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SUSTAINABLE SUPPLY CHAIN MANAGEMENT IN THE AUSTRALIAN ENERGY INDUSTRY

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ABSTRACT

A survey of Australian energy generators, consultants and retailers identified sustainability objectives reflecting to external factors (such as regulatory requirements), but not reflecting internal conditions (such as purchasing). The industry was found to be pursuing regulatory compliance rather than leadership in regards to their sustainability performance. The research also determined that process characteristics (such as transportation) and current operations management approaches did affect the approaches used for sustainable supply chain management. Economic criteria were found to be the principal focus for these sustainable supply chain management decisions with social and environmental criteria only applying to externally oriented sustainability objectives. Future sustainability objectives identified included integration of sustainable operations management systems with other operations management systems.

Keywords: Manufacturing Management, Supply Chain Management

INTRODUCTION

Creating sustainable energy generation operations has been identified as a major challenge globally [1]. The Australian energy industry is one of the highest contributors of greenhouse gases per head of population [2]. This industry has a major challenge in meeting Australia’s commitment to the Kyoto protocol, whilst maintaining costs at reasonable levels. The creation of sustainable operations in the energy industry involves technology and integration with other process operations. Its cost effective implementation can be viewed as an operations management objective [3]. Therefore, it is appropriate to examine the operations management context for sustainable energy generation in Australia. This paper reports on the findings of a survey conducted of all Australian energy industry generators, energy retailers and energy industry consultants. The paper identifies the industry’s operations and sustainability objectives.

The sustainable energy generation perspective adopted for this research is sustainable supply chain management, in reflection of the recent convergence in supply chain and sustainability research. For the purposes of this project, the scope of the energy generation process supply chain has been defined as including the following processes:

1. Mining and raw material extraction
2. Transportation of raw materials
3. Storage of received raw materials (inventory)
4. Establishment and design of energy generation facilities
5. Operation of energy generation facilities
6. Control of energy generation facilities
7. Distribution of energy
8. Retail of energy supply

An important input into this industry which operates in parallel with the raw materials is the input from industry consultants. The industry has a small number of generators and makes use of a large number of consultants to support the processes that occur within the raw material procurement, energy generation and transmission activities. The industry concludes with a very large number of retailers, although most of these do not possess any physical power generation or transmission infrastructure. Their principal operational contribution to the supply chain is in the area of marketing and customer data management. The literature does not identify strong relationships between these last two activities and achieving sustainable operations, therefore, the energy retailers have been included in the research as either subsidiaries of energy generators or as subject matter experts who can report on sustainability in the entire energy supply chain.

LITERATURE REVIEW

One of the important issues for the energy industry is the sustainability of the mining process as it relies heavily on mined products including coal and gas. Criticisms of the mining industry focus on the efforts of the industry to minimise their commitments to sustainability (e.g. responsibility for toxic by-products) and use of technology, rather than appropriate mining practices [4]. Sustainable development in the mining and processing stage of the energy industry’s operations should include the optimal use of resources energy and capital, management of material and energy flows and control over the industrial systems to minimise environmental impact [5].

The energy industry is also an infrastructure heavy industry, which uses technology to increase the sustainability of operations. Boyer et al [6] found that infrastructure improvement had a strong positive impact on performance improvements resulting from the adoption of advanced technologies and that the impact increases with the level of investment in technology.

SSCM literature

There has been a convergence in general supply chain management and sustainability research [7]. Sustainable supply chain management (SSCM) is frequently defined as the consideration of environmental, social and economic performance (triple bottom line objectives) in the management of the supply chain [3, 8, 9]. External factors, such as regulation, customer requirements and societal factors, appear to be the main driving forces for companies to move to SSCM [10]. For example, customers are usually concerned that suppliers meet environmental compliance requirements without increasing the cost of goods and services [11].

By comparison, it would appear that there has been little or no convergence between environmental concerns and SCM in industry practices. For example, many equipment
suppliers now claim that they are sustainable supply chains members just because their products have been improved to reduce energy consumption, although product improvement is not adequate qualification for sustainable operations [12]. Similarly, literature from the energy industry suggests they hold a purely economic perspective on sustainability and of SSCM. For example, a publication from Shell titled “Promoting Sustainable Development through the Enhancement of Local Employment and Supply Chain Opportunities Generated by Energy Companies” [13] focused purely on Shell’s ability to provide employment in the medium-term in less developed countries. Internal barriers to SSCM include cost and a low strategic priority, whilst external barriers include port commitment from suppliers and the impact of regulation [10].

There is an expected relationship between SSCM and business performance. The development of strong supply chains (high number and quality of suppliers and customers), has been linked with the triple bottom-line measures of sustainability (economic, environmental and social responsibility performance) [14]. This suggests that there is a strongly financial bias in SSCM practice. For example, a recent Ernst and Young survey of US companies with turnovers over one billion US dollars determined that [15]:

- 12% rated sustainability as one of the top three supply chain priorities
- 44% are confident that they can create sustainable operations
- 71% believe that brand development will be one of the greatest benefits of sustainable operations

A number of business conditions also appear to support the development of SSCM. For example, SMEs are particularly well positioned to become efficient sustainable components of global supply chains because of their ability to act on disruptive opportunities more quickly and effectively than large organisations and because their relatively high influence in the niches in which they often operate [16]. Good supply chain management processes can also assist with operationalising sustainability by creating a better integrated and leaner process which will be more attuned to sustainability objectives [17].

SSCM Frameworks

Sustainability must focus on the entire supply chain to achieve corporate sustainability [18]. It is, however, a very complex process and when product life cycle considerations are included, the objectives can become very ambiguous [9]. In the energy industry, life cycles are extremely varied. The life cycle of supplied energy is very small (or sometimes zero as the product is consumed instantly). The life cycle of power stations is very large (up to 100 years with updates for hydroelectric power systems). The life cycle of energy transmission infrastructure is of an intermediate and difficult to identify span as it is under constant renewal. As a result of the short lifespan of the end product and the long lifespan of some intermediate stages of the supply chain that produce it, it can be expected that sustainability objectives in the industry will be ambiguous.

Practices which are likely to lead to sustainable supply chain management incorporate the importance of resources, the costs associated with the supply chain transactions and the impact on the local environment [8], however, a SSCM approach must also incorporate the organisation’s environmental management plans [19] and integrate it with the rest of the business operations [17].

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The SSCM frameworks identified in the literature were based on the following sets of factors:

- strategy, organisational culture, transparency, risk management, economic performance, environmental performance and social performance [8]
- purchasing, social responsibility, sustainable transportation, sustainable packaging, sustainable warehousing and reverse logistics [20]
- by-products of the supply chain, the entire life cycle of the product, total cost optimisation and be reversed supply chain [7]
- interdependence between social, economic and environmental issues and understanding the uncertainties this provides [9]
- innovation and networks [16]
- consolidation of independent supply chain management processes and network optimisation [17]
- connected nature of the primary supply chain to consequential and preceding supply chains and the scope for increasing sustainability across sequential chains [21]
- supply chain strength links with economic, environmental and social responsibility [14]
- drivers for SSCM are predominately external, whilst barriers are both internal and external [10]
- collaborative management through social networks [22]
- stakeholder view of SSCM [3]

The frameworks above can be grouped as:

- external conditions (social, economic and downstream factors)
- internal conditions (culture, purchasing and strategy)
- product features (packaging, entire life cycle and cost optimisation)
- process (warehousing and transportation)
- system design (integration of SCM processes, networks and downstream effects).

The most commonly identified criteria for SSCM in the literature was the triple bottom line (economic, social and environmental performance) [3]. These criteria will be used to frame the discussion of results in this paper. The five identified categories of frameworks have been used to identify the following hypotheses to be examined in relation to SSCM in the Australian energy industry:

1. External conditions, such as social, economic and downstream factors are the primary factors affecting SCCM objectives in the Australian energy industry.
2. Internal conditions, including culture, purchasing and strategy secondary factors affect SCCM objectives in the Australian energy industry.
3. Product features, including packaging, cost optimisation and the overall lifecycle of the product materials affect SCCM outcomes in the Australian energy industry.
4. Process characteristics such as transportation affect the approaches taken for SCCM outcomes in the Australian energy industry.
5. System design and the use of operations management approaches affect the approaches taken for SCCM outcomes in the Australian energy industry.

**METHODOLOGY**
The sample was constructed from searches in a business database ("Australia on Disc") supplemented by extensive manual online searches. A total of 391 addresses were identified in the following categories; Consultant, Generator and Distributor. Respondents were sent a letter inviting them to participate in a Web-based survey (survey took five minutes to complete). Where possible, invitation letters were sent to a named individual. Where this was not possible, an appropriate job title was used for the address and 'Sir/Madam' for the salutation.

An initial draft of the survey protocol was developed based on the principle issues identified in the literature review above. This included energy industry management and environmental supply chain management perspectives. No single framework from the frameworks identified in the literature review was found to be suitable for the project. Instead, the key issues were incorporated in the question design for the survey protocol. The hypotheses were adopted as the research framework as they incorporated the themes from all of the frameworks identified in the literature review. The survey questions were then examined by academic peers researching in the area. Following this, the survey questions were finalised with input from a small group of practitioner subject matter experts.

The overall response rate was very low – only 5% of the total population. Table 1 below, shows, however, that the response rate from the energy generators was 22% - sufficiently high for the responses to be representative of this subgroup. As the issue concerned the environmental aspects of the energy generation supply chain, it is proposed that the two most significant groups were the energy generators and energy industry consultants.

The energy generators were the drivers of the supply chain in the industry, creating the demand for raw materials, road transportation of raw materials and the need for the energy transmission infrastructure. The energy generators, by virtue of possessing the principal manufacturing process, were also the component of the supply chain where the biggest single environmental impact occurred. Energy generators also typically have their own distribution and retail activities and are significant participants in this part of the supply chain in terms of the percentage of total energy retailed. Their observations regarding environmental supply chains in the energy industry would therefore be very representative.

The response rate of the energy industry consultants was only 7%, however, it can be argued that the view of these subject matter experts regarding environmental supply chain issues in the industry is quite heterogeneous, given the relatively small number of generators in the industry (36). Therefore, a 7% response rate should result in representative responses from this subgroup. The initial input from the energy industry consultants who assisted with the survey protocol design indicated that the consultant group frequently dealt with supply chain and environmental control issues in the services they provide for the industry. It is reasonable to can assume that this group were subject matter experts and were all equally familiar with the environmental and supply chain issues along the entire energy supply chain.

The small n precluded exploratory statistical analyses and so the findings have been represented as percentages or averages.

<table>
<thead>
<tr>
<th>Respondent type</th>
<th>Number of invitations sent</th>
<th>Number of Valid Responses</th>
<th>Percent of Valid Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy generator</td>
<td>36</td>
<td>8</td>
<td>38</td>
</tr>
</tbody>
</table>
FINDINGS

Performance objectives for energy industry operations

The participants identified [scale 1-5 with 5 most important] the most important operations objectives to be output control (ave. rating 4.7), raw materials supply control (4.5), environmental impact (4.4), quality control (4.3) and cost control (4.2). Table 2 provides average ratings for both generators and consultants for all objectives including the objectives identified by the participants.

The most important objectives for sustainability identified were reduce carbon emissions (4.5), reduce input energy consumption (4.6), reduce consumption of associated resources (4.0) and produce fewer noncarbon pollutants (3.9). Table 3 provides average ratings for both generators and consultants for all sustainability objectives including the objectives identified by the participants.

The participants rated [scale 1-3 with 3 being high] the energy industry’s performance against these sustainability objectives as being best in reducing consumption of associated resources (ave. rating 2.2), reduce impact on natural landscape (2.2 – this objective was given a low importance rating as an objective), recycling of waste materials and products (2.1 – also given a low importance rating as an objective) and reduce input energy consumption (2.0). Table 4 provides average ratings of the self-assessed performance of the energy generating industry in Australia against these objectives for both generators and consultants.

<table>
<thead>
<tr>
<th>Objective</th>
<th>Generator (ave)</th>
<th>Consultant (ave)</th>
<th>Total Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output (product) control</td>
<td>4.6</td>
<td>4.8</td>
<td>21</td>
</tr>
<tr>
<td>Raw material supply control</td>
<td>4.3</td>
<td>4.6</td>
<td>20</td>
</tr>
<tr>
<td>Environmental impact</td>
<td>4.3</td>
<td>4.5</td>
<td>21</td>
</tr>
<tr>
<td>Quality control</td>
<td>4.1</td>
<td>4.5</td>
<td>20</td>
</tr>
<tr>
<td>Cost control</td>
<td>4.1</td>
<td>4.2</td>
<td>21</td>
</tr>
<tr>
<td>Flexibility</td>
<td>3.7</td>
<td>4.1</td>
<td>20</td>
</tr>
<tr>
<td>Other key objectives*</td>
<td>5</td>
<td>5</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 1. Respondent profiles

Table 2. Performance objectives for energy industry operations

Table 3. Sustainability objectives

Table 4. Self-assessed performance of the energy generating industry in Australia
Table 2. Importance of energy generating objectives

* These were innovation, safeguarding energy sources and safety. As each suggested objective was only identified by one respondent, they are not as important as the other objectives which were all considered to be at least fairly important by between 95% and 100% of respondents.

<table>
<thead>
<tr>
<th>Objective</th>
<th>Generator (ave)</th>
<th>Consultant (ave)</th>
<th>Total Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce carbon emissions</td>
<td>4.5</td>
<td>4.5</td>
<td>20</td>
</tr>
<tr>
<td>Reduce input energy consumption/increase efficiency</td>
<td>4.4</td>
<td>4.7</td>
<td>20</td>
</tr>
<tr>
<td>Reduce consumption of associated resources</td>
<td>3.6</td>
<td>4.3</td>
<td>20</td>
</tr>
<tr>
<td>Produce fewer non-carbon pollutants</td>
<td>3.4</td>
<td>4.3</td>
<td>20</td>
</tr>
<tr>
<td>Recycling of waste materials and products</td>
<td>3.4</td>
<td>4.3</td>
<td>20</td>
</tr>
<tr>
<td>Reduce impact on natural landscape</td>
<td>3.4</td>
<td>4.0</td>
<td>20</td>
</tr>
<tr>
<td>Renovate or recondition damaged natural landscape</td>
<td>3.2</td>
<td>3.9</td>
<td>20</td>
</tr>
<tr>
<td>Other objectives*</td>
<td>5</td>
<td>5</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 3. Importance of Objectives for industry sustainability

* These were tariffs to drive users to be more efficient and increase generation efficiency (this is the same as increase efficiency objective above). As each suggested objective was only identified by one respondent, they are not as important as the other objectives which were all considered to be at least fairly important by between 95% and 100% of respondents.

<table>
<thead>
<tr>
<th>Objective</th>
<th>Generator (ave)</th>
<th>Consultant (ave)</th>
<th>Total Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce consumption of associated resources</td>
<td>2.4</td>
<td>1.9</td>
<td>20</td>
</tr>
<tr>
<td>Recycling of waste materials and products</td>
<td>2.4</td>
<td>1.7</td>
<td>18</td>
</tr>
<tr>
<td>Reduce impact on natural landscape</td>
<td>2.1</td>
<td>2.2</td>
<td>19</td>
</tr>
<tr>
<td>Reduce input energy</td>
<td>2.3</td>
<td>1.7</td>
<td>20</td>
</tr>
</tbody>
</table>
consumption/increase efficiency

<table>
<thead>
<tr>
<th>Renovate or recondition damaged natural landscape</th>
<th>2.3</th>
<th>1.7</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>Produce fewer non-carbon pollutants</td>
<td>2.2</td>
<td>1.4</td>
<td>17</td>
</tr>
<tr>
<td>Reduce carbon emissions</td>
<td>2.0</td>
<td>1.5</td>
<td>19</td>
</tr>
<tr>
<td>Other objectives*</td>
<td>5</td>
<td>5</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 4. Performance Against Objectives for Industry Sustainability

* This was a suggested change to higher efficiency generators. As this suggested objective was identified by only one respondent, it is not as important as the other objectives which were all considered to be at least fairly important by between 95% and 100% of respondents.

Current energy industry operations management techniques

The most commonly identified operations management practices in the industry were activity-based costing (83%), raw materials inventory management (72%) and quality control/management (65%). Forty-three percent of respondents (generators) claimed that their current sustainable operation systems were integrated with other operations systems and 57% claimed that they operated independently and in parallel with other operations systems. Table 5 shows the frequency with which generators and consultants identified the current operations management practices used in the industry. The frequent identification of activity-based costing and inventory management, together with the comparable rates between generators and consultants suggests that operations management is primarily cost and inventory focused in the industry. This further supports the finding that cost and inventory were important objectives for the industry (Table 2). It provides no apparent support however, for all the importance rating given to environmental control in Table 2.

<table>
<thead>
<tr>
<th>Objective</th>
<th>Generator (%)</th>
<th>Consultant (%)</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity-based costing</td>
<td>88</td>
<td>77</td>
<td>14</td>
</tr>
<tr>
<td>Raw Materials inventory management</td>
<td>88</td>
<td>55</td>
<td>12</td>
</tr>
<tr>
<td>Quality control/quality management</td>
<td>63</td>
<td>66</td>
<td>11</td>
</tr>
<tr>
<td>Just in time</td>
<td>38</td>
<td>33</td>
<td>6</td>
</tr>
<tr>
<td>Six sigma</td>
<td>13</td>
<td>22</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>8</td>
<td>9</td>
<td>17</td>
</tr>
</tbody>
</table>

Table 5. Current Operations Management Practices Used in Industry
Supply chain effects

The participants identified the supply chain as equally supporting their sustainability objectives and not being related to their sustainability objectives. Only 20% of total participants identified the supply chain as a barrier to achieving their sustainability objectives. In addition, both types of respondent (generator and consultant) were in reasonable agreement, except that significantly more generators identified the supply chain as not being related to their sustainability objectives than consultants. Table 6 shows the responses for both generators and consultants as a percentage for each of these questions.

<table>
<thead>
<tr>
<th>Effect</th>
<th>Generator (%)</th>
<th>Consultant (%)</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supports sustainability objectives</td>
<td>38</td>
<td>50</td>
<td>7</td>
</tr>
<tr>
<td>Is not related to our sustainability objectives</td>
<td>50</td>
<td>25</td>
<td>6</td>
</tr>
<tr>
<td>Is a barrier to achieving a sustainability objectives</td>
<td>12</td>
<td>25</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 6. How the supply chain effects achieving sustainable operations.

Only two respondents (both generators) provided information on whether their suppliers operated more sustainably than they did. One respondent indicated that suppliers did operate more sustainably and the other indicated that they did not. The same two respondents both indicated that their suppliers did not help them to develop sustainable systems and did not encourage them to become more sustainable. This is consistent with Walker et al’s findings for both public and private sector companies [10].

One respondent (a generator) indicated that their suppliers do not resist complying with their sustainable operations requirements and systems. One respondent (a generator) indicated that their suppliers only complied with environmental regulations that were relevant to their own operations. One respondent (a generator) indicated that they did not change suppliers frequently and one respondent (a generator) indicated that it was not difficult to integrate their suppliers with their sustainable operations systems.

Future sustainability operations objectives

Table 7 shows that future sustainable operations objectives included improving sustainability performance, including cost and control, the introduction of more technology into the management of sustainable operations and increasing its integration with other operations in the organisation. Only eight participants responded to this question, so it is quite likely that the remaining 13 respondents did not have future objectives for the sustainability of their operations.

<table>
<thead>
<tr>
<th>Objective</th>
<th>%</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improved average sustainability performance levels</td>
<td>62.5%</td>
<td>5</td>
</tr>
<tr>
<td>Increase the integration of sustainability operations with other organisational operations</td>
<td>62.5%</td>
<td>5</td>
</tr>
<tr>
<td>Reduce the cost of achieving sustainable operations</td>
<td>62.5%</td>
<td>5</td>
</tr>
<tr>
<td>Introduce more technology into the management of sustainable operations</td>
<td>62.5%</td>
<td>5</td>
</tr>
<tr>
<td>Increase control over the sustainability performance variations</td>
<td>37.5%</td>
<td>3</td>
</tr>
</tbody>
</table>
Table 7. Future Objectives for Sustainable Operations

DISCUSSION

The following discussion considers the findings above as they relate to each of the hypotheses. The findings are also categorised according to the sustainability criteria that they reflect (economic, environmental or social).

1. **External conditions, such as social, economic and downstream factors were the primary factors affecting SCCM objectives in the Australian energy industry.** The most important sustainability objectives for the respondents were environmental criteria (carbon emissions) and economic criteria (energy consumption). These were external conditions. Social criteria did not appear to be a significant sustainability objective. Not surprisingly, their performance was strongest in the social and economic areas, in the same order of performance as the importance of the objective. By comparison, the overall operations objectives focused on internal factors such as output control, raw materials control and then on external factors falling under the environmental and cost criteria. These findings support hypothesis one for the Australian energy industry.

2. **Internal conditions, including culture, purchasing and strategy were secondary factors affecting SCCM objectives in the Australian energy industry.** Participants did not identify typical internal objectives, except perhaps for recycling of waste materials. This could be considered both a social responsibility and economic criteria. This is consistent with the identified objective of conforming with regulatory requirements, rather than attempting to achieve a leadership position. This hypothesis was also supported by the findings, although the lack of identification of internally focused objectives also reflected a lack of consideration of the contribution of operations management to achieving sustainable outcomes.

3. **Product features, including packaging, cost optimisation and the overall lifecycle of the product materials affect SCCM outcomes in the Australian energy industry.** The participants did not identify any product features including product life cycle which affected SSCM outcomes. This hypothesis was not supported by the data.

4. **Process characteristics such as transportation affect the approaches taken for SCCM outcomes in the Australian energy industry.** The most commonly identified operations activities included raw materials inventory management and just in time which indicates that supply chain management is a high level concern for the industry. This is a purely economic criteria focus. Both these activities are associated with the transportation of raw materials to be processed and suggests that SSCM activities are likely to be concentrated in this area. The participants appeared to be divided in their opinion as to whether sustainability objectives were supported by their supply chain, reflecting the focus on raw materials supply over other areas of the supply chains such as the downstream delivery side. There also appeared to be a lack of certainty amongst the participants as to whether suppliers operated more sustainability than they or not, suggesting a high focus on process issues in regards to SSCM. The data provides supports this hypothesis.

5. **System design and the use of operations management approaches affect the approaches taken for SCCM outcomes in the Australian energy industry.** Limited responses
were provided regarding the cooperation of supply chain members in sustainability, although single responses did indicate long-term relationships with suppliers and that these suppliers were integrated with their sustainable operation systems as well as cooperating with their sustainability expectations. This displays an economic criteria focus only. Again, the focus on raw materials transportation in the supply chain management suggests that limited closed loop communication over issues of sustainability is the cause of limited response to this question. The high-ranking future objective of integrating sustainability systems with other internal operations management systems suggest that the existing operations management systems drive the SSCM approaches, and therefore affected the SSCM outcomes. The data provides implied support for this hypothesis.

CONCLUSION

The research has identified sustainability objectives in response to external factors and no objectives in relation to internal conditions, supporting hypotheses one and two. Surprisingly, no responses were identified regarding product features and their role in SSCM. By comparison, process SSCM characteristics were identified as key operations activities, in particular raw materials management, suggesting that this is the primary area where SSCM has an impact on the organisation. This supported hypothesis four and was confirmed by the limited awareness participants appeared to possess regarding the sustainability capability of their suppliers, even though these participant’s future sustainability objectives were to integrate their sustainability systems with other their operations management systems. This would suggest a trend towards allowing internal conditions (i.e. their current operations management approaches) to define the scope for SSCM. This supported hypothesis five. Of the three criteria for sustainability (economic, social and environmental performance), the findings supporting hypotheses one, two, four and five, were economic, whilst the findings supporting hypothesis one were also categorised as social and environmental performance criteria. This suggests a predominantly economic focus regarding sustainability and is consistent with the identified regulatory conformance approach to SSCM. This supports the development of economic models for SSCM, with independent variables relating to external and internal environmental conditions, process and system design.

Whilst it is important to note that this paper does not claim to have proven hypotheses one, two, four and five, it has identified significant evidence that supports them. In reference to the literature, this provides empirical support for frameworks based on the impact of external and internal conditions, process factors and system design. In particular, it indicates that, even in an industry with sustainability objectives that not are strongly defined, sustainability systems with low levels of integration and which focuses heavily on operational cost control criteria, these frameworks still provide valid explanations for SSCM behaviours. This is important contextual information for developing these frameworks as macro SSCM theories.

Further research is now required to identify the conditions behind the support identified for hypotheses one, two, four and five. Qualitative research examining each of these four hypotheses would clarify the operations and planning approaches that have led to these findings.

