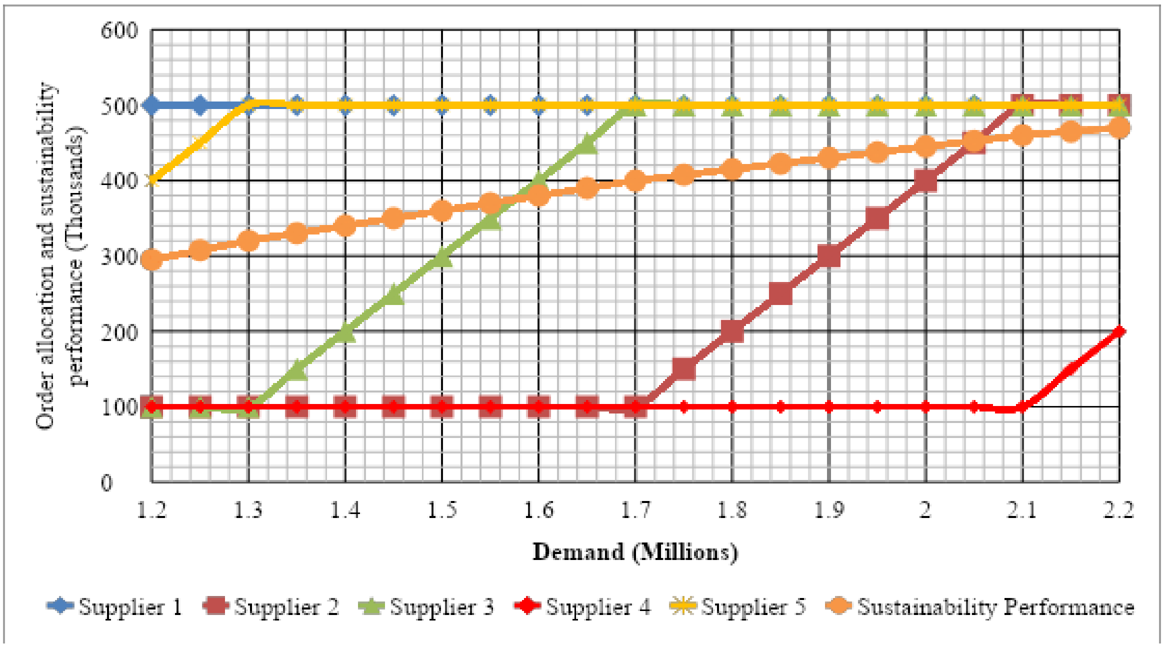

Fig. 3: Order allocation and performance with changing demand

6. Discussions

This section first discusses the results of this study based on the research questions. To address research question 1, six sustainability requirements of the stakeholders were identified, as shown in Table 3. Of the sustainability requirements, affordable price, working environment and fair wages are identified as the most important stakeholder requirements (see Table 6).

Suppliers and focal companies need to comply with the sustainability requirements of the stakeholders as failure to do so is a major cause of sustainability risk. Therefore, sourcing from low-cost countries is subject to severe international scrutiny due to past violations of social and environmental standards (Islam and Deegan 2008). The decision makers' comments revealed that, although the stakeholders (consumers, consumer groups, government agency, NGOs) pressure companies to comply with sustainability standards, most consumers want products at cheaper prices which is at odds with sustainability (Ageron et al., 2012, Barve and Muduli, 2012). Considering these constraints, companies need to establish procurement strategies that can optimize the sustainability requirements of stakeholders. In this study, we identified the sustainable procurement strategies of the company, which correspond to the stakeholders' requirements (see Table 4). It was revealed that the case study company has established nine procurement strategies to meet the sustainability requirements of the stakeholders. We then investigated the impact of the company's procurement strategies on the stakeholders' sustainability requirements, the results of which are shown in Table 7. Table 7 shows the relationship between the sustainability requirements and procurement strategies of the firm in fuzzy triplets. It is observed that the highest relationship triplet is (8, 9, 10) between some sustainability requirements and procurement strategies (for example, between WP and DR3). However, some low relationship triplets (2, 3, 4) also exist.

We found that, of the nine procurement strategies, DR2 (product with high quality and safety standards), DR1 (sourcing at a competitive price), DR3 (ensuring socially responsible purchasing) and DR7 (sourcing products that meet customer satisfaction) are the most effective strategies for meeting the sustainability requirements. Again, it was revealed that cost is a strategic factor in procurement decisions. High quality products that meet safety standards and ensure social responsibility tend to be more expensive. However, companies need to be able to manage the trade-off between cost and quality efficiently.

To address research question 2, we identified 12 criteria for supplier assessment (see Table 8) corresponding to the procurement strategies. Table 9 presents the relationship between the procurement strategies and the assessment criteria in fuzzy triplets. The RI_j row of Table 9 shows the derived weights of the assessment criteria. DR9 (price), DR3 (safe and hazard-free working environment) and DR5 (control of banned chemicals) are the most important criteria contributing to the company's sustainable procurement strategies. As maintaining competitive pricing is one of the most important factors, companies concentrate on the price of the suppliers' products provided that they also take into consideration the social and environmental factors. However, too much concentration on cheaper products results in poor performance in terms of social and environmental responsibility. Therefore, companies need to rethink the degree to which they will focus on price when sourcing from low-cost countries. Otherwise, sustainability risk issues such as the violation of social and environmental standards will occur concurrently and ultimately make the company unsustainable.

To address research question 3, we determined the ranking of the five suppliers based on their contribution to each assessment criteria. Table 10 shows the relationship matrix between the supplier's assessment criteria and the five suppliers in fuzzy triplets. The RI_j row of Table 10 shows the ranking of the suppliers. Suppliers 2 and 5 had the highest relative ranking according to the assessment criteria. The scores of these suppliers were high for very important assessment criteria such as price, quality, hazard and safety, and control of banned chemicals. We then developed the optimization model (see Equations 11 -21) to determine the optimal order quantities for each supplier. However, we present the optimization results using random experiments to address research question 4.

Finally, to address research question 4, by means of dynamic optimization, we determine the optimal supply portfolio of suppliers based on their scores with respect to the sustainability assessment criteria. As previously discussed, the criteria weight and demand can change from period to period based on the stakeholders' expectations. We generated 100 random cases by changing the criteria weight of each supplier and demand per period. For a sample representation, the results of five arbitrarily-selected instances are presented in Table 11. The detailed results can be found in Appendix 4. We observed that, with changes in demand and criteria weight over time, the order allocation and total sustainability performance are changed. In real-life cases, if the criteria weight and total demand changes due to changes in stakeholder perceptions, a decision maker can use this model to find the optimal order allocation and the suppliers' sustainability performance.

7. Implications and conclusions

This study establishes a decision support approach for suppliers' sustainability assessment and order allocation to the suppliers while simultaneously addressing changes in stakeholders' sustainability requirements. The proposed decision support approach considers the voice of stakeholders and the voice of the company in order to translate the stakeholders' sustainability requirements to sustainable procurement strategies of the company to supplier assessment criteria and ranking the suppliers. Relying on the dynamic capability theory, it also determines the optimal supply portfolio based on the changing scores of the suppliers on the sustainability assessment criteria. Previous studies on supplier selection focused mainly on cost and the operational aspects of the suppliers, while a sustainability-focused, multi-criteria decision model incorporating the voice of both stakeholders and the company has not been adequately explored. Although Dai and Blackhurst (2012) suggest a framework for a sustainability-focused, multi-criteria decision model incorporating the voice of both the stakeholders and the company, their study fails to develop a framework that can help managers in the face of constantly changing stakeholders' sustainability requirements and determine a relevant optimal supply portfolio. Therefore, the decision support approach developed in this study is unique and significantly contributes to the existing literature on supplier assessment.

7.1. Theoretical Implications

This study has significant theoretical implications. This is one of the few studies which considers all three sustainability dimensions (economic, social and environmental) in a systematic way. It focusses on the micro-foundations of the dynamic capability view. Teece (2007) states that the micro-foundations of DCV consist of various skills, processes and procedures which need to be developed by allocating resources to effectively address the dynamic changes in the environment. To this end, this study proposes an interlinked QFD process (Hauser and Clausing 1988) as a micro-foundation, which translates the stakeholders' requirements into an optimal portfolio of suppliers and corresponding optimal order allocations. This ensures maximum sustainability while sourcing products from low cost destination. In an experimental setup, this study also shows how the order allocation to the chosen suppliers changes due to changes in the suppliers' priority weights as a result of changes in stakeholders' sustainability requirements. We consider this to be the most significant theoretical implications of our research.

7.2. Managerial Implications

This study has significant managerial implications as well. The proposed decision support approach is an effective tool for supply chain managers to evaluate suppliers and their supply portfolio according to the changing nature of stakeholders' sustainability requirements. From the sustainability requirements of the stakeholders, it first develops ranking weights of the chosen suppliers followed by optimal order allocations. As the outsourcing of apparel products from low cost countries is under close scrutiny by stakeholders, apparel supply chain managers will greatly benefit from the framework developed in this study. It will also assist procurement managers to identify changes in the priorities of stakeholders' sustainability requirements over time and any resulting changes in supply portfolios. This is one of the major applications of our proposed decision support tool, which will help the decision makers to understand the dynamics of the changes in stakeholders' sustainability requirements and thus will help them to make requisite decisions. This model will also help the chain managers of apparel supplies to ensure the long-term sustainability of supplies from low cost countries, and it can be extended to address stakeholders' sustainability requirements in other contexts also.

7.3. Overall Contributions, Limitations and Future Directions

Compared to previous studies, our research makes the following contributions. First, a unique decision support model for sustainability-focused supplier assessment has been developed by adopting dynamic optimization integrated fuzzy-AHP and the interlinked QFD method. Secondly, it addresses the call from stakeholders to translate their sustainability requirements into sustainable procurement strategies. It also uses supplier assessment criteria to determine the best suppliers in light of the relevant sustainability criteria. Thirdly, by applying dynamic optimization, it determines the portfolio of supplies from the suppliers which supports the relevant procurement policy (multiple suppliers) of the company and addresses changes in the sustainability requirements of the stakeholders. The framework developed in this study is quite new and advances the knowledge regarding supplier assessment. It also has substantial managerial value as supply chain managers will be able to incorporate the voice of the stakeholders and the company to assess the suppliers based on sustainability criteria. It will also enable managers to determine the optimal supply portfolio of the suppliers. The portfolio approach will also assist decision makers to address the dynamic changes of stakeholders' sustainability requirements. Further, managers who face challenges associated with sourcing from low-cost countries will benefit significantly from this study.

However, this study also has some shortcomings which offer opportunities for future research. The study was limited to one case company. To demonstrate its external validity, this research needs to be replicated in other apparel companies. Moreover, the applicability of the model can also be tested in other industries to determine its validity in different contexts. On the theoretical side, the study uses only one objective (maximizing sustainability requirements) in order to determine the optimal allocation. Multi-objective optimization should be used in future research to maximize sustainability requirements and minimize risks at the same time in order to determine the optimal allocation to suppliers along the lines of Moheb-Alizadeh and Handfield (2019) using the interactive methodology of Chowdhury and Quaddus (2015).

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List of tables

Table 1: Comparison of closely related papers in the literature

Reference	Sustainability in supplier selection	Alignment with organization	MC DM	Optimized Order allocation	Dynamic requirements of stakeholders	Integration of theory
This study	✓	✓	✓	✓	✓	✓
Shaw et al. 2012	✓		✓			
Ravindran et al. 2010			✓			
Levary 2007			✓			
Amid et al. 2006			✓	✓		
Kahraman et al. 2003			✓			
Gencer and Gürpinar, 2007			✓			
Kilic, 2013			✓	✓		
Pazhani, Ventura and Mendoza, 2016			✓	✓		
Sodenkamp, Tavana and Di Caprio, 2016			✓	✓		
Lee et al., 2009	✓		✓	✓		
Kannan, Govindan and Rajendran, 2015	✓	✓	✓	✓		
Büyüközkan and Çifçi, 2011	✓		✓			
Xia and Wu, 2007			✓			
Demirtas and Üstün, 2008			✓	✓		
Verma and Pullman, 1998			✓			
Banaeian et al., 2018	✓		✓			
Hamdan and Cheaitou, 2017	✓	✓	✓	✓		
Ng, 2008			✓			
Li, Yamaguchi and Nagai, 2007			✓	✓		
Ghodsypour and O'Brien, 2001			✓	✓		
Amid, Ghodsypour and O'Brien, 2006	✓		✓			
Bai and Sarkis, 2010	✓		✓	✓		
Mafakheri, Breton and Ghoniem, 2011			✓	✓		
Goebel et al., 2012	✓		✓			
Jadidi, Zolfaghari and Cavalieri, 2014			✓	✓		
Sarkis and Dhavale, 2015	✓	✓	✓			
Scott et al., 2015		✓	✓	✓		
Ghodsypour and O'Brien, 1998			✓	✓		
Lee, 2009			✓	✓		

Boran et al., 2009			✓			
Sanayei, Farid Mousavi and Yazdankhah, 2010			✓	✓		
Amin, Razmi and Zhang, 2011			✓			
Shaw et al., 2012		✓	✓	✓		
Kannan et al., 2013	✓		✓	✓		
Trapp and Sarkis, 2016	✓		✓	✓		
Luthra et al., 2017	✓	✓	✓	✓		
Yazdani et al., 2017	✓		✓	✓		
Gupta and Barua, 2017	✓		✓	✓		
Galankashi, Helmi and Hashemzahi, 2016			✓			
Prasannavenkatesan and Goh, 2016			✓	✓		
Dulmin and Mininno, 2003			✓			
Reuter, Goebel and Foerstl, 2012	✓		✓			
Amindoust et al., 2012	✓		✓			
Azadnia et al., 2012	✓		✓			
Ghadimi and Heavey, 2014	✓		✓			
Galankashi et al., 2015	✓	✓	✓			
Mani, Agrawal and Sharma, 2014	✓	✓	✓			
Bhutta and Huq, 2002			✓			
Jayaraman, Srivastava and Benton, 1999			✓	✓		
Kannan and Tan, 2002		✓	✓			
Azadnia, Saman and Wong, 2014	✓		✓	✓		
Chan, 2003			✓			
Garoma and Diriba, 2014			✓			
Kuo and Lin, 2012			✓			
Dursun and Karsak, 2013			✓			
Hsu et al., 2013	✓		✓	`		
Shyur and Shih, 2006	✓		✓			
Hsu, Wang and Tzeng, 2012	✓		✓			
Zouggari and Benyoucef, 2012			✓	✓		
Önüt, Kara and Işik, 2009			✓			
Vinodh, Anesh Ramiya and Gautham, 2011			✓			
Dalalah, Hayajneh and Batieha, 2011			✓			
Büyüközkan and Çifçi, 2012	✓	✓	✓			
Wang, Cheng and Huang, 2009			✓			

Lima Junior, Osiro and Carpinetti, 2014			✓			
Ghorbani, Mohammad Arabzad and Shahin, 2013			✓			
Yazdani, 2014	✓		✓			

Table 2: Overall research design

Phases	Research Objectives	Data collection	Data analysis
Phase 1	Identifying the sustainability requirements of stakeholders (Consumers, consumer groups, NGOs, and government agency), the corresponding procurement strategies and to what extent the procurement strategies satisfy the sustainability requirements (also, known as relationship between the WHATs and HOWs in QFD literature).	Review of relevant literature and semi-structured questionnaire to collect data on sustainability requirements as well as the procurement strategies of the case company. Then structured questionnaire is used for determining the relationship between the sustainability requirements and procurement strategies.	Content analysis of literature search and analysis of data from field study then Fuzzy-AHP-QFD is used for determining the importance of each sustainability requirement followed by the relationship between the sustainability requirements and the procurement strategies.
Phase 2	Identifying the supplier assessment criteria corresponding to procurement strategies.	Semi-structured interview from the case company decision maker about the supplier assessment criteria of the case company corresponding to the procurement strategies. Then structured questionnaire is used to determine the relationship between the procurement strategies and supplier assessment criteria	Content analysis of literature search and analysis of data from field study to determine supplier assessment criteria. Then Fuzzy-QFD is used for determining the relationship between the procurement strategies and supplier assessment criteria.
Phase 3	Ranking the suppliers based on fuzzy suitability index	The decision makers evaluate five of their suppliers based on the assessment criteria.	Fuzzy suitability index is developed to determine the score and to rank the suppliers based on the scores.
Phase 4	Determining optimal quantity of the supplies	The scores of the suppliers based on the assessment criteria.	Multi-objective optimization
	Population	Ready- made garments supply chain of Bangladesh	
	Case Company	A major European buyer.	

Table 3: Sustainability requirements of the stakeholders

1. Fair wages and payment to workers (WP)
2. Safe working environment (WE)
3. No Child labour (CL)
4. Reducing environmental impact (EI)
5. Efficient use of resources (EUR)
6. Affordable price (AP)

Table 4: Sustainable procurement strategies

Sourcing products at competitive price (DR1)
Product with high quality and safety standard (DR2)
Ensuring socially responsible purchasing (DR3)
Ensuring environmentally responsible purchasing (DR4)
Developing green supply chain (DR5)
Buying new and innovative products (DR6)
Sourcing products that ensure customer satisfaction (DR7)
Keeping alternative suppliers (DR8)
Sourcing from responsive supplier (DR9)

Table 5: Fuzzy-AHP comparison matrices for sustainability requirements

	WP	WE	CL	EI	EUR	AP
WP	(1,1,1)	(.33,.5,1)	(.5, 1,1)	(2,3,4)	(3,4,5)	(.25,.33,.5)
WE		(1,1,1)	(1,2,3)	(3,4,5)	(2,3,4)	(.33,.5,1)
CL			(1,1,1)	(1,2,3)	(2,3,4)	(.25,.33,.5)
EI				(1,1,1)	(1,2,3)	(.25, .33, .5)
EUR					(1,1,1)	(.20, .25, .33)
AP						(1,1,1)

Where, WP= Fair wages and payment to workers, WE= Safe working environment, CL= No Child labour, EI=Reducing environmental impact, EUR=Efficient use of resource and AP= Affordable price.

Table 6: Crisp comparison matrices of Fuzzy-AHP weight

	WP	WE	CL	EI	EUR	AP	Weight
WP	1	0.583	0.875	3	4	0.353	.156
WE		1	2	4	3	0.583	.236
CL			1	2	3	0.353	.149
EI				1	2	0.353	.079
EUR					1	0.26	.056
AP						1	.325

Note: Inconsistency ratio for AHP weight calculation = 0.04

Table 7: Relationship between sustainability requirements and procurement strategies

	Weight (WHAT)	DR1	DR2	DR3	DR4	DR5	DR6	DR7	DR8	DR9
WP	0.156	(6,7,8)	(4,5,6)	(8,9,10)	(4,5,6)	(6,7,8)	(0,1,2)	(6,7,8)	(2,3,4)	(4,5,6)
WE	0.236	(4,5,6)	(8,9,10)	(8,9,10)	(2,3,4)	(6,7,8)	(0,1,2)	(4,5,6)	(2,3,4)	(4,5,6)
CL	0.149	(4,5,6)	(6,7,8)	(6,7,8)	(0,1,2)	(4,5,6)	(0,1,2)	(4,5,6)	(4,5,6)	(4,5,6)
EI	0.079	(2,3,4)	(4,5,6)	(6,7,8)	(8,9,10)	(8,9,10)	(2,3,4)	(2,3,4)	(2,3,4)	(2,3,4)
EUR	0.056	(6,7,8)	(2,3,4)	(4,5,6)	(6,7,8)	(6,7,7)	(2,3,4)	(6,7,8)	(2,3,4)	(2,3,4)
AP	0.325	(8,9,10)	(6,7,8)	(2,3,4)	(6,7,8)	(2,3,4)	(2,3,4)	(6,7,8)	(6,7,8)	(6,7,8)
AIj		(5.918, 6.571, 7.572)	(5.784, 6.785, 7.786)	(5.378, 6.379, 7.38)	(4.014, 5.015, 6.016)	(4.566, 5.567, 6.658)	(0.92, 1.921, 2.922)	(4.92, 5.921, 6.922)	(3.6, 4.601, 5.602)	(4.384, 5.385, 6.386)
Crisp value		6.658	6.785	6.38	5.02	5.57	1.92	5.92	4.6	5.385
RIj		0.138	0.141	0.132	0.104	0.115	0.039	0.123	0.095	0.112

Where, WP= Fair wages and payment to workers, WE= Safe working environment, CL= No Child labour, EI=Reducing environmental impact, EUR=Efficient use of resource and AP= Affordable price.

Table 8: Suppliers' sustainability assessment criteria

Supplier selection criteria
DR1-Standard payments and benefits (SP)
DR2- Health and Sanitation (HS)
DR3- Safe and hazard free working environment (SF)
DR4-Human rights (Restricting child labour, force labour in organization (HR)
DR5-Control of banned chemical (Azo, Amo, Lead etc.) (BC)
DR6-Pollution controlling measures (Recycling, water treatment) (PC)
DR7-Conformance quality (CQ)
DR8-Delivery reliability and low lead time (DR)
DR9-Price (PR)
DR10-Experience (EX)
DR11-Financial strength of the company (turn over) (FS)
DR12-Readiness for responding to disaster (safety training, security system) (RED)

Table 9: Relationship between procurement strategies and supplier assessment criteria

	Weight (WHAT)	DR1	DR2	DR3	DR4	DR5	DR6	DR7	DR8	DR9
WP	0.156	(6,7,8)	(4,5,6)	(8,9,10)	(4,5,6)	(6,7,8)	(0,1,2)	(6,7,8)	(2,3,4)	(4,5,6)
WE	0.236	(4,5,6)	(8,9,10)	(8,9,10)	(2,3,4)	(6,7,8)	(0,1,2)	(4,5,6)	(2,3,4)	(4,5,6)
CL	0.149	(4,5,6)	(6,7,8)	(6,7,8)	(0,1,2)	(4,5,6)	(0,1,2)	(4,5,6)	(4,5,6)	(4,5,6)
EI	0.079	(2,3,4)	(4,5,6)	(6,7,8)	(8,9,10)	(8,9,10)	(2,3,4)	(2,3,4)	(2,3,4)	(2,3,4)
EUR	0.056	(6,7,8)	(2,3,4)	(4,5,6)	(6,7,8)	(6,7,7)	(2,3,4)	(6,7,8)	(2,3,4)	(2,3,4)
AP	0.325	(8,9,10)	(6,7,8)	(2,3,4)	(6,7,8)	(2,3,4)	(2,3,4)	(6,7,8)	(6,7,8)	(6,7,8)
AIj		(5.918, 6.571, 7.572)	(5.784, 6.785, 7.786)	(5.378, 6.379, 7.38)	(4.014, 5.015, 6.016)	(4.566, 5.567, 6.658)	(0.92, 1.921, 2.922)	(4.92, 5.921, 6.922)	(3.6, 4.601, 5.602)	(4.384, 5.385, 6.386)
Crisp value		6.658	6.785	6.38	5.02	5.57	1.92	5.92	4.6	5.385
RIj		0.138	0.141	0.132	0.104	0.115	0.039	0.123	0.095	0.112

Table 10: Supplier assessment and ranking

	Weight (WHAT)	S1	S2	S3	S4	S5
SP	0.088	(2,3,4)	(6,7,8)	(4,5,6)	(2,3,4)	(4,5,6)
HS	0.062	(1,2,3)	(7,8,9)	(3,4,5)	(3,4,5)	(2,3,4)
SF	0.113	(4,5,6)	(5,6,7)	(4,5,6)	(2,3,4)	(4,5,6)
HR	0.064	(3,4,5)	(6,7,8)	(5,6,7)	(4,5,6)	(5,6,7)
BC	0.11	(6,7,8)	(7,8,9)	(5,6,7)	(6,7,8)	(6,7,8)
PC	0.104	(2,3,4)	(4,5,6)	(2,3,4)	(2,3,4)	(3,4,5)
CQ	0.097	(4,5,6)	(6,7,8)	(3,4,5)	(4,5,6)	(4,5,6)
DR	0.058	(4,5,6)	(5,6,7)	(4,5,6)	(5,6,7)	(7,8,9)
PR	0.115	(6,7,8)	(5,6,7)	(6,7,8)	(5,6,7)	(7,8,9)
EX	0.054	(4,5,6)	(6,7,8)	(2,3,4)	(3,4,5)	(6,7,8)
FS	0.078	(3,4,5)	(5,6,7)	(3,4,5)	(4,5,6)	(7,8,9)
RED	0.06	(4,5,6)	(7,8,9)	(4,5,6)	(3,4,5)	(6,7,8)
AIj		(3.75, 4.815, 5.714)	(5.678,6.681, 7.684)	(3.863, 4.866, 5.869)	(3.565, 4.63, 5.679)	(5.049, 6.052, 6.591)
Crisp value		4.774	6.681	4.866	4.626	5.936
RIj		0.178	0.249	0.181	0.172	0.221

SP= Standard payment, HS= Health and Sanitation, SF= Safe and hazard free working environment, HR= Human rights, BC= Control of banned chemical, PC= Pollution controlling measures, = Conformance quality, DR= Delivery reliability and low lead time, PR= Price, EX= Experience, FS= Financial strength of the company, RED= Readiness for responding to disaster

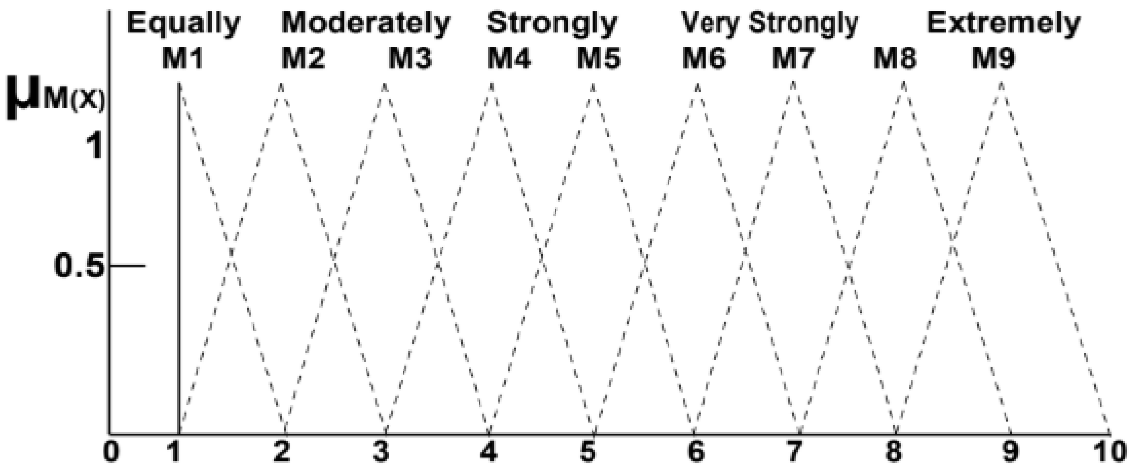
Table 11: Five sample instances

Instance number (from Appendix 4)	Demand	Supplier weight based on criteria weight					Sustainability performance
		Supplier 1	Supplier 2	Supplier 3	Supplier 4	Supplier 5	
2	1392526	0.2248	0.1787	0.1895	0.1980	0.2090	291833.9
9	1535366	0.1979	0.1918	0.2018	0.2280	0.1805	318488.8
16	1704085	0.2009	0.1815	0.2263	0.2028	0.1885	352761.7
41	2141602	0.1855	0.1881	0.1966	0.2249	0.2048	433513.5
50	2021470	0.2039	0.2023	0.2078	0.1693	0.2166	416387.4

Appendix-1 Crisp and Fuzzy AHP scales

Linguistic variables	AHP scale	Fuzzy AHP scale	
		TFNs	Reciprocal TFNs
Equally important (M1)	1	(1,1,1) if diagonal (1,1,2) otherwise	(1,1,1) (1/2,1,1)
Important (M2)	2	(1,2,3)	(1/3,1/2,1)
Moderately more important (M3)	3	(2,3,4)	(1/4,1/3,1/2)
Intermediate (M4)	4	(3,4,5)	(1/5,1/4,1/3)
Strongly more important (M5)	5	(4,5,6)	(1/6,1/5,1/4)
Intermediate (M6)	6	(5,6,7)	(1/7,1/6,1/5)
Very strongly more important (M7)	7	(6,7,8)	(1/8,1/7,1/6)
Intermediate (M8)	8	(7,8,9)	(1/9,1/8,1/7)
Extremely more important (M9)	9	(8,9,10)	(1/10,1/9,1/8)

Appendix 2: The membership function of the TFNs for δ=1, and α=0.5.



Appendix 3: Sustainability requirements of the stakeholders

Variable	References
Wages and benefits	Islam and Deegan, (2008); Chowdhury et al. (2019); Mahmud and Kabeer, (2003); Minimum Wage Fixing Convention, (1970).
Hazard and safety	Islam and Deegan, (2008); Emmelhainz, (1999); Chowdhury et al. (2019).
Health and sanitation	Islam and Deegan, (2008); Emmelhainz, (1999); Mahmud and Kabeer, (2003).
Human rights	Vugrin, Warren, and Ehlen (2011); Emmelhainz, (1999); Mahmud and Kabeer, (2003).
Restricting child labour and forced labour	Islam and Deegan, (2008); Emmelhainz, (1999); Chowdhury et al. (2019); Mahmud and Kabeer, (2003)
Pollution (air, water and soil)	Chowdhury et al. (2019); Gripsrud, Jahre, and Persson (2006), Epstein and Wisner, (2001); Chowdhury et al (2012).
Recycling wastes	Epstein and Wisner, (2001); GRI (2011).
Product safety and restricting the use of hazardous material	Islam and Deegan (2008); Gripsrud, Jahre, and Persson (2006).
Complying environmental legislation	Chowdhury et al. (2019); Cooper and Ellram(1993)
Sales and business volume	Khan et al. (2016); Cooper and Ellram(1993)
Delivery lead time	Lefebvre and Miller (2006); Bateman and David (2002); Hadjikhani (2005)

Meeting quality, cost and other specification	Chowdhury et al. (2019).
Efficient and updated machinery and technology	Aragón-Correa & Sharma (2003)
Monitoring the social performance of suppliers	Epstein and Wisner (2001)
Social and environmental certification and audit	Emmelhainz (1999); Giunipero et al. (2008).

Appendix 4: Detailed results from random experiment

Instance number	R_1	R_2	R_3	R_4	R_5	Demand	x_1	x_2	x_3	x_4	x_5	Sustainability performance
1	0.247	0.215	0.171	0.221	0.147	1930608	500000	500000	330608	500000	100000	412312.6
2	0.225	0.179	0.190	0.198	0.209	1392526	500000	100000	100000	192526	500000	291833.9
3	0.179	0.207	0.181	0.216	0.217	2086940	100000	500000	486940	500000	500000	425955.2
4	0.204	0.197	0.220	0.194	0.184	1537506	500000	337506	500000	100000	100000	316524.8
5	0.190	0.208	0.208	0.176	0.217	2140628	500000	500000	500000	140628	500000	436585.5
6	0.191	0.170	0.226	0.221	0.192	1912487	312487	100000	500000	500000	500000	396268.2
7	0.185	0.187	0.202	0.182	0.243	1378695	100000	178695	500000	100000	500000	292879.0
8	0.226	0.213	0.173	0.214	0.175	2072959	500000	500000	100000	500000	472959	426214.0
9	0.198	0.192	0.202	0.228	0.181	1535366	335366	100000	500000	500000	100000	318488.8
10	0.187	0.240	0.156	0.209	0.208	1657691	100000	500000	100000	500000	457691	354126.8
11	0.177	0.185	0.259	0.159	0.220	1978419	378419	500000	500000	100000	500000	414778.3
12	0.204	0.236	0.171	0.167	0.223	1684396	484396	500000	100000	100000	500000	361717.8
13	0.193	0.189	0.208	0.196	0.213	1769414	169414	100000	500000	500000	500000	360411.3
14	0.189	0.243	0.186	0.193	0.188	1316082	116082	500000	100000	500000	100000	277758.8
15	0.203	0.179	0.187	0.238	0.194	1389600	500000	100000	100000	500000	189600	293595.4
16	0.201	0.181	0.226	0.203	0.189	1704085	500000	100000	500000	500000	104085	352761.7
17	0.125	0.247	0.189	0.227	0.212	1660529	100000	500000	100000	500000	460529	365794.6
18	0.185	0.185	0.206	0.203	0.222	1967667	100000	367667	500000	500000	500000	401707.2
19	0.208	0.170	0.169	0.231	0.222	1492521	292521	100000	100000	500000	500000	321253.8
20	0.158	0.202	0.198	0.211	0.231	2198649	198649	500000	500000	500000	500000	452482.4
21	0.209	0.176	0.224	0.235	0.156	1671208	471208	100000	500000	500000	100000	361046.4
22	0.200	0.219	0.238	0.164	0.180	2113127	500000	500000	500000	113127	500000	436625.5
23	0.150	0.212	0.216	0.234	0.188	1217781	100000	100000	417781	500000	100000	262101.3
24	0.167	0.207	0.224	0.200	0.201	1388118	100000	500000	500000	100000	188118	290408.2
25	0.196	0.220	0.186	0.199	0.199	1900066	300066	500000	100000	500000	500000	386387.2
26	0.160	0.202	0.225	0.224	0.189	1404318	100000	204318	500000	500000	100000	300396.2
27	0.234	0.188	0.149	0.229	0.200	1585219	500000	100000	100000	500000	385219	342288.5
28	0.188	0.229	0.203	0.192	0.187	1863004	263004	500000	500000	500000	100000	380498.8
29	0.189	0.206	0.222	0.177	0.206	1424219	100000	500000	500000	100000	224219	296651.3
30	0.192	0.185	0.207	0.205	0.211	1586574	100000	100000	500000	386574	500000	326088.2
31	0.187	0.213	0.196	0.219	0.185	1817481	217481	500000	500000	500000	100000	373425.0
32	0.150	0.223	0.187	0.195	0.244	1463922	100000	500000	100000	263922	500000	319046.7
33	0.186	0.219	0.162	0.224	0.208	1486610	100000	500000	100000	500000	286610	316233.7
34	0.211	0.202	0.186	0.206	0.195	1437407	500000	237407	100000	500000	100000	294413.9

35	0.170	0.165	0.218	0.227	0.219	1447479	100000	100000	247479	500000	500000	310619.2
36	0.222	0.239	0.175	0.162	0.201	1804358	500000	500000	204358	100000	500000	383329.2
37	0.159	0.188	0.237	0.212	0.203	1405689	100000	100000	500000	500000	205689	301198.2
38	0.177	0.169	0.237	0.225	0.193	1731150	131150	100000	500000	500000	500000	367132.3
39	0.200	0.226	0.186	0.206	0.181	2122668	500000	500000	500000	500000	122668	431663.5
40	0.145	0.206	0.224	0.199	0.226	1251562	100000	100000	451562	100000	500000	269164.5
41	0.186	0.188	0.197	0.225	0.205	2141602	141602	500000	500000	500000	500000	433513.5
42	0.234	0.218	0.158	0.204	0.185	2097299	500000	500000	100000	500000	497299	436152.4
43	0.226	0.199	0.205	0.187	0.184	1980022	500000	500000	500000	380022	100000	404122.2
44	0.192	0.195	0.243	0.184	0.186	1350004	150004	500000	500000	100000	100000	284754.7
45	0.198	0.212	0.165	0.220	0.206	1399060	100000	500000	100000	500000	199060	293067.3
46	0.158	0.217	0.216	0.207	0.202	1474260	100000	500000	500000	274260	100000	309137.5
47	0.208	0.173	0.179	0.227	0.212	1672521	472521	100000	100000	500000	500000	353223.5
48	0.198	0.202	0.166	0.226	0.207	2029112	429112	500000	100000	500000	500000	419362.7
49	0.215	0.216	0.198	0.187	0.184	1232437	432437	500000	100000	100000	100000	258121.9
50	0.204	0.202	0.208	0.169	0.217	2021470	500000	421470	500000	100000	500000	416387.4
51	0.195	0.144	0.202	0.259	0.201	2020040	420040	100000	500000	500000	500000	426963.3
52	0.215	0.182	0.175	0.223	0.205	1612720	500000	100000	100000	500000	412720	339061.2
53	0.166	0.235	0.178	0.184	0.237	1609670	100000	500000	100000	409670	500000	345958.5
54	0.207	0.224	0.209	0.196	0.164	2121152	500000	500000	500000	500000	121152	437764.7
55	0.166	0.181	0.220	0.205	0.227	1383905	100000	100000	500000	183905	500000	296118.3
56	0.190	0.193	0.234	0.189	0.194	1221202	100000	100000	500000	100000	421202	255862.5
57	0.213	0.176	0.204	0.202	0.206	1205462	500000	100000	100000	100000	405462	247925.9
58	0.169	0.220	0.252	0.176	0.184	1344927	100000	500000	500000	100000	144927	296768.2
59	0.239	0.192	0.210	0.170	0.188	1865012	500000	500000	500000	100000	265012	387812.2
60	0.192	0.219	0.199	0.199	0.190	1550082	100000	500000	350082	500000	100000	317338.5
61	0.188	0.207	0.217	0.212	0.176	1700118	100118	500000	500000	500000	100000	354319.6
62	0.173	0.174	0.264	0.208	0.181	1874432	100000	274432	500000	500000	500000	391330.9
63	0.218	0.209	0.227	0.181	0.166	1242032	442032	100000	500000	100000	100000	265306.4
64	0.179	0.203	0.224	0.180	0.214	1646323	100000	446323	500000	100000	500000	345639.0
65	0.236	0.194	0.194	0.169	0.207	2132895	500000	500000	500000	132895	500000	437924.6
66	0.207	0.152	0.240	0.192	0.208	1878537	500000	100000	500000	278537	500000	396496.3
67	0.215	0.209	0.191	0.212	0.172	1408916	500000	208916	100000	500000	100000	293685.1
68	0.202	0.192	0.204	0.177	0.225	1689151	489151	100000	500000	100000	500000	350036.8
69	0.147	0.223	0.190	0.228	0.213	2051372	100000	500000	451372	500000	500000	432132.2
70	0.200	0.191	0.210	0.195	0.205	1405241	205241	100000	500000	100000	500000	286907.0
71	0.181	0.230	0.216	0.176	0.197	1284355	100000	500000	484355	100000	100000	275160.5
72	0.175	0.227	0.184	0.194	0.220	2089642	100000	500000	489642	500000	500000	428087.0
73	0.220	0.164	0.208	0.180	0.228	1804881	500000	100000	500000	204881	500000	381131.3
74	0.219	0.213	0.174	0.213	0.182	1899349	500000	500000	100000	500000	299349	394003.4
75	0.210	0.171	0.224	0.196	0.199	1911588	500000	100000	500000	311588	500000	394639.1
76	0.203	0.177	0.195	0.218	0.207	2042832	500000	100000	442832	500000	500000	417951.7
77	0.195	0.198	0.160	0.212	0.235	1927649	327649	500000	100000	500000	500000	402356.9
78	0.210	0.231	0.186	0.188	0.186	1649582	500000	500000	100000	449582	100000	341941.7

79	0.191	0.208	0.212	0.162	0.228	1426138	100000	226138	500000	100000	500000	302011.7
80	0.207	0.204	0.211	0.196	0.182	1349075	500000	149075	500000	100000	100000	277334.2
81	0.196	0.183	0.175	0.242	0.204	1475695	275695	100000	100000	500000	500000	312926.8
82	0.171	0.216	0.185	0.219	0.210	1307739	100000	500000	100000	500000	107739	275572.2
83	0.231	0.206	0.189	0.198	0.177	1340007	500000	500000	100000	140007	100000	282433.0
84	0.202	0.240	0.191	0.183	0.184	1478784	500000	500000	278784	100000	100000	311165.0
85	0.197	0.196	0.192	0.194	0.221	1875251	500000	500000	100000	275251	500000	379520.2
86	0.175	0.189	0.186	0.233	0.217	1316479	100000	116479	100000	500000	500000	283299.6
87	0.191	0.186	0.202	0.253	0.168	2118750	500000	500000	500000	500000	118750	436019.4
88	0.229	0.147	0.179	0.220	0.225	1818221	500000	100000	218221	500000	500000	390827.0
89	0.192	0.188	0.203	0.224	0.192	1784839	184839	100000	500000	500000	500000	364267.2
90	0.196	0.206	0.200	0.188	0.209	2093328	493328	500000	500000	100000	500000	423430.8
91	0.224	0.229	0.160	0.205	0.182	1921089	500000	500000	100000	500000	321089	403470.8
92	0.187	0.232	0.197	0.163	0.221	1859753	259753	500000	500000	100000	500000	389874.8
93	0.219	0.212	0.199	0.213	0.157	1378986	500000	178986	100000	500000	100000	289641.7
94	0.164	0.229	0.184	0.211	0.212	1336049	100000	500000	100000	136049	500000	284023.8
95	0.196	0.231	0.170	0.183	0.220	2059383	500000	500000	100000	459383	500000	424619.2
96	0.197	0.223	0.199	0.200	0.181	2060808	460808	500000	500000	500000	100000	419900.7
97	0.188	0.219	0.207	0.170	0.216	1325991	100000	500000	125991	100000	500000	279408.8
98	0.207	0.194	0.202	0.211	0.186	1725547	500000	125547	500000	500000	100000	352930.5
99	0.203	0.176	0.195	0.239	0.187	1658658	500000	100000	458658	500000	100000	346518.6
100	0.216	0.184	0.195	0.222	0.182	1690036	500000	100000	490036	500000	100000	351375.2

Reference issues

- Delete red highlighted references from table 1
- Bendul et al. 2017 shall be replaced by Bendul et al. 2016
- Mahmud and Kabeer 2003 shall be replaced by Kabeer and Mahmud 2003
- Sönnichsen and Clement 2020 shall be Sönnichsen and Clement 2019.
- Galankashi et al. 2015 shall be replaced by 2016

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