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Supplier sustainability assessment for the UK defence industry

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Abstract
Purpose – The purpose of this paper is to design a framework for assessing supplier sustainability (in terms of survivability) within the defence industry based on financial and operational dimensions.

Design/methodology/approach – The research employs a case study approach to identify a research gap in the area of supplier performance measurement and proposes five dimensions to assess supplier sustainability from the review of literature and industry practice while employing a systematic approach to generate measures for each dimension with suggested actions to improve sustainability.

Findings – The sustainability measures, dimensions and improvement actions developed were validated with industrial experts from three defence companies and implemented as a sustainability system. A case study was applied and the results were generated.

Research limitations/implications – Future research could include further case study application and application of dimensions and measures to other industries.

Practical implications – The paper offers managerial implications about the need to consider the survivability of suppliers in the long term, especially in the current economic climate and think about mitigation strategies to enable economic sustainability.

Originality/value – This paper adds to the existing knowledge in the supply chain area and proposes a novel approach to supplier performance measurement and management which is holistic.

Keywords Defence contracting, Defence industry, Defence supply chain, Supplier performance measurement, Supplier sustainability, Sustainability dimensions

Paper type Case study

1. Introduction
The effective and efficient management of the Supply Chain (SC) is a major source of competitive advantage which enables a company to remain sustainable, especially within the defence industry (Bojarski et al., 2009). Here sustainability is explained as the ability of the supplier to survive and maintain the required level of quality of products and services in the long-term. For this reason, various initiatives and techniques have been developed in this area to improve Supply Chain Management (SCM). Kim (2007) emphasised the need for firms to set up independent SCM departments in order to manage their SCs more effectively while Supply Chain Risk Management (SCRM) was introduced to develop approaches for the purpose of identification, assessment, analysis and treatment of areas of vulnerability and risk in SCs. An application of SCRM is Dow Chemical Company’s purchasing risk and mitigation methodology which helps to identify substitute products/suppliers to replace those
suppliers with high risk (Trkman and McCormack, 2009). Also, business analytics approaches and procedures have been introduced to be used in combination with other systems to gain information, analyse and predict outcomes of problem solutions. Schlafke et al. (2013) introduced performance management analytics as an instrument to understand relevant business dynamics and control key performance drivers, in order to improve the operations of organisation. However, more effort could be expended in order to ensure the sustainability of suppliers as diversity of industries (market forces) requires diversity of innovation to ensure sustainability since no universal solution is optimal for all firms (Trkman et al., 2010). Sustainability research focuses on economic, social and environmental dimensions. Environmental sustainability initiatives could lead to cost savings overall as seen in the case of Xerox's US$300 m saving through reuse and remanufacturing (Hart, 1997; Bojarski et al., 2009), however, financial and operational sustainability is crucial for suppliers to compete effectively in the long-term. This is underscored by some of the challenges faced by the UK defence SC which are reflected in the following quotes: “as a result of a combination of shortages of initial stockholdings and serious weaknesses in logistic systems, troops at the frontline did not receive sufficient supplies in a range of important equipment” (House of Commons Public Accounts Committee), “huge logistics effort was fundamental to the success of the operation, but improvements need to be made to ensure effective delivery of supplies to the frontline” (UK National Audit Office) (Tatham, 2005, p.17). Supplier flexibility consists of building organisational capabilities to sense threats to supply continuity and quickly respond. This would enhance organisational resilience to disruption, creating competitive advantage for the supplier (Zsidisin and Wagner, 2010). These suggest there is need for suppliers with the degree of flexibility which enables them to be both efficient and effective to satisfy customer requirement. This flexibility can only be guaranteed when suppliers are financially and operationally sustainable. This has motivated research into the sustainability of defence suppliers, especially at the bidding stage before the contract is awarded. The aim of the paper is to identify measures and dimensions for assessing the sustainability of a supplier (in terms of survivability) within the defence industry based on financial and operational dimensions over a given period. The result of this research provides the design of a decision support model for supplier sustainability assessment. It provides a contribution to knowledge by developing a structure to operate an appropriate model for assessing supplier sustainability.

Usually at the bidding stage, prime contractors assess and select suppliers to engage within the contract in order to ensure that defence capability is delivered over the life cycle of the contract while maintaining competitive advantage in terms of cost, profitability and quality.

The authors of this paper believe that sustainability consideration should include financial and operational dimensions. This would apply to new suppliers at the bidding stage and existing suppliers during the project life cycle.

Within the defence sector, the customer requirement is greatly affected by the external environment such as war or peace time; hence a “Sense and Respond” (organisation's ability to identify changing customer needs and new business challenges as they occur and respond accordingly) approach is required (Bradley and Nolan, 1998, p. 4). While sufficient work has been done in the area of SCM and supplier performance, little or no research has been done to investigate the financial and operational sustainability of suppliers within the defence sector.

This paper presents a decision support model for supplier sustainability which underscores the financial and operational approach to supplier sustainability.
Section 2 provides a literature review around the defence SC with its challenges, the methodology employed in conducting the research and developing the sustainability model is explained in Section 3. Section 3 also explains the design of the model and the process of parameterising the model using the dimensions and measures for supplier sustainability assessment at the bidding stage and during the project lifecycle of defence contracts. Section 4 provides guidance for the use of the model while the model was applied to a case study from the defence sector and detailed analysis of the results is provided in Section 5. Finally, Section 6 contains discussion and conclusion.

2. Defence supply chain

2.1 Literature review
In order to conduct a study in this area, the authors investigated existing literature in the area of supply chain, supplier performance, performance management as well as sustainability. The literature review included a definition of sources and procedures for the search of articles, the careful review of articles and an analysis of the results. This was done in order to understand current research in the area of supply chain management, sustainability study and supplier performance measurement. The literature search which covered publications from 1997 to 2013, was conducted using databases such as Scopus, Inspec, Google scholar and Emerald; using “supply chain, supplier performance, supplier sustainability” as keywords which helped to identify various journals and articles related to these topics. The results from the search were reviewed to select the most relevant articles for the study. Industrial articles related to the defence supply chain were also consulted in order to understand current developments in the industry.

The findings revealed that the environment within the defence supply chain is determined by the nature of defence contracting and the market forces, a major part of which is the customer budget. These are examined in more detail within this section.

2.2 Defence contracting
In the defence industry, like other industries, strategic decisions have to be made by different parties at the stages leading to the contract award (Liew and Sundaram, 2009). The process starts with the customer, for example the UK Ministry of Defence (MoD), identifying a defence need. Then different contractors are invited to tender and bid for the contract before awarding the contract to one contractor who becomes the prime contractor and works along with first and second-tier suppliers to deliver the contract (competitive bid). At other times, the customer decides to negotiate with one contractor to deliver the project (single bid) along with low-tier suppliers. In a competitive bid situation, a prime contractor could win a bid on the basis of capability (technology expertise) or on the basis of cost-leadership. In some contracts, the customer could be involved in the selection of sub-contractors (suppliers) to work with the prime contractor, but in many cases the prime contractor chooses the subcontractors to involve within the project. After contracting, the life cycle of defence contracts is represented in the leave caps Concept, Assessment, Demonstration, Manufacture, In-Service and Disposal (CADMID) cycle. The customer can contract for some phases of the CADMID or all phases.

One factor that affects defence bids is the relationship between the customer and the prime contractor (Graham and Hardaker, 1998). This could affect the decision on the procurement method which could be either single source or competitive bid. The UK MoD would only award the contract to a contractor through a single source
arrangement as a result of a good relationship, based on past performance. Also in a
competitive bid, a good relationship based on past performance could have an impact
on a contractor’s ability to win a contract. This explains the motive behind smart
acquisition initiative to encourage through-life consideration and effective delivery in
terms of cost, performance and time (UK MoD, 2005).

In supply chain literature, scholars identified a two-dimensional view of demand
collaboration between the customer and contractor firms. One dimension was relational,
based on trust and commitment between collaborating firms, while the other dimension
was technological, based on the use of information technology and data sharing
to support the collaboration effort (Kahn et al., 2006). Within the defence sector, both
dimensions exist.

Initiatives such as the private finance initiative and the public private partnerships
are designed to encourage a closer working relationship with key suppliers to provide
better value capability and profit returns to both parties (UK MoD, 2005). The MoD’s
Defence Industrial Strategy states that partnership relationships are designed for
mutual benefits to share risks and reward performance. This is in alignment with
Mohr and Spekman’s (1994) definition of partnerships as being “purposive strategic
relationships between independent firms who share compatible goals, strive for mutual
benefit, and acknowledge a high level of mutual interdependence”. The sustainability of
supplier and contractors is indispensable to realise the benefits of partnership. Nyaga
and Whipple (2011) went further by stating the need to excel at an end-to-end supply
chain is increasingly important for two reasons. First, in order to make profitable
strategic decisions amidst tough economic conditions; second, to mitigate potential risks
and disruptions such as quality problems (internal), supply constraints (external) and
demand variability (external) in an uncertain global environment. This paper contributes
to the existing body of knowledge by identifying measures of supplier sustainability
from a financial and operational perspective, verifying them with industry experts and
presenting them in a sustainability model which was applied within a case study.

2.3 Market forces
In addition to the issues highlighted above, Tatham (2005) mirrored the context of the
defence SC by describing some factors which influence supplier performance such as:

- enormous inventory which must be optimized to meet 90 percent of unpredictable
demand;
- failure to meet customer requirements which may have severe consequences to
end users such as bodily injury or loss of life;
- poor infrastructure on the battlefront leading to scarcity of good communication
and provision of data; and
- the need for a “Controlling Mind” to help overcome the challenges of imperfect
availability of critical (battle winning) commodities.

These are only some of the challenges that defence suppliers may face and they vary
depending on peace time or war situation. This means that the defence supplier is
required to be robust in order to handle these challenges and still meet customer demand,
while maintaining competitive advantage. Long-term financial and operational
sustainability is inevitable to be able to achieve this. From the perspective of a prime
contractor, the sustainability of a low-tier supplier is important because of the reasons
presented in Table I.
It is better to know the state of the supplier sooner during contract negotiation rather than later as this could become a major source of risk and uncertainty; having a negative financial impact.

2.4 Customer budget
Another dilemma which faces UK defence is that of the customer’s budget. While there is a move towards strategic partnership, in practice the relationship is driven by “significant overstretch of MoD operating budgets (i.e. conflict in Iraq and Afghanistan) and commitment to longstanding capital equipment plans (e.g. “Eurofighter/Typhoon, Future Carrier/CVF” (Johnsen et al., 2009, pp. 7-8). This would affect the partnering relationships as the MoD aims to reduce costs by outsourcing maintenance and support of ancillary infrastructure and frontline support, whilst maintaining military effectiveness in the face of spiralling technology prices (Johnsen et al., 2009).

In January 2008, the MoD announced a £1.5 billion yearly budget cut over the next three years (Smith, 2009) and another report reveals the cut could result in the closure of Royal Air Force bases around the UK creating an atmosphere in which armed forces would contend to secure funding for various defence projects such as new ships, aircraft and armoured vehicles (Newman, 2009). In 2012, the UK government announced further cuts in government spending which means the main defence customer within the UK has a reduced budget to pass on to its prime contractors and suppliers. This elucidates the need for the customer and/or contractors to ascertain the strength of their suppliers to remain financially viable over the life cycle of defence projects. Seuring and Muller (2008) highlighted the shortage of SCM and purchasing literature on financial and social issues affecting sustainability. The review of the authors (Seuring and Muller, 2008) revealed that there is sufficient research in the area of supply chain management, supply chain risk management, supplier performance measurement and supplier sustainability. However, the research done in these areas provided models and techniques for managing the performance and risk of suppliers and supply chain across different sectors. Generally, sustainability varies in its meaning and it could mean different things to different people. Sustainability is usually viewed from social, economic and environmental perspectives. While some economic initiatives may achieve cost savings and enhance financial profitability; this may not guarantee long-term financial sustainability.

Also, a model such as the European Foundation for Quality Management excellence model is comprehensive, but supplier sustainability, especially at the bidding stage, requires a concise set of measures focusing on the financial and operational

<table>
<thead>
<tr>
<th>Counterfeit products</th>
<th>There are much counterfeit equipment worldwide which resemble the original; hence it is important to ensure that the suppliers providing equipment are trustworthy and their products are original</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality standards</td>
<td>There are quality standards for many components including wood. Suppliers could mislead contractors to think that such components are meeting quality standards by processing old component to look like new. For this reason, it is important to ensure suppliers comply with the quality standards and new legislation on quality continually</td>
</tr>
<tr>
<td>Financial sustainability</td>
<td>Good cash flow management is important because cash flow problems could lead to bankruptcy as seen in the case of Chrysler’s supplier, Plastech, which caused the automotive manufacturer to temporarily close down four plants in 2008, thereby losing $millions (Trkman and McCormack, 2009)</td>
</tr>
</tbody>
</table>
sustainability of defence suppliers. This limits the applicability of such model at the bidding stage of defence contracts due to the effort that may be required to apply the model in terms of information and time.

Researchers in SCM have designed different performance evaluation approaches as explained by Vaidya and Hudnurkar (2013). Gunasekaran et al. (2001) and Taylor (2004) discussed time as a strategic metric in performance measurement alongside cost and efficiency. Gunasekaran et al. (2001, 2004) designed a framework to measure supplier performance at strategic, tactical and operational levels. Nevertheless in assessing the sustainability of suppliers, there is the need to focus specifically on those dimensions of performance which would affect the supplier’s ability to maintain full capability over the life cycle of the project. Others like Beamon and Chen (2001) employed a methodology using regression analysis for supply chain evaluation, McCarthy and Golicic (2002) proposed a performance improvement approach which integrated sales forecasting and supply chain collaboration (Vaidya and Hudnurkar, 2013). However, Shepherd and Gunter (2006) identified a gap in SCM literature where limited reflection had been one on the important subject of performance measurement. Comparatively few studies have developed performance measurement systems, delineated metrics, or benchmarked supply chain practices. Therefore the authors provided metrics and measurement systems used to evaluate supply chain performance. Again the measurement system proposed by the authors is generic and not specific to any sector. The peculiarities characteristics of the defence supply chain such as the duration of contract and the bidding stage prior to the start of the contract requires a performance measurement system which is adapted and suitable for the sector.

2.5 Supplier sustainability
Sustainable development has been described as “a development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (United Nations, 1987). Sustainability in simple terms is associated with the ability to sustain; and “sustain” means to support or keep going. The environmental domain tends to focus on the natural environment relating to ability to use a resource so that the resource is not depleted or permanently damaged. It is believed, that sustainability demand is changing to adopt a lifestyle that will improve the quality of our lives and the lives of our children while restoring the natural systems that our lives depend upon. For the purpose of this research, supplier sustainability has been defined as the capability of a supplier to maintain (make, deliver and retain) products and services in a dependable manner. This is in order to ensure their availability and operability over the project life cycle with flexibility to adapt to changing customer requirement in a cost effective and ethical way (Bankole, 2011). This paper focuses on the sustainability of suppliers from a financial and operational perspective, though, an environmental dimension has been considered since this is becoming increasingly important for survival in the current economic climate (Hennessy et al., 2009). The next section provides the methodology employed in the research activity.

3. Methodology
3.1 Research approach
Previous sections have highlighted the main challenges facing the defence SC so this section describes the process employed in the research to identify the sustainability dimensions and measures which were implemented in a model. In order to explore this
research area, an exploratory case study approach was adopted (Voss et al., 2002). Yin (2009) described a case study as an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context especially when the boundaries between phenomenon and context are not clearly evident. This means that case study research is not just a data collection tactic but it encompasses the logic of design, data collection techniques and specific approach to data analysis (Yin, 2009). In this paper, the case study approach was employed in order to capture a broad view of supplier sustainability assessment from the review of literature articles and industry practice with different organisations within the defence sector. The finding from this approach is applicable to the major defence organisations including both customers and manufacturers.

The process began with the identification of research themes within defence contracting, followed by the design of research protocol including the familiarisation questionnaires for interview sessions (Figure 1). To investigate industry practice, familiarisation interviews were held with functional experts, project managers who were six in number, chosen from three defence companies (prime contractors and customer) to gain fundamental understanding of defence environment and identify

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**Figure 1.**
Research method
issues associated with the contracting and delivery of these contracts throughout the lifecycle. The respondents were chosen because of their knowledge and experience in supplier engagement, selection and management within defence industry. The respondents have over ten years of experience in job roles related to contract management which includes supplier management of defence contracts. A pilot of the interview protocol was conducted with an industrial partner, after which familiarisation interviews were conducted with other industrial partners.

Familiarisation interviews were held with three companies to gain fundamental understanding of the defence industry and help the respondents understand the context of the study in order to commence initial data collection and to identify potential case studies for the study. In addition to the interviews, relevant literature in SCM and the defence industry were being consulted in order to find out existing knowledge in the areas. Literature review was an on-going activity throughout the research process.

After the initial sessions, the authors identified specific industrial experts in supplier engagement in order to draw on their knowledge in this area. Therefore further interviews were focused on the supplier sustainability research. In preparation for the interviews, questionnaires were developed and reviewed to carry out the research. A semi-structured interview method was adopted among best practise research techniques, as it was best suited to capture the industrial practice. Also, semi-structured interview sessions also allowed the flexibility required for the researcher to gain additional information from respondents.

The results of the interviews were analysed and the important role of suppliers in delivering defence projects was identified. This confirmed the need for major defence suppliers to be sustainable throughout the duration of the defence contract. The results of all the interviews sessions also provided the basis for model development in terms of the sustainability dimensions, measures, weights, score and improvement actions.

As the model development (see Section 3.2) approached a mature stage, a verification exercise (see Section 3.3) was carried out with industrial experts and finally the model was applied to a case study (see Section 5).

### 3.2 Design of the model

The literature review helped to identify dimensions for managing sustainability in terms of financial and operational dimensions (Griffith University, 2009) which were refined by Bankole, 2011. As derived by Bankole, 2011, the authors of this paper adopted the following five dimensions of supplier sustainability which are: management, cost, quality and delivery, stakeholders and environment. The authors of this paper felt they could be supported by findings from literature as presented below:

- management (people and resources) (Shepherd and Gunter, 2006);
- cost (Shepherd and Gunter, 2006);
- stakeholders (Kahn et al., 2006);
- quality and delivery (Gunasekaran et al., 2004; Shepherd and Gunter, 2006); and
- environment (Hennessy et al., 2009).

There was a need to derive actual measures which could be applied to assess sustainability for each dimension. A systematic approach developed by Del Rey Chamoro et al. (2003) to generate measures for key performance indicators in
measuring knowledge management solutions, was employed by the authors of this paper. The steps involved in the systematic approach are presented below:

(1) understanding sustainability dimension;
(2) the conceptual description of the measurable actions under each dimension;
(3) prioritisation and selection of the major measurable actions based on the feasibility and importance scores; and
(4) sustainability measure generation

The sustainability measures generated for each dimensions were based on the approach stated above. Based on findings from the literature review, the five dimensions of supplier sustainability proposed by Bankole, 2011 are adopted in this paper, as explained in Table II and presented in Figure 2.

A supplier who is operationally sustainable must be able to deliver customer requirement at the right quality, cost and time. Also such a supplier must be able to manage its human and material resources in order to maintain its capability and sustainability. Financial sustainability requires a supplier to be able to manage its cost efficiently in order to maintain and increase profit level in order to invest and maintain strong financial base. Such a supplier must be able to manage stakeholder expectation effectively and maintain good reputation overtime. Additionally, environmental sustainability is a necessity for any supplier who aims to compete and demonstrate sustainability in the current economic climate. These dimensions are required for the supplier to maintain operability and availability of products and services over the life cycle. This explains how the dimensions mentioned in Section 2, fit into the financial and operational perspectives of sustainability and further explanation is provided in

| Management (people and resources) | This dimension examines the ability of the supplier to manage it resources. Resources can be assets, systems and also the skills and expertise of the supplier’s workforce. This is important because the effective management of resources (human and material) would have significant impact of supplier performance (operational) and financial sustainability (Supply Chain21, 2009) |
| Delivery and quality | This dimension is important because the supplier’s capability to deliver products and services of good quality on time and in full is crucial to sustain the satisfaction of customer requirement and maintenance of competitive advantage in the long term (Supply Chain21, 2009; Whicker et al., 2009) |
| Cost | The ability to manage cost in supply chains is vital in order to gain and maintain competitive advantage (Whicker et al., 2009). This dimension is important in order to assess the supplier’s ability to manage its cost in order to offer competitive price |
| Stakeholders | This dimension is important because the stakeholders in the company especially customers are keen to ensure that the supplier is flexible and agile to respond to changes in demand and maintain competitive advantage in the market. This enables its sustainability over time |
| Environment | This dimension is becoming increasingly important with growing concern for environmentally friendly processes and initiatives to for companies and nations in the twenty-first century. This was seen in the last United Nations Conference on Climate Change held at Copenhagen in December, 2009 (Hennessy et al., 2009). Environmental sustainability is a mandatory requirement for companies to be sustainable |

Table II. Sustainability dimensions explanation
Table II. The methodology developed by Del Rey Chamoro et al., 2003 was employed to generate qualitative and quantitative measures for each dimension of sustainability. While many performance measures were generated, the research focused on those measures which give an indication of long-term sustainability, which forms part of the contribution of this paper. Sustainability indication can be assessed by monitoring the variation in the performance of a supplier based on these measures over a given period. Also, these measures were ranked based on the feasibility and importance scores and presented in the order of importance as shown in Figure 3 (note that most measures under the quality and delivery dimension are of equal importance).

Schlafke et al. (2013) stated the need to understand the rationale behind the choice of performance measures in order to ensure appropriateness. Teeratansirikool et al. (2013) also emphasised the need to employ appropriate measures which are in line with an organisation’s strategy to carry out performance measurement. This explains the reason why the sustainability measures within the model are weighted based on their importance and relevance within a particular project before scores are provided in order to generate results.

The sustainability dimensions and measures were incorporated into a supplier sustainability model using the Microsoft Excel Software to carry out a supplier sustainability assessment. The assessment requires the user input numerical scores provided within the model in order to generate pictorial and numerical output. The user assigns scores (1, 3 or 5) 1 being the highest and 5 the lowest, and weights (1, 2, 3, 4 or 5) with 1 being the lowest and 5 the highest for each sustainability measure (see Tables III and IV). The scores are summed up and average is generated. Sustainability assessment requires assessing performance over a period of time as this variation over a period gives an indication of sustainability. This means that information about supplier performance over a period e.g. five years must be available in order to perform the sustainability assessment. The module development required verifications and validation of the ideas, logic and content in order to parameterise the model. This is further explained in Section 3.3

3.3 Parameterising the model
To verify the validity of the measures, weights, score and improvement actions, validation sessions were held with three industrial experts from one of the defence
Figure 3.
Sustainability measures and dimensions
companies from the familiarisation interviews as well as two additional companies which were not involved in the familiarisation interview sessions. This was to ensure that the dimensions and measures as well as the suggested actions for improvement were appropriate. The verification also helped to triangulate the results from different experts and ascertain they are applicable to many defence contractors. The four semi-structured validation sessions involved an explanation of the context of supplier sustainability with the dimensions and the approach employed to generate sustainability measures under each dimension for the industry experts to do the verification. In addition, another questionnaire was designed to verify the logic, usability, clarity and content of the model as well as the improvement actions. Some of the questions included within the questionnaire are presented below:

- What is the role of suppliers in maintaining capability contracts over the life cycle?
- What would be the customer's confidence level about the supplier sustainability assessment?
- How would this improve chances of winning the bid?

The results of the questionnaires revealed the importance of assessing supplier sustainability within defence contracts and provided suggestions to refine and improve the model including the improvement actions. The key sustainability measures were identified under each sustainability dimension as scores were allocated to each measure based on feasibility and importance. These measures were refined and additional measures were added as suggested by the experts. The final measures are presented in Section 4. Subsequently, the supplier sustainability dimensions and measures were implemented in a model which was further validated by applying to a case study from a defence company. The case study session was held through discussions with project managers to understand the case study and populate the model with relevant data to assess the financial and operational sustainability of a major supplier. The session lasted about two hours and the result of the assessment is presented in Section 5.

4. Using the supplier sustainability assessment model
The model containing the sustainability dimensions and measures has three main activities namely, sustainability assessment, improvement actions generation and

<table>
<thead>
<tr>
<th>Weight</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The sustainability dimension is unimportant</td>
</tr>
<tr>
<td>2</td>
<td>The sustainability dimension has little importance</td>
</tr>
<tr>
<td>3</td>
<td>The sustainability dimension has some importance</td>
</tr>
<tr>
<td>4</td>
<td>The sustainability dimension has more importance</td>
</tr>
<tr>
<td>5</td>
<td>The sustainability dimension has most important</td>
</tr>
</tbody>
</table>

Table III. Sustainability dimension weighting

<table>
<thead>
<tr>
<th>Score</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Low level of data to assess sustainability dimension</td>
</tr>
<tr>
<td>3</td>
<td>Medium level of data to assess sustainability dimension</td>
</tr>
<tr>
<td>5</td>
<td>High level of data to assess sustainability dimension</td>
</tr>
</tbody>
</table>

Table IV. Sustainability dimension scoring
sustainability assessment storage. The model architecture is presented in Figure 4 and the three main activities described next:

1. The sustainability assessment is done by the user providing contextual information about the supplier, scores and weights for first year (see Figure 5), and weighted scores for years two to five. The scores are assigned based on the supplier’s capability to deliver the project while the weights are assigned based on the importance of the sustainability measure within the project. Similar to Teeratansirikool et al.’s (2013) application of Likert rating scale, the sustainability measures are weighted between 1 and 5 while the scores are allocated at 1, 3 or 5 for appropriateness. Then the model generates an average of the weighted scores (weight × scores) for sustainability measures over the number of years; and yields output in tables (using a traffic light system) and line and spider charts.

2. A set of improvement actions are generated from the literature review for each sustainability measure within the model based on the sustainability assessment. This is done by the user clicking the tick-boxes next to the improvement actions which are applicable to improve supplier sustainability. The selected actions are then presented in a summary report which the user could print.

3. In order to activate the sustainability assessment storage the user must indicate that a new supplier is being assessed before starting the assessment. This enables the storage facility to capture all the assessment and store in a retrievable manner.

A user guide was designed to provide a description of terms and concepts used within the worksheets and how to provide the information required to populate the model. The storage sheets are designed to capture all input and output of the sustainability assessment, and the improvement actions in order to allow the user to retrieve the data from the storage into the assessment sheets later on. Data retrieval requires the user to enter the supplier name in the cell next to the “Load supplier data” button on the sustainability assessment worksheet.
Stage 1a: Supplier Information

Please provide information about the Supplier in the spaces provided below.

<table>
<thead>
<tr>
<th>Supplier Name</th>
<th>eric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier Industry</td>
<td>a</td>
</tr>
<tr>
<td>Supplier value within the overall contract cost (%)</td>
<td>2%</td>
</tr>
<tr>
<td>Prime contractor's value within the supplier turnover (%)</td>
<td>2%</td>
</tr>
<tr>
<td>Contracting Environment</td>
<td>Perfect competition</td>
</tr>
<tr>
<td>Data of assessment</td>
<td>d</td>
</tr>
<tr>
<td>Type of contract</td>
<td>Incentive contracts</td>
</tr>
</tbody>
</table>

Stage 1b: Scoring based on each of the measures of supplier sustainability

<table>
<thead>
<tr>
<th>Explanation</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium level of capability</td>
<td>3</td>
</tr>
</tbody>
</table>

Please select a score under each component of the qualitative sustainability factors based on information available about the project in the cells provided below by clicking on the cells to select from the drop-down list that appears.

1. Quality & Delivery

<table>
<thead>
<tr>
<th>Rate of Conformance over time</th>
<th>Quality Score (Quality Function Deployment (QFD))</th>
<th>Score (1, 3, 5)</th>
<th>Weight (1-5)</th>
<th>Weighted Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate of On Time Delivery over time (Quantity)</td>
<td>No of scheduled delivery - late delivery</td>
<td>10-2</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>Agility to customer requirement change over time</td>
<td>Order delivery date - Order entry date</td>
<td>20/12/09 - 12/12/09</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

Rate of Defects over time

<table>
<thead>
<tr>
<th>Rate of Stockout over time</th>
<th>Score (1, 3, 5)</th>
<th>Weight (1-5)</th>
<th>Weighted Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total No of Delivery</td>
<td>2/10</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>Total No of requirement missed</td>
<td>6/10</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

2. Management (People & Resources)
The user interface comprises three areas namely; the sustainability assessment, analysis and improvement actions selection. The model has been formatted to only accept the values provided in the drop-down box which are 1, 3, 5 for scores and 1-5 for weights. The weighted scores which are between 1 and 25 are displayed using the traffic light system which is described in Table 5.

A low score (coloured green) leading to a lower weighted score means the supplier is more sustainable. Therefore, lower weighted scores suggest higher capability for sustainability with low risk. Medium weighted scores (coloured amber) reflects medium level of sustainability capability while higher weighted scores (coloured red) reflect lower sustainability capability with high risk. This could vary at different phases of the project life cycle. The sustainability summary worksheet (Figure 6) provides a summary of weighted scores obtained from the analysis worksheet for the five years and an average under each sustainability dimension.

These averages are clearly presented in a line and a spider chart to enable the user to monitor the variation in the supplier performance from one year to another, in assessing sustainability including an explanation of how each dimension relates to supplier sustainability. On each worksheet command buttons are provided which helps the user to navigate the model.

5. Case study application
The case study is based on a five-year non-competitive firm price contract between a prime contractor and the UK MoD division. The contract was for a user control device-next generation communications system. The existing project had obsolescence issues which were inherited by the new project. The contract covers the “ADMI” phases of the “CADMID” cycle which was five years. The total cost over the five years was over £12 m and the obsolescence challenges accounted for about 60 per cent of the whole life cost. Initially, the project was awarded on a single source basis; however, the customer decided to run a small competition to further assess value for money in the project as the former contractor was running the program at a loss. However, the previous sub-contractors/suppliers were retained and included in the new contract. The project was contracted on cost plus arrangement and one of these suppliers is another division of the new prime contractor which is based overseas. This is the supplier whose sustainability is assessed within this case study. The supplier’s sustainability position would change over time; hence the initial assessment could only be done for the first two years. This means that the sustainability assessment would be repeated after two years. A snapshot of data input to the model was provided earlier in Figure 5 and it shows that the sustainability model could be applied at the bidding stage of a new project (new supplier) as well as during the project life cycle (existing supplier).

The detailed results in Table 6 and 7 which contains a summary of the initial supplier assessment under each dimension based on the measures, show

<table>
<thead>
<tr>
<th>Colour</th>
<th>Capability Level</th>
<th>Average</th>
<th>Level of risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green</td>
<td>High</td>
<td>&lt;12</td>
<td>Low risk</td>
</tr>
<tr>
<td>Amber</td>
<td>Medium</td>
<td>≥12, &lt;16</td>
<td>Medium risk</td>
</tr>
<tr>
<td>Red</td>
<td>Low</td>
<td>≥16</td>
<td>High risk</td>
</tr>
</tbody>
</table>

Table 5.
Sustainability dimension scoring using traffic light system
### Stage 2b: Summary of Sustainability Weighted Scores

<table>
<thead>
<tr>
<th>Sustainability Dimensions</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality and Delivery</td>
<td>15</td>
<td>13</td>
<td>16</td>
<td>15</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Management (People &amp; Resources)</td>
<td>16</td>
<td>20</td>
<td>10</td>
<td>20</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td>Cost</td>
<td>14</td>
<td>15</td>
<td>20</td>
<td>20</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Stakeholder</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>17</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>Environment</td>
<td>14</td>
<td>20</td>
<td>15</td>
<td>20</td>
<td>15</td>
<td>15</td>
</tr>
</tbody>
</table>

**Colour Coding Explanations**

- **Colour**: High, Medium, Low risk
- **Capability Level**: Average
- **Level of risk**: High risk (≥16), Medium risk (12-16), Low risk (<12)

**Variation of Supplier performance over time to determine sustainability**

**Figure 6. Sustainability analysis worksheet**

- Quality and delivery - The rate of supplier performance in delivering products and services on time and in full over a period of time gives an indication of their ability to be sustainable overtime.
- Management (People & Resources) - The ability of a supplier to manage its assets, tools, skills and expertise of its workforce overtime is important because the effective management of these resources would have significant impact on its operational and financial sustainability.
- Cost - The supplier’s ability to manage its cost overtime along the supply chain is vital in order to provide competitive price to the prime contractor and to maintain competitive advantage in the long term.
- Stakeholders - The supplier’s ability to generate value for its stakeholders including customers overtime is important as it gives an indication of their ability to be sustainable overtime.
- Environment - The supplier’s ability to respond to new government legislation and environmental quality standards overtime is crucial to its long term sustainability.
It was assumed that the supplier’s capability would be constant over the two years; therefore, the assessment for both years is the same without any variation. Due to budget constraints, the contract was re-negotiated and the project life was extended in order to spread the cost of delivering the project over a longer period of ten years. The actual sustainability assessment was done over five years as this was considered

<table>
<thead>
<tr>
<th>Sustainability Dimensions</th>
<th>Measures</th>
<th>Year 1</th>
<th>Year 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Quality and Delivery</td>
<td>Rate of conformance overtime</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Rate of On time Delivery overtime</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Rate of Stock out</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Order lead time overtime</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Rate of Defects overtime</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Agility to customer requirement over time</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>2. Management (People &amp; Resources)</td>
<td>Rate of Human Resource Productivity over time</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Rate of Staff Turnover over time</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Rate of Return on Asset turnover</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Rate of Inventory turnover over time</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Rate of Investment Capability over time</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Rate of Quality of training of employees overtime</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Adaptability to market changes over time</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>3. Cost</td>
<td>Variation in Cost of Income ratio overtime</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>4. Stakeholders</td>
<td>Rate of Innovation Capability overtime</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Rate of Organisational Flexibility over time</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Variation in Market Position overtime</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Rate of Relationship Management over time</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>5. Environment</td>
<td>Rate of compliance with environmental quality standards</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Rate of Responsiveness to change in legislation overtime</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Rate of waste and emission reduction over time</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 6. Supplier sustainability assessment weighted scores (measures)

that the supplier is sustainable (green cells) in terms of all the dimensions but cost (red cell).
a suitable duration for such assessment. This meant the actual sustainability would be different from the initial assessment of two years as a result of the following:

- increase in whole life cycle cost due to obsolescence issues;
- increase in whole life cycle cost due to exchange rate fluctuations;
- increased customer requirements;
- increased utilisation and usage rates of equipment;
- higher attrition and failure rates due to the factors listed above;
- extended range of use due to new emerging customer requirements;
- closure of previous repair facility resulting in increased sales of spares;
- single source of component supply from a foreign major resulting in monopoly of spares and repair capability resulting in higher support costs than originally planned; and
- near neighbour project was taken out of service thus limited opportunities for economies of scale for new orders and spares purchases.

The actual supplier performance is presented in Figure 6 which shows that the supplier is sustainable (green cells) in terms of the environmental and management dimensions. The red cells for the cost dimension suggests that the supplier prices were high while quality and delivery, and stakeholder dimensions suggest the capability was kept at a satisfactory level (green and amber cells). The impact of these changes on supplier sustainability is further explained below:

- Delivery and quality – enhanced customer requirements and increased utilisation and usage rates of equipment meant the supplier may not have the capability to absorb and adapt to the dynamics of the requirements and usage rates. Delivery lead-time could have been longer than expected and the supplier’s solution may not fully conform to customer expectation during operations, leading to higher attrition and failure rates. This explains the reason for the increase in weighted scores for most of the five years of assessment meaning that the capability reduced over time.

- Management (people and resources) – although the supplier employed the same level of resources throughout the lifecycle of project, the level of efficiency could have been higher in order to meet changing demand. The manufacturer believed that this dimension did not really change over the lifecycle, which explains why the weighted score was the same over the five years.

- Cost – Single source of component supply from a foreign major supplier result in monopoly of spares and repair capability meant the supplier prices were high.

<table>
<thead>
<tr>
<th>Sustainability Factors</th>
<th>Year 1</th>
<th>Year 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality and Delivery</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Management (People and Resources)</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Cost</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Stakeholders</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Environment</td>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>

Table 7. Supplier sustainability assessment weighted score (dimensions)
This led to higher support costs for the manufacturer. The single source position (no competition) of the supplier meant that it had the ability to maintain the same high price over the five years. This is the reason why the weighted score stayed at the highest through the sustainability assessment.

- Stakeholders – the supplier’s ability to adapt to changing customer requirements was crucial to satisfy the stakeholder, which the supplier was not able to achieve over time. This explains why the weighted score increased in years two and four. However, the fact that the weighted scores were lower in years 1, 3 and 5 suggests that the supplier took steps to improve its capability to satisfy its stakeholders.
- Environment – the supplier solution met the environmental quality standards and this project was not affected by new environmental legislation, hence the weighted scores were low throughout the five years of assessment.

Overall the supplier sustainability position is favourable in all four dimensions but cost. This occurred because the supplier had the capability required to deliver the project and it charged higher prices for it. However, there could be a delay in the delivery of customer requirement, due to the dynamic nature of the requirement. The model offers some improvement actions which the supplier could take in order to minimise its cost and maintain quality delivery such as:
- the contractor could seek justification of supplier’s price and perform audits where applicable;
- ensure that customer requirement are clearly communicated frequently and captured by the supplier;
- employ cost reduction techniques like lean principles in order to reduce cost and improve competitiveness; and
- identify means of offering extra value to the customer, within the price

These actions could be proposed by the prime contractor to its supplier and if taken, the supplier price could be reduced without compromising the quality of delivery.

6. Discussion and conclusion
The nature of defence contracts which involves complex systems and long life cycle requires the support of suppliers with high capability to be able to deliver it (UK MoD, 2005). This explains why the sustainability of suppliers is of importance to the prime contractor. The case study presented reveals the importance of considering different dimensions when assessing supplier sustainability, as a supplier with high competence to deliver quality offering, may not offer a competitive price. Also, the high price may not be affordable to the prime contractor in the long term.

The dynamic nature of customer requirement which is influenced by defence needs has an impact on the success of the project as it leads to higher attrition and failure rate. Additionally, the manner in which the supplier manages its resources and the systems, skills and expertise of its workforce could help achieve cost savings and offer competitive price to improve financial sustainability (Tatham, 2005). The supplier’s ability to deliver customer requirement in full and on time could also help in achieving cost savings and improve financial sustainability in the long-term by avoiding
penalties and extra cost of investment (Tatham, 2005). However, the supplier in this case had core capability and its prices are set based on its strategic aim of maintaining its brand. For this reason, the prime contractor is sourcing for other suppliers in order to reduce the whole life cost of the project.

With the background information provided in Section 2, the case study revealed the impact of factors which affect the delivery of defence contracts which are summarised below:

- A good relationship based on past performance as well as the supplier being a sister-company to the manufacturer affected the manufacturer’s decision to contract with the supplier even when its price was high. This is in alignment with findings from Graham and Hardaker (1998).

- Also one motivation for assessing supplier sustainability is quality standards. The motivation for contracting with the supplier in the case study was in order to deliver the customer requirement at good quality, though this may take some time due to the dynamic nature of customer requirement. This is in alignment with findings from Tatham (2005).

- The dynamic nature of defence contracts and the impact of the customer budget on project delivery was shown the sustainability assessment of the supplier presented in Section 5. This is in alignment with findings from Tatham (2005).

- Contract re-negotiation which occurred due to budget constraints in the case study from five to ten years reveals the impact of constrained customer (MoD) budget on the delivery of defence projects. This also led to delays due to increased duration or cancellation of some defence contracts which supports findings from Smith (2009); Newman (2009).

Other factors to be taken into account in assessing supplier sustainability include supplier industry, supplier position in the industry, supplier’s stake in the proposed contract and the prime contractor’s stake within the supplier’s company, and the type of contract.

In conclusion, to achieve the aim of the study, this paper identified and adopted five dimensions for assessing supplier sustainability from a financial and operational perspective. Sustainability measures were generated under each dimension following a systematic approach and the dimensions and measures formed the main input for the sustainability model. The model output assesses supplier sustainability using scores and weights after which possible actions to improvement supplier sustainability were provided within the model. Therefore, the design of a decision support model for supplier sustainability assessment was provided in this paper. Although the model focuses on the defence sector, it could be revised to make it more applicable to other industries, especially those involving contracts with long life cycle. A systematic case study approach employed within this paper validated the applicability of the sustainability dimensions and measures to assess the sustainability of supplier within the defence sector at the bidding stage as well as during the lifecycle of the project. The implication for practice is that practitioners within the defence industry can employ the supplier sustainability methodology and model to assess new and existing suppliers. The implication for research is that it provides more depth to research in supplier management and performance management in long-term contracting.
References


**Further reading**


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Dr Oyetola Emmanuel-Ebikake has experience of using best practice research methods to achieve research output for external organisations and generating academic publications. Additionally, she is an experienced Operations Manager in capturing and analysing organisational processes, costing and proffering solutions to senior management team and designing plan for implementation. She is currently a Principle Investigator of a supply chain management research with an industrial partner in the automotive sector while lecturing at Edge Hill University Business School. She has published 3 journal papers, 4 conference papers and 1 industrial paper. Dr Oyetola Emmanuel-Ebikake is the corresponding author and can be contacted at: oyetola.emmanuel-ebikake@edgehill.ac.uk

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Dr Essam Shehab has developed a strong reputation in research and teaching activities. He has contributed heavily in establishing Cranfield as one of the centres of excellence in Cost Engineering and knowledge-based decision support systems. He is leading the research in both areas within the Product and Service Innovation Centre, and has developed new research areas in the application of Knowledge Management to product and service design. He has published over 100 journal and conference papers and edited two books. He has successfully completed the supervision of more than 60 PhD/MSc Theses and one Knowledge Transfer Partnership (KTP) project. He is currently supervising 17 PhD/EngD researchers jointly with other colleagues. He has secured over 50 research projects from Government grants (UK, EU and overseas) and industry income. He is the Principal Investigator of a €12 million EU-FP7 project with other partners including IBM and three EPSRC/EngD research projects with Rolls-Royce.

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