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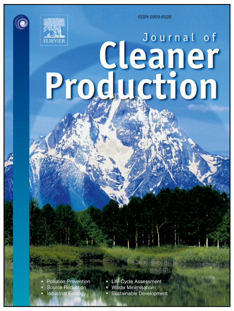

Supply chain integration in the UK bioenergy industry: Findings from a pilot study

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Abstract

Interest in bioenergy as a viable alternative to fossil fuels is increasing. This emergent sector is subject to a range of ambitious initiatives promoted by National Governments to generate energy from renewable sources. Transition to energy production from biomass still lacks a feasible infrastructure particularly from a supply chain and business perspective. Supply chain integration has not been studied widely providing a deficit in the literature and in practice. This paper presents results from a pilot study designed to identify attributes that helps optimise such supply chains. To consider this challenge it is important to identify those characteristics that integrate bioenergy supply chains and ascertain if they are distinct from those found in conventional energy models. In general terms the supply chain is defined by upstream at the point of origin of raw materials and downstream at the point of distribution to final customer. It remains to be seen if this is the case for bioenergy supply chains as there is an imbalance between knowledge and practice, even understanding the terminology. The initial pilot study results presented in the paper facilitates understanding the gap between general supply chain knowledge and what is practiced within bioenergy organisations.

Keywords: bioenergy, supply chain integration, pilot study.

1. Introduction

How is a bioenergy supply chain organised? The question is a fundamental one because we still lack understanding in supply chain configuration in bioenergy, which leads on to what are the factors that integrate a 'typical' bioenergy supply chain? To date, there has not been a study that defines bioenergy organisations. According to Jungbluth, (2007) bioenergy is characterised by its outputs. This follows current examples of bioenergy production in the UK and supply chain characteristics that, on one hand converts biomass into bioenergy such as biogas, biofuel and electricity for distribution on the national grid, and additionally, there are those downstream bioenergy organisations which convert biomass into energy to power their manufacturing process. The latter group may in addition, have the potential to sell surplus energy on to the national grid where demand arises. This provides a challenge from a supply chain perspective due to an uneven and lumpy infrastructure, (Adams et al., 2011). North West Europe, including the UK lacks consistency in regulations that govern supply, (Bauen et al., 2009; Jablonski et al., 2008; Perry and Rosillo-Calle, 2008). Historically, organisation of conventional energy systems is vertically integrated where every area from exploration to distribution has its own discrete supply chain, (Hilson, 2000). This has disadvantages in terms of inflexibility and increased risk due to lack of information and knowledge flows across different areas of the supply chain, (Alajoutsijärvi et al, 2012). Bioenergy firms on the other hand, operate matrix structures that function both vertically within sections and horizontally between main divisions in the supply chain, (Rivza and Rivza, 2011). In this context bioenergy supply chains are highly visible for their accountability and compliance, but there is a lack of knowledge of how such companies perform over the long-term, and in particular, what are the most feasible models that support the business case for bioenergy. European Governments are committed to produce a higher proportion of energy from renewable sources as recommended by the Kyoto Protocol, (United Nations, 1997 and in Oberthür and Pallemaerts, 2010), and earlier Brundtland Report, (1987). The main objective of this paper is to explore the constructs of supply chain integration in bioenergy. Identification of supply chain characteristics pertinent to the bioenergy supply chain is reviewed in the literature given in section two of this paper. Once ascertained, bioenergy supply chain constructs were tested through conducting a pilot study discussed in section three. The literature review helped develop the questionnaire for the pilot study, which was distributed amongst respondents' representative of a 'typical' bioenergy supply chain. Findings from the pilot study revealed how such organisations performed upstream and downstream operations. The final section concludes with a discussion of the main findings from the survey and corresponding literature in realising where the gaps in knowledge and practice constrain development of supply chain integration in bioenergy.

2. Review of the literature

2.1 The bioenergy supply chain deconstructed and defined

McCormick and Kåberger, (2007) confirm that barriers to implementing bioenergy in European States are non-technical barriers rather than technical. In support of this argument, Gold and Seuring, (2011) find complexity in bioenergy systems that result from combinations of monitoring, notification and simulation, to list but a few of the differing interventions proffered by actors at all levels. What the literature reveals is that there appear to be sub-sets within sets of attributes that are not properly defined to accurately reflect the characterisation of bioenergy supply chains, (Rivza and Rivza, 2011; Altman, 2008). Despite significant improvement in technical feasibility of bioenergy production, the UK is still no further ahead in viable distribution. To understand what a bioenergy supply chain means it is necessary to ascertain what is meant by this term. Most definitions in bioenergy supply chain integration perceive it has a process, defined by a set of events that enable end-to-end visibility across the supply chain, (Folinas et al., 2010). The same concept applies to Winkelmann et al., (2008) because factors that enable an integrated system are fundamental to decision-making, which, in turn, bring all the actors together to plan and develop a business. In a general sense this approach can be replicated for any given industry. However, supply chain elements that shape bioenergy are distinct from those in manufacturing and conventional energy sectors. Despite these organisations being small-scale production facilities, there is considerable complexity in the bioenergy supply chain, (Hamelinck et al., 2005). This presents a gap in the current knowledge in how to measure performance by identifying what performance indicators are required. As an end-to-end entity bioenergy supply chains are difficult to define due to the fact that they comprise both primary and secondary activities. Sambra et al., (2011, p. 3) on the former observe: '*the biomass supply chain is made up of arrange of activities which include harvesting, baling, storing and transport of biomass both on the field and to the bio refinery'*, but in terms of secondary activities such as post-conversion to bioenergy, secondary distribution processes come into play such as, *'…handling and transport of residues and by-products'.* This is reiterated in McBride et al., (2011, p. 1277) who define bioenergy supply chains as, *'the production or procurement of biomass feedstock, post-production processing and conversion…and beneficial transport stages'.* In relation to supply chain management, this indicates that what appears to be a primary function in one-sector converts to secondary downstream operations in another within the bioenergy industry. McBride et al., (2011) include secondary customers in relation to value-added attributes: '*Beneficial co-producers (e.g. distillers' grains) and waste by-products (e.g. bio refinery effluent) maybe created at different stages in the supply chain'.*

Definitions confirm that bioenergy supply chains are divided into two areas of upstream and downstream characteristics shaped by primary and secondary activities, (Poeschl et al., 2012; Eikeland, 2007). Supply chain integration is an eclectic topic and utilises a range of theories by which to model supply chain constructs, (Glavic and Lukman, 2007). Upstream studies in bioenergy concentrate on technological and scientific features. Such attributes are relatively easy to distinguish compared with downstream factors in bioenergy supply chains, (Adams et al., 2011). Theoretical references have evolved considerably since Stock's paper in 1997 on 'Applying theories to logistics', which places environmental supply chain management and logistics in the corporate social responsibility literature.

2.2. Theoretical perspectives in bioenergy supply chain integration

Corporate social responsibility (CSR), cited in the green supply chain and logistics literature is underpinned by Agency Theory, (Daugherty and Fried 2007; Dowlatshahi 2000; Carter and Ellram 1998), but do not align with bioenergy supply chain characteristics. Alternative theoretical views err towards economic perspectives, (Grimm 2008). Transaction Cost Theory is cited widely in supply chain management because it helps explain intra and extra-organisational transactions that determine a firm's make or buy decisions, (Ribbink and Grimm 2008; Williamson 1985). Resource-based Theory, (Barney 2001; Peteraf 1993) and related to this, Dynamic Capability Theory, (Teece et al., 1997) all consider competitive advantage posed by Porter and van der Linde, (1985). Strategic alliances and inter-traded supply in the extended enterprise takes Porter and van der Linde's concept of competitive advantage amongst firms that collaborate further, (Hines and Rich, 1997; Hines, 1994). Other supply chain approaches utilise simulation and modelling found in operational science and mathematics, (Tang and Teunter 2006). None of these principles are appropriate because rules that apply to supply chain integration in bioenergy require confirmation.

Bayesian probability models derived from an 18th Century theologian and mathematician, Thomas Bayes underpin theories applicable to bioenergy supply chains. In the context of this paper, Bayes Theory of Probability applies to a set of uncertain factors which either judgements or probabilities are assigned, (Stigler 1986). Multi-attribute Theory by the same token considers the heuristic nature based on a set of probable outcomes, namely assumptions for which users can make important decisions. Bioenergy organisations contrast from conventional energy producers in that their supply chains are smaller and operate horizontally, across the different functions. An investigation into the constructs of a bioenergy supply chain would help provide a frame of reference and establish factors that optimise supply chain performance. In practice, this incorporates a set of initiatives that interlink from initial planning phases to execution and production. A typical bioenergy supply chain is divided into three main areas of procurement, energy conversion and distribution, (McBride et al., 2011). Taking the first point, this relates to location, quality and quantity of biomass, (Rauch et al., 2010) and supplier agreement, (Altman and Johnson, 2008). Secondly, energy conversion links with technical integration and sits upstream within the supply chain. Thirdly, post-conversion factors such as distribution are downstream in the supply chain and present a deficit in the current literature, (Dornburg et al., 2010; Eikeland, 2007). For the most part, third parties manage downstream operations, (Lehtovaara et al., 2011).

From a theoretical view, bioenergy organisations and their respective supply chains in the UK tend to be relatively small but lack of knowledge about the performance of those supply chains are worth investigating. Multi-attribute theory engages Fuzzy Logic approaches where there is a degree of uncertainty, yet supply chain integration is based around a hierarchy of attributes, (Cigolini and Rossi, 2008). Analysis of the main characteristics of supply chains taken from the literature help deconstruct and understand the components of how a bioenergy supply chain might be framed. This approach provides the basis of the pilot study and the questionnaire.

2.3. Supply chain and logistics planning

Constructs of bioenergy supply chains presented in this paper follow the same characteristics found in generic supply chain and logistics operations. Networks for logistics and transport operations require planning collaboration across the supply chain. Lee et al., (2001) discuss the critical importance in establishing cohesive relationships between upstream and downstream operations to mitigate risk in the supply chain. Robust agreements between parties are more effective to offset competition from similar organisations. According to Sahay, (2013) there are three types of supply chain collaboration to enable visibility; firstly, between raw materials' suppliers; secondly between manufacturers and retailers and thirdly, collaboration between third parties. In bioenergy third party collaboration is both upstream and downstream. The literature mainly refers to examples in manufacturing and retail where supply chains are established and biased towards global integration. Evidence in bioenergy planning and organisation finds human interaction is pivotal to location decisions and sourcing appraisal, (Venema and Calemai, 2003). In addition, emphasis on location decisions is seen from an ecological design perspective rather than business operability. Synergies between ecological design and bioenergy production planning underpin renewable energy development. European Governments operate subsidies and in doing so, centralise provision and operation of alternative energy systems, (McCormick and Kåbergr, 2007). Whilst this may appear to encourage and promote uptake of renewable energy, this approach also serves as a barrier because it means that bioenergy cannot be accurately measured against conventional energy provision. Partnership relationships in bioenergy production are highly visible and simplistic because there are few linkages. Despite bioenergy supply chains being small, they adopt a similar format to that of traditional energy supply chains. Puttilli and Tecco, (2010) note in their work, collaboration between raw material suppliers and logistics providers. In support of such co-operation between parties, Jablonski et al., (2008) identify models of vertical integration where operations upstream are outsourced. Examples of this are seen in the UK bioenergy industry by the type of arrangements between forestry providers and CHP production. Supply chain and logistics planning is based at the strategic level in the supply chain, (Gold and Seuring, 2011). To explore bioenergy supply chain constructs this paper is organised into sections that comprise operational and functional factors in generic supply chain operations.

2.4. Logistics function and waste management

Logistics and transport are managed vertically in the supply chain and in the UK by third parties, (Slade et al., 2011). This gives companies advantages in focusing on their core operations of energy production. From this perspective, logistics are widely acknowledged as being upstream within the bioenergy literature, (von Blottnitz and Curran, 2007). Attributes of downstream processes are less documented, (Hassan et al., 2011). Waste bi-products of biomass post-production provide value and can be recycled, (Ranganathan et al., 2008; Forsberg, 2000). Realisation of value from waste provide two considerations, the first is how bioenergy producers manage distribution into mainstream energy markets, and secondly, how do bioenergy bi-products enhance the value from the core product? From a logistics perspective there may not be any requirement to utilise this function because of the type of biomass required by the enterprise. Forsberg, (2000) indicates discrete points in the supply chain where transport required will depend on whether or not sufficient, economical volumes of biomass provides justification for transport. Bioenergy plants are often co-located near feedstock, which serves to reduce risk from other competitors and supply. Evidence in the literature confirms a lack of knowledge of factors attributing to downstream operations in bioenergy, (Frondel et al., 2010; International Energy Agency, 2009). This leads into the next sub-section to examine how bioenergy organisations perceive their role in the wider community.

2.5. Organisational role, user satisfaction, impact of use and information technology

'Organisational role' in the context of this paper refers to core functional elements of bioenergy operations, for example, logistics, distribution or transport of biomass. 'User satisfaction' focuses in relationships of the bioenergy enterprise with its employees and actors involved in the day-to-day operations and 'impact of use' refers to how such organisations market and promote bioenergy to their stakeholders, investors and interested parties. Information technology in relation to management of data reflects the type and level of decision with bioenergy enterprises. In this case decisions used to plan location of bioenergy installations apply to technical feasibility studies for physical processes and calorific values of a given biomass, but not necessarily the viability of the supply chain, (Albertazzi et al., 2005; Demirbas, 2005; Tatsiopoulos and Tolis, 2003). This limits application of decision support systems (DSS) to pre-planning stages. For example, DSS is incorporated in geographic information systems (GIS). Furthermore, most DSS programs focus on one specific type of biomass and do not manage multiple choices of biomass across a range of different scenarios, (Garcia-Quijano et al., 2005; Mitchell, 2000). As Ayoub et al., (2007, p. 710) state: *'...the need for a system that handles all bioenergy production stakeholders' objectives in both national and regional levels involve different* *possible types of biomass with effective potential for energy production'.* Söderberg, (2011) finds that bioenergy supply chains are multi-faceted and determined by Regional and Governmental conditions. A structure for integration is challenged by the fact that there are no universal standard and common terminology, which impede organisational role and impact of use factors. ISO standards for bioenergy production do not exist but are under development (at the time of writing). Such standards are important because they help integrate organisations with one another by adding value and enhance cohesiveness. Roos et al., (1999) identify factors that hinder bioenergy integration is variation between standards between countries. Environmental standards pertinent to bioenergy differ globally but they tend to serve a common purpose to ensure sustainability of bio-crops whilst protecting the integrity of the local environment. Whether such initiatives are fit for purpose is an area for debate as Hilary and Thorsen, (1999) consider self-regulation amongst enterprises. Currently there are a plethora of certification schemes and initiatives that serve to conflict opportunities for alternative agriculture and economic growth. Scarlat and Dallemand, (2011) identify the depth and range of environmental initiatives that are essentially stakeholder based that cover a multitude of environmental, economic and social stability characteristics. The ISO 14001 provides evidence of environmental conformance in operational processes amongst enterprises, (Nawrocka et al., 2009; Niina et al., 2008). The role of IT aids adherence to standards in this respect but differences in language, culture and regulations amongst suppliers from differing nations challenge conformity. In the case of bioenergy supply chains there are wider issues of sustainability in supply and quality of biomass, but Arimura et al., (2011) find a strong correlation between companies with ISO 14001 and adoption of more efficient environmental criteria across the supply chain. Global standards, however, need to take account factors that reduce risk as van Dam et al., (2010, p. 2445) state: '*Key recommendations to come to an efficient certification system include the need for further harmonization, availability of reliable and linking indicators on a micro, meso and macro levels'*. Factors pertaining to organisational role and user satisfaction attributes in the bioenergy supply chain help improve the flow of information and product, (Bioenergy in Europe, 2008).

Thus bioenergy organisations tend towards horizontal structures rather than vertical supply chains common to conventional energy supply chains. Better co-ordination in sourcing biomass upstream, which, at present without uniformity across international standards causes a confused array of different initiatives that to serve to compete with one another rather than cohesion, (Junginger et al., 2006). Supply chain integration is not just a technical issue as the literature shows that as a sector, bioenergy is intersected by many competing characteristics which when isolated from each other, are factors that serve to ensure good practice, but on the converse impact negatively in the supply chain. It is a cause for concern with so many initiatives there is a tendency to add complexity rather than ease integration.

3. Pilot study methodology

The approach adopted and presented in the paper was first to align existing bioenergy knowledge taken from the literature with conventional supply chain processes to identify key characteristics for bioenergy supply chains, and furthermore to ascertain what gaps exist in the current knowledge between upstream and downstream supply chain integration. The prime function of a pilot study is to test the feasibility and sustainability of research methods for a given study, (van Teijlingen and Hundley, 2001). This has a dual role, firstly to trial and design the research approach, and secondly, to gather greater insight into the study. This helps mitigate risk and thus*, '…give advance warning about where the main research project should fail',* (van Teijlingen and Hundley, 2001, p. 1). In this case, as Tashakkori and Teddlie, (1998) recommend a pilot study begins by collecting qualitative data around a topic that previously has not been extensively researched. Design and organisation of the questionnaire, (refer to Appendix 1: Pilot Study Questionnaire), was taken from a generic supply chain and logistics study by Bernon et al., (2008). Modifications were made so that questions related closer to 'typical' bioenergy businesses found reviewing the literature on bioenergy and supply chain constructs given in section two of this paper. The study focused on UK-based companies and its purpose was to gauge the current organisation of the bioenergy industry in the UK and was conducted between 2010 and 2011. Questionnaires were sent to 100 participants involved in the UK bioenergy industry and representative of the supply chain. The response rate totalled 26 completed questionnaires as described in 'Table 1: Participants in the Pilot Study'.

[Insert Table 1: Participants in the Pilot Study here]

There were eight sections in the questionnaire and participants ranked questions on a scale 1-5, (1-unimportant to 5-highly important). The eight sections allocated questions and statements pertinent to specific areas of the supply chain given as:

Supply chain and logistics planning: This section involves supply chain characteristics at a strategic level and includes the total end-to-end supply chain to ascertain integration between up and downstream functionality.

Logistics functions: This includes transport operations to the site, on-site and distribution channels, (e.g. pipelines for gas/fluids), containers and transport adapted for biomass.

Organisational role: The questions refer to individual supply chain operations, for example co-ordination of feedstock, managing suppliers, or customers etc.

User satisfaction: This section refers to how bioenergy organisations promote their public image.

Impact of use: The section gauges questions on how the bioenergy organisation treats its employees and actors across the supply chain.

Organisational performance costs: Operational costs involved in the day-to-day operations of the bioenergy organisation and its supply chain.

IT applications: Functions and operations across the bioenergy supply chain that involve the use of Information Technology, e.g. auditing, procurement, vehicle routing and scheduling.

Waste management: Whilst biomass feedstock can be derived from another sector's waste stream, this section is concerned with how bioenergy organisations process their waste from energy conversion.

Data were analysed using SPSS to collate and calculate the mean figure and weighted average according to the ranked scale of 1 to 5. The results were tested for reliability using Cronbach's Alpha in SPSS and as table 2 shows .995 reliability out of the 26 respondents.

[Insert Table 2: Reliability of Pilot Study Results using Cronbach's Alpha here].

4. Results and Findings

4.1. Overview of participants in the pilot study

Participants represented operations across the bioenergy supply chain, which totalled 26 respondents, (refer to Table 1: Participants in the Pilot Study). There were no participants from downstream areas of the bioenergy supply chain such as marketing and distribution. It was observed that downstream operations ended at the point of production and did not continue in distribution. Additionally, it was noted that synergies between a timber feedstock provider and a logistics company were co-located by a 30 MW plant. Despite co-location, formal long-term contracts had been established amongst both timber and logistics companies which locked them into the minimum of five year contracts to supply this particular CHP plant. It confirms co-location between firms is an important characteristic of upstream integration.

The role of bioenergy consultants in the study helped give an overview of this sector. Factors pertaining to how renewable energy is distributed and implemented into existing energy markets that are already heavily regulated and controlled are yet to be determined, (Tate and Mbzibain, 2012). Amongst the list of participants, there were a number of equipment manufacturers. Most of these were located in Denmark, but one participant from a boiler-manufacturer was based in the UK. Timber CHP utilises coal-fired technology and it was ironic that coal mining and its inherent industry has declined in the UK, (Beatty and Fothergill, 1995). It may be the case that any manufacturer seeking to diversify into bioenergy production will be faced with increasing competition from overseas providers. Thus one of the key challenges for fledgling bioenergy businesses in the UK is how to break into bioenergy markets?

4.2. Results from the pilot study questionnaire

4.2.1. Section one: Supply chain and logistics planning

Security and reduction of risk in supply chain and logistics necessitate robust collaboration with suppliers through partnership and procurement arrangements. Dedicated UK bioenergy businesses are compelled to operate in this way, primarily due to the regulatory framework, and secondly, in order to meet planning and selection criteria with main stakeholders involved from pre-planning phases to full production. Figure 1: Supply Chain and Logistics Planning, gave a range of questions on supplier selection, inventory replenishment and carrier selection.

[Insert Fig. 1: Supply Chain and Logistics Planning here]

The results showed that '1.4. Direct transport services are important to bioenergy supply chain planning and logistics, (AVGw: 4.192) was ranked highest followed by, '1.1. Supplier selection including energy companies is important to ensure security of supply of resources', (AVGw: 3.769), ranked second highest in this section. This would indicate that direct transport of feedstock into the conversion plant are regarded as most important in planning the supply chain and this could show a positive relationship between supplier selection ranked second highest in this section. The lowest score, '1.2. Inventory replenishment is important to ensure effective operations of bioenergy production', (AVGw: 3.385), indicated that this was not an important factor in supply chain and logistics planning. It was found that all participants that responded to the pilot study sought long-term contracts with feedstock providers of up to 5 years in the smaller plant (15 MW) and up to 25 years in the largest plant, which participated in the study, (30 MW plant). These forms of supplier agreements are not typical of co-generation and conventional energy producers. It may be the case that dedicated bioenergy companies who participated in the study sought longer term contracts to retain viability. Slade et al., (2011) confirm this as a characteristic of such plants.

The accountant participant explained: '*We usually devise contracts with our suppliers of up to 10 years*', but on the contrary, the Plant Manager from Co-Generation Company stated that their contracts, *'…lasted up to one year'.* This indicated the distinction in supplier agreements between traditional energy providers who offset energy production with biomass and dedicated bioenergy producers. Further comments related to the quality of biomass and contract issues about the type of contracts in bioenergy production reinforced the need to investigate this issue further as it was found to be one of the factors identified at the time the pilot study was conducted.

4.2.2. Logistics functions

This section of the pilot study related to logistics operations in transportation and processing biomass from feedstock provider to bioenergy producer. Collaboration with third party logistics was in place prior to production and thus central to the strategic planning within the supply chain. Out of five variables in section two, '2.2. Storage of bio-fuels/mass is a feature of the logistics operations', (AVGw: 3.923) was ranked as the most important followed by, '2.5. Our company outsources all of the above', (AVGw: 3.769). This was attributed to the fact that bioenergy is an industry that is new and novel to the UK. Therefore, there are few companies specialising in transportation if biomass. Co-location of feedstock producers and energy producers is documented in the literature and may well have been one of the factors that accounted for these findings given in Fig. 2: Logistics Functions. Transportation of feedstock was not considered to be one of the main factors that played a major part of the supply chain in bioenergy.

[Insert Fig. 2: Logistics Functions here]

The lowest ranking variables in Logistics Functions gave the same AVGw. 2.423. These were, '2.1. The collection of bio-fuel/mass resources is an important feature in the logistics operations of the bioenergy organisation' and '2.3. Sorting is part of the logistics operations in the organisation'. Such findings confirm that logistical operations were not wholly integrated within the management of bioenergy supply chains. Section three of the pilot study considered organisational role within the bioenergy business that sought to ascertain what functional characteristics were ranked higher than others in bioenergy businesses. In addition to the data provided, the one logistics provider who participated pointed out a significant investment in a fleet of 50 specialist vehicles to transport from biomass supplier to conversion sites. In relation to this they were also expected to store biomass until it reached the correct moisture levels pre-conversion. This indicated in the majority of cases, bioenergy companies co-located in order to minimise distance travelled to conversion sites. This finding showed the relationship between downstream companies and bioenergy production.

4.2.3. Organisational role

Organisational role comprised six questions on the range of operations and processes in bioenergy production. The majority of respondents ranking questions in the section confirmed the highest score awarded to, '3.6. Partnerships and responsibility to Project Mgt. Team, Funding Bodies are an important feature in the overall organisational strategic aims and objectives', (AVGw: 4.615). This confirmed bioenergy organisations in the UK tend to involve a large number of stakeholders, public and private sector partners. The second highest score, '3.1. Co-ordination and organisation of delivery is undertaken by the organisation', (AVGw: 4.192), indicated the day-to-day operations were necessary to effective supply chain management despite the number of outside agencies that were involved. This was confirmed by a comment made by one of the Plant Managers at a bioenergy CHP plant:

'There are too many parties that are not part of the day-to-day operations who interfere with getting on with running the plant'.

The lowest ranked score, '3.3. Waste management is critical to the operations of our organisation', (AVGw: 3.038), showed utilisation and management of waste products were not seen as part of the responsibility of bioenergy production.

[Insert Fig. 3: Organisational Role here].

4.2.4. User Satisfaction

Closely related to operations addressed in, 'Fig. 3: Organisational Role', 'User Satisfaction', considered questions about customer relations management in bioenergy organisations. Highest ranking was, '4.4. Marketing and brand image is important to competitive strategy of the organisation', (AVGw: 4.385) followed by, '4.3. Cost saving enables the organisation to be more competitive', (AVGw: 3.962). Such responses indicated that relationships between organisations in the supply chain are important factors. Bioenergy organisations in the UK tend to have an open door policy, which means that they promote bioenergy to the wider public. Many of these organisations are funded from the public sector through National Government Initiatives and the European Union and therefore have an 'open door' policy as part of a public relations exercise thereby permitting the public to visit bioenergy sites, (Faaij, 2006; Domac et al., 2005).

[Insert Fig. 4: User Satisfaction here]

4.2.5. Impact of Use

Aligned with 'Organisational Role', and 'User Satisfaction', the fifth section, 'Impact of Use', related to employee relations in bioenergy organisation. This was the smallest section in the pilot study containing three questions that ranged from customer satisfaction, profitability and employee morale. Question 5.2, 'Profitability is a key indicator of usage of bioenergy in our organisation', (AVGw: 4.115), followed by, '5.1. Customer satisfaction is measured by the organisation', (AVGw: 3.769) and the least important in this section, '5.3. Employee morale is a measure of effective operations in the organisation', (AVGw: 3.115). This was an interesting result because it confirmed bioenergy organisations being a relatively new sector have yet to acquire an infrastructure for internal operations such as human resources, training and development of employees.

[Insert Fig. 5: Impact of Use here]

4.2.6. Organisation Performance Costs

This section did not require respondents to identify specific costs of value and running operations in their organisations. Instead, questions were aimed at identifying how important costs were to the overall performance of the organisation. Of the five questions in section five of the pilot study, '6.4. Flexibility in bioenergy production is important to the business', (AVGw: 4.308) was ranked as most important, followed by, '6.5. Customer satisfaction is a performance measure', (AVGw: 4.154). Firstly, supply chain performance costs were difficult to specify due to the number of third parties involved. This was a major factor in the bioenergy organisations taking part in the pilot study, thus costs were merged with total operating costs of the main company. Secondly, there were no models of best practice and as the literature confirms current costs of energy produced from renewable sources are higher compared to energy production from fossil fuels which challenges some the viability of horizontal integration as opposed to vertical integration found with conventional energy supply chains. In section two of the questionnaire, Logistics Functions, it was found, not only were these outsourced but also co-location helped reduce such costs according to Johnson et al., (2011); Pereira, (2011); Lam et al., (2010) and Rentizelas et al., (2009).

[Insert Fig. 6: Organisational Performance Costs here]

4.2.7. IT Applications

The next section required participants to respond to six statements on how they applied Information Technology programs to bioenergy operations. These included functions such as auditing, procurement and other aspects of financial management for example. The results showed, '7.3. IT is used for planning the supply chain', (AVGw: 4.038) as most important followed by, '7.1. IT is used in storage management', (AVGw: 3.923). Information Technology and information sharing in bioenergy are central to decision-making and integration for generating visibility and parity between partners. In the case of CHP bioenergy in the UK and organisations involved in this pilot study, visibility in the supply chain was built into the strategic development plan from the onset. The least important factors in section seven were, '7.2. IT is used for order management', (AVGw: 3.00) and '7.5. IT is used for freight payment', (AVGw: 3.00). IT software specifically developed for bioenergy operations was not in evidence during the pilot study. IT programs used by the companies were already in circulation and inherited from previous business operations.

[Insert Fig. 7: IT Applications here]

4.2.8. Waste Management Operations

Waste management operations were the final section of the pilot study questionnaire and requested participants to rank in order of importance statements on managing the bi-products post energy conversion. The content of this section was distinct from questions and statements from using waste products as biomass feedstock. The results showed, '8.2. The company sorts its own bi-products from bioenergy production', (AVGw: 4.231) was considered highly important compared to the remaining four questions which gave a AVGw score of <4. It should be noted that the majority of participants (given in Table 1) came from biomass production and conversion, rather than marketing and distribution. This may explain lower weighted average scores in downstream areas of bioenergy.

[Insert Fig. 8: Waste Management Operations here]

The majority of participants reported negligible levels of waste disposal with bioenergy production. Apart from the timber CHP Company that reported high levels of alkaline in their ash from burning wood chip. It should be noted that this was against a low volume of waste as most wood chip was utilised in the conversion process. Levels of alkaline in the ash meant that it could neither be spread on agriculture land nor disposed of in landfill. Instead, accredited waste incineration companies were contracted to treat the ash waste prior to disposal. The Production Manager from the 15 MW CHP plant stated: '*There are only two companies who are accredited to take our ash away and dispose of it correctly*', which indicated that waste management is an area that is less well developed from a supply chain perspective.

4.3. Discussion of Findings

It was assumed that participants were familiar with terms used in supply chain management and this was not going to present any confusion in completing the questionnaire. On reflection this was not the case, particularly as some of the respondents did not fully understand the context of some questions. Further use of the survey method will have to overcome misunderstandings by either providing explanations or, rephrasing questions. It was apparent that consensus had developed from particular questions given in each section. Section one, (supply chain and logistics planning), identified direct transport services as being highly important to bioenergy supply chain planning and logistics. Most of the companies participating used third party logistics providers that, in turn, invested in a fleet of specialist trailers with moving floors and blowers. This is contrary to what is cited in the literature where feedstock providers (namely from the farming sector) are responsible for transport to bioenergy conversion facilities, (Ebadian et al., 2011). In 'Logistics Functions', the highest score was sorting and storage of biomass, which confirms a robust contractual relationship between energy production and long-term relationships between third parties and feedstock providers. It was evident that involvement from numerous actors and third parties permeate the bioenergy industry, which is also confirmed in the literature, (Scott et al., 2013) and results from the pilot study. In section three, 'Organisational Role', participants identified their relationships with public sector bodies as being more important. This is not an unusual result, as all UK bioenergy companies must seek prior approval from public sector organisations. However, just how many governmental bodies are involved at the initial planning stages is a question that needs to be addressed. Section four, 'User Satisfaction' dealt with the extent of public relations as a marketing exercise, but more searching questions on information sharing would have better informed this sub-section. In section five of the questionnaire, 'Impact of Use', the results confirmed how nascent the bioenergy industry is in the UK compared to other EU countries. Acquisition of skill sets and human resource management are key to effective supply chain management within the organisation but this remains under-developed as Watkinson et al., (2012) confirm. 'Organisational Performance Costs', in section six of the pilot study acknowledge that data on total supply chain costs need to be identified, particularly in the UK, as this would provide the business case for both new and existing bioenergy businesses. Effective supply chain performance is key to viability of any business, (Grubic et al., 2010). From an economic perspective, Olssen et al., (2011) find costs of biomass depend on processes that directly link with one another. This is referred to as 'co-integration' and thus for the purpose of this study, organisational performance costs should not be just seen as internal to the organisation but instead, across the whole bioenergy supply chain. Control of the supply chain helps add value particularly where treated as a total entity. The greater the number of linkages within the supply chain adds complexity but on the contrary bioenergy firms tend not to have many links. This creates a challenge because there are not sufficient working examples and more importantly, there is a lack of a common framework which is apparent particularly as there are many European and Regional variations, (Kraxner et al., 2013; Hamelinck et al., 2005). Section seven on 'IT Applications' considered functional operations but unlike the literature did not ascertain the level of information flow internal and external to bioenergy firms. Responses were bias towards application of information technology in storage and logistics. In the final section, 'Waste Management Operations', similar to the previous section of the questionnaire, responses erred towards functional aspects rather than strategic features of bioenergy operations. The respondents showed bias towards sorting and decontaminating bi-products post-conversion. There were insufficient data within the pilot study to ascertain whether there was a potential market opportunity for waste from bioenergy and if such bi-products could be recycled. It would appear that bioenergy supply chains are not truly integrated due to lack of maturity. Upstream integration in bioenergy supply chains is determined by ability to compete with other agricultural production and land use. The view that upstream integration given in the literature is less challenging is a misconception because attributes in bioenergy organisations are difficult to standardise as they will vary by size and type of feedstock used. Co-location from biomass source to conversion plant is a significant characteristic but it is a factor that is perceived as part of downstream attributes of supply chain integration rather than how renewable energy is sold and physically distributed, (Banks et al., 2011). Domain experts leading strategic bioenergy programmes in North West Europe view the end point of the downstream process is conversion to energy.

In terms of data collection, finding relational values of bioenergy supply chain characteristics up and down stream would give credence to a decision framework, measure performance and assess long-term sustainability of renewable energy. Methods applicable to measuring performance using conventional quality tools are not appropriate because further research needs to be conducted in order to identify supply chain characteristics of bioenergy of which this pilot study was a first attempt at undertaking this task.

5. Conclusion

In this context the literature defines bioenergy as a set of principles and processes. Supply chains in bioenergy are less well defined due to variation of infrastructure in different countries. Fundamental to the supply chain and emanating from the pilot study is the need to fully understand the role of the contract within the industry. Lack of universal standards specific to bioenergy followed by a plethora of dovetailed initiatives adds further complexity to this sector, (Scarlat and Dallemand, 2011). Conventionally, supply chain constructs involve contractual relationships both formal and informal between suppliers and their customers and bioenergy supply chains should not be any different to those found in other forms of energy production. Supplier agreements featured as highly important amongst respondents but length of agreement was dependent upon whether contracts were either based upstream or downstream in the supply chain. This contrasted to co-generation and fossil fuel plants that sought short-term arrangements with their suppliers. In bioenergy, feedstock supply to conversion plant tended to elicit long-term contracts between parties of five up to twenty-five years in length, which impacted in relationships with third party logistics providers. Inherit in this type of contract carries considerable risk particularly where locked into a long-term agreement that has become uncompetitive. Upstream integration in the supply and processing of biomass was a key area of collaboration between feedstock producers, logistics providers and conversion facilities. However, the same could not be said for downstream integration. Here, energy distribution depends on a number of factors, which were identified through discussion with participants at the time of data collection. Both dedicated bioenergy and co-generation plants in the UK are in receipt of Renewable Energy Certificates (RECs) and Renewable Obligation Certificates (ROCs). RECs represent a contractual right of the holder to claim any benefit that is associated with energy created from renewable sources. They are sometimes known as 'Green Tags' or 'Renewable Energy Credits'. Each REC certifies that a single megawatt-hour (mwh) of electricity was generated from renewable sources. Renewable Obligation Certificates (ROCs) are green certificates issued to operators of accredited renewable generating stations for the eligible renewable electricity they generate. Operators can trade ROCs with other parties. These came into force in England, Wales and Scotland during 2002, and with Northern Ireland following suite in 2005. Commercially, dedicated bioenergy producers benefit more from RECs and ROCs than co-generation plants but such facilities in the UK tend to be from small-scale producers. Further questions need to be developed within the section on 'Organisation Performance Costs' in order to elicit data on the effectiveness of such initiatives. Respondents to this pilot study alluded to providing a high degree of accountability but findings proved inconclusive as such questions were not well scoped in the questionnaire, particularly on sections such as 'User Satisfaction' and 'Impact of Use'. Specific questions on costs and length of agreement between suppliers would have helped form the basis of a quantitative study. Information technology found in section seven of the pilot study questionnaire concentrated on upstream characteristics of supply of feedstock, quality assurance and conversion operations and did not include downstream processes of marketing and distribution of bioenergy. Respondents indicated the importance of co-location such as shared facilities between feedstock suppliers, logistics providers and conversion plant which was attributed to upstream operations but other downstream operations such as the management of waste and bi-products post-conversion were less defined. One respondent reported that this was outsourced which, if proved significant in a further study would add further complexity and cost if such bi-products could not be reused as feedstock. Increasingly supply chain relationships depend on 'soft' data, which embellish the depth of integration between parties.

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Table 1: Participants in the Pilot Study

Type of Company	Role in the Company
Timber CHP Plant 15 MW	**Plant Manager:** Operations and production
	Account Director: Overall responsibility for financial accounting in the company and development plan
	Project Engineer: Installation Engineering Company
Energy Provider	**Supply Chain Manager:** Global sourcing and procurement of feedstock
	Supply Chain Manager: Green energy projects
Timber CHP 30 MW	**Plant Manager**: operations and production
	Logistic Manager: Biomass vehicle routing and scheduling, fleet management
Boiler Manufacturer	**Company Director**: Design and building bespoke CHP boilers
UK District Energy Company specializing in renewable energy	**Managing Director:** District heating
	Operations Manager: Day to day operations for public and district heating projects
Bioenergy Consultants Regional Development Agency and Board of Directors for Bioenergy Ltd Company.	**Bioenergy Consultants x 5**: independent consultancies, Regional Development Agencies who acted as intermediaries for fledgling bioenergy businesses. Board of Directors for bioenergy businesses. Their role was to advise on policy, regulation and financial opportunities
Logistics Company	**Biomass Logistics Manager**: Responsible for scheduling transport but has wider role in storage and processing feedstock
	Procurement Manager: 3PL contracts
Timber Supplier	**Operations Manager:** Growing, sourcing timber from forestry, sawmills, chipping and storage of biomass. Timber supplier was co-located to 30 MW Timber CHP Plant.
	Procurement Manager and Officer: Biomass contracts
Co-Generation Coal/CHP Firing Station	**Procurement Manager**: responsible for coal and biomass contracts
	Operations Manager: Day-to-day plant operations
	Marketing and Communications Officer: Company marketing and communications
Incineration Plant (waste company)	**Procurement Manager:** Biomass contracts, fleet leasing,
	Operations Manager: Responsible for day-to-day operations on site
	Logistics Manager: Vehicle routing and scheduling, storage management

Table 2. Reliability of pilot study results using Cronbach's Alpha (equal to 0.995 for 39 items).

Case Processing Summary			
		N	%
Cases	Valid	26	100.0
	Excluded	0	.0
	Total	26	100.0

Pilot Study Figures

Fig.1: Supply Chain and Logistics Planning

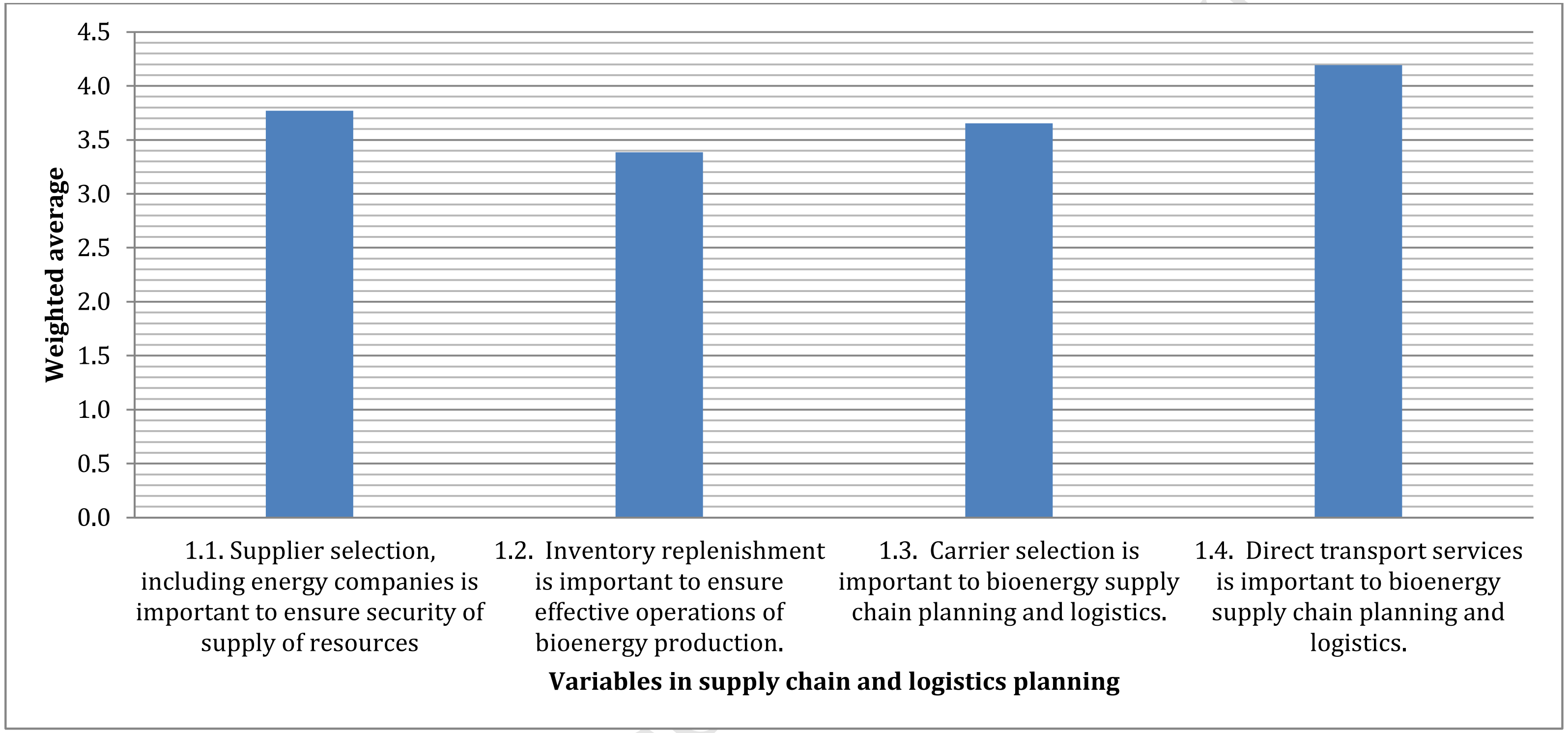


Fig. 2: Logistics Functions

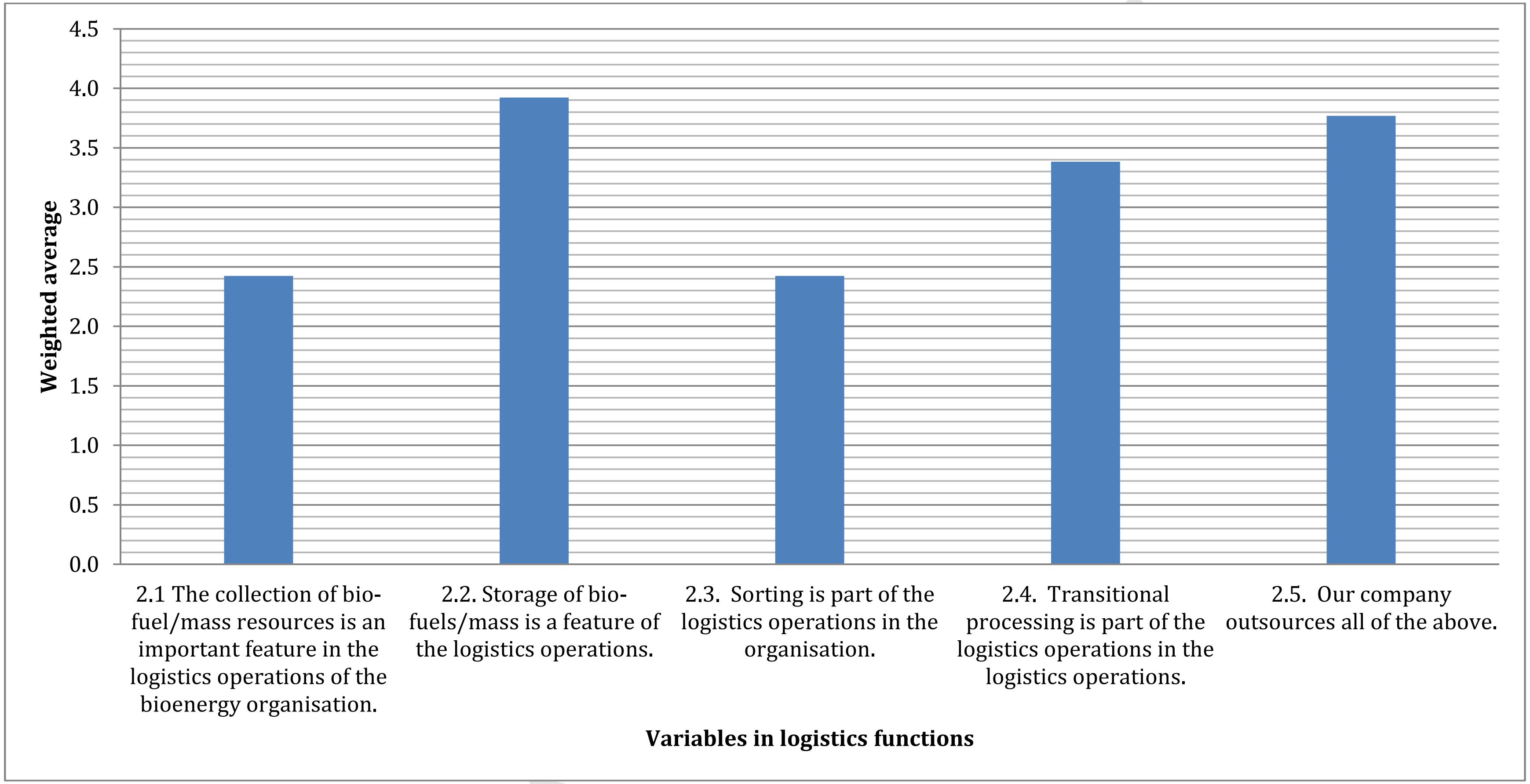


Fig. 3: Organizational Role

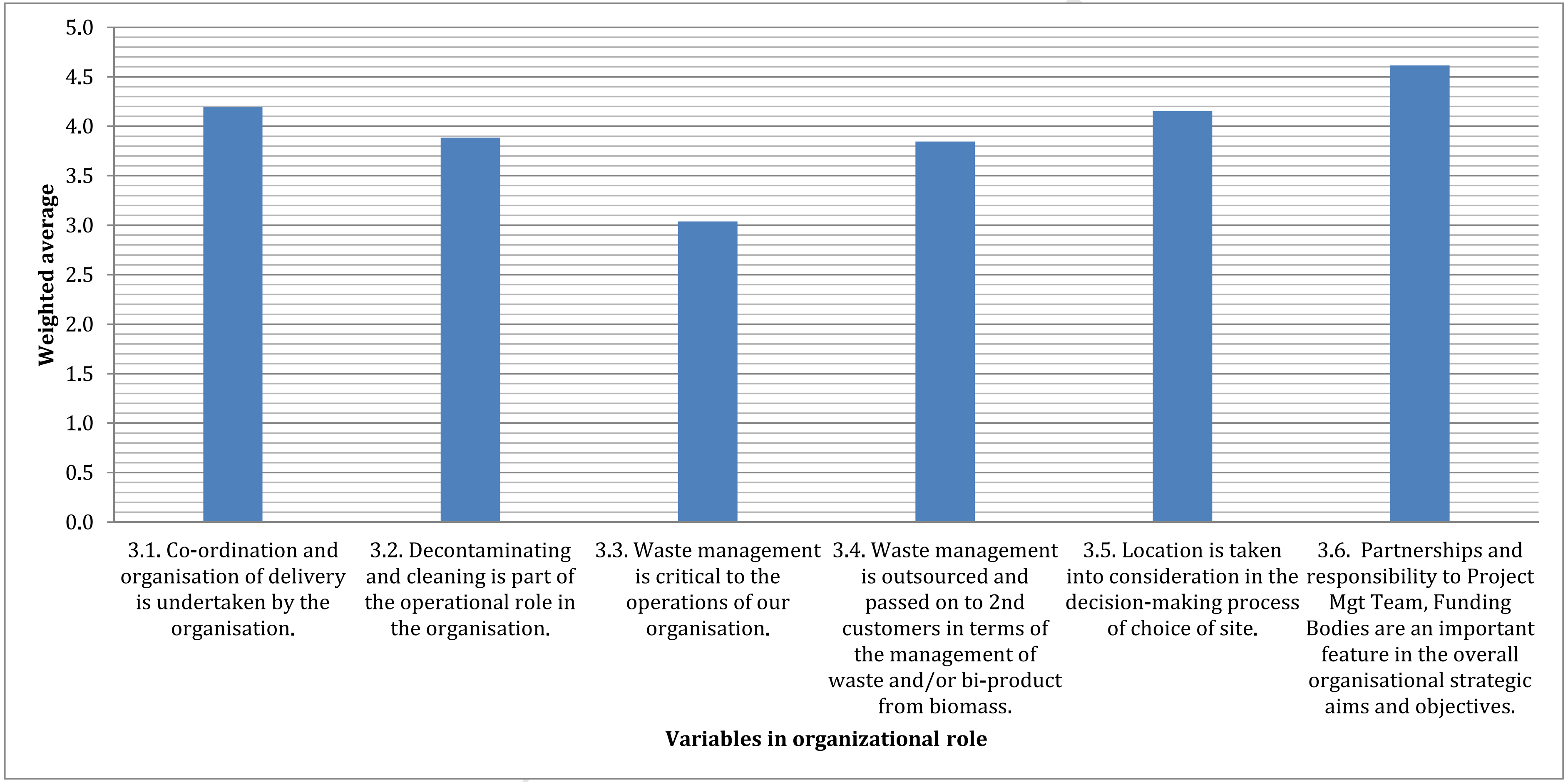


Fig. 4: User Satisfaction

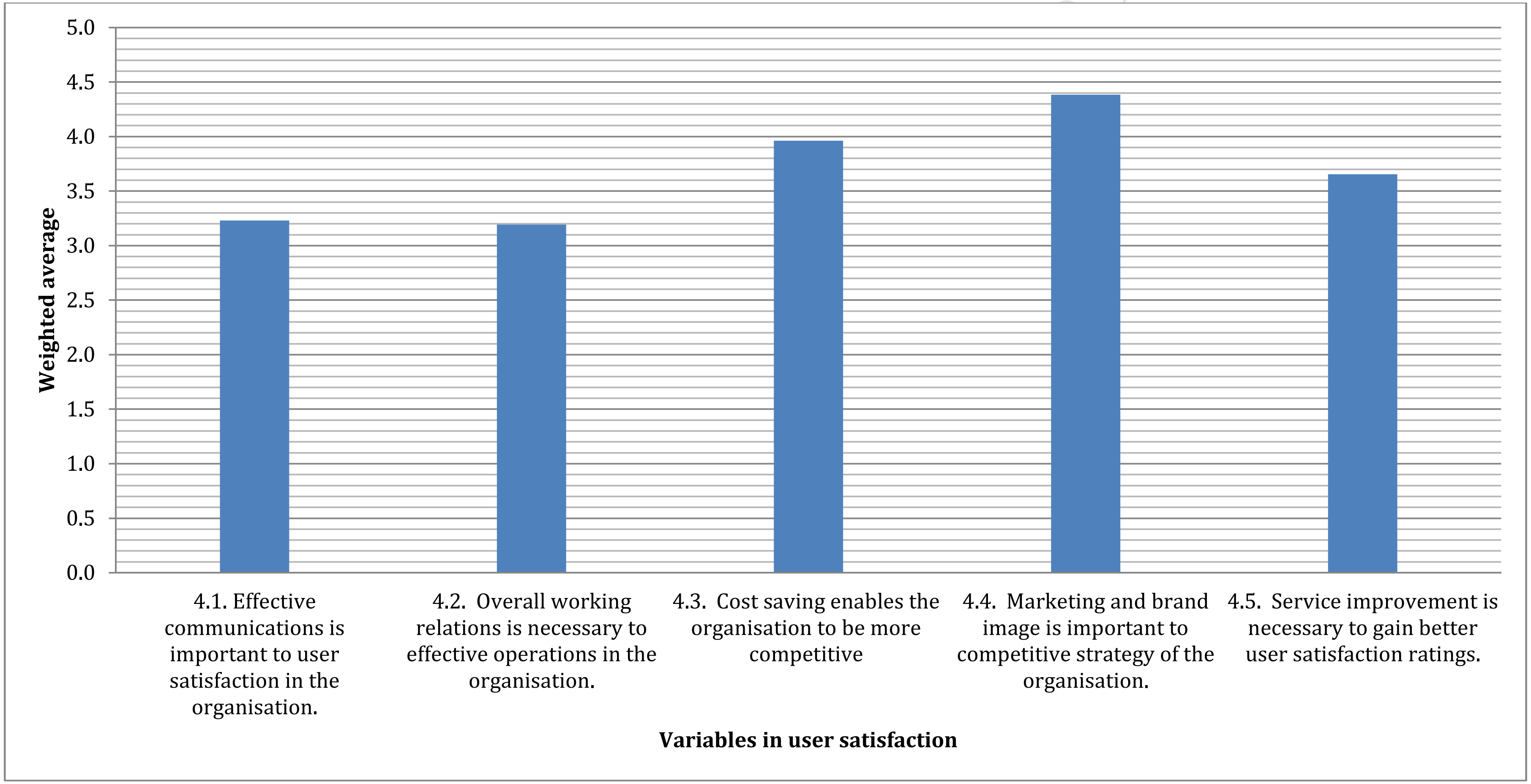


Fig. 5: Impact of Use

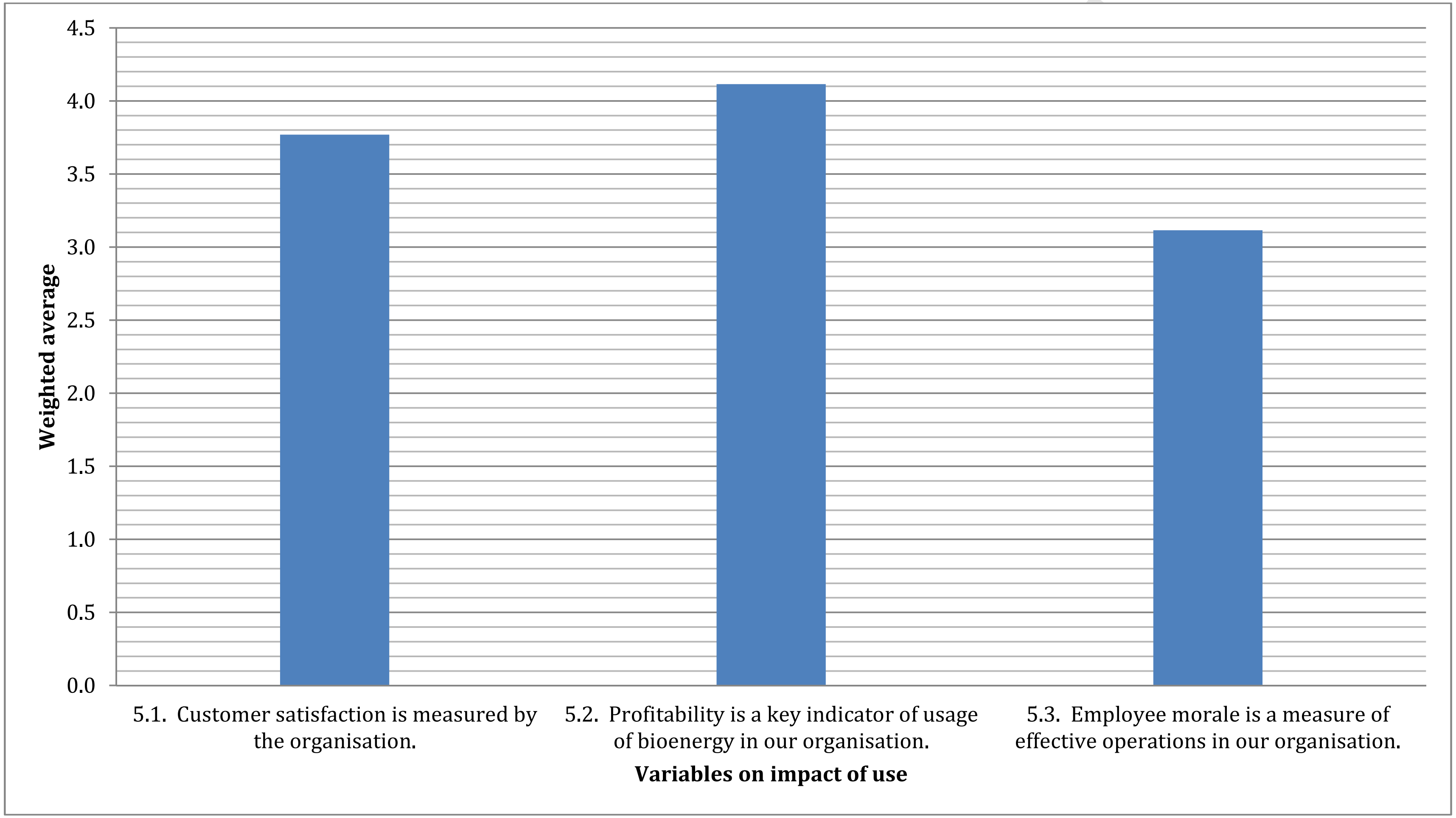


Fig. 6: Organization Performance Costs

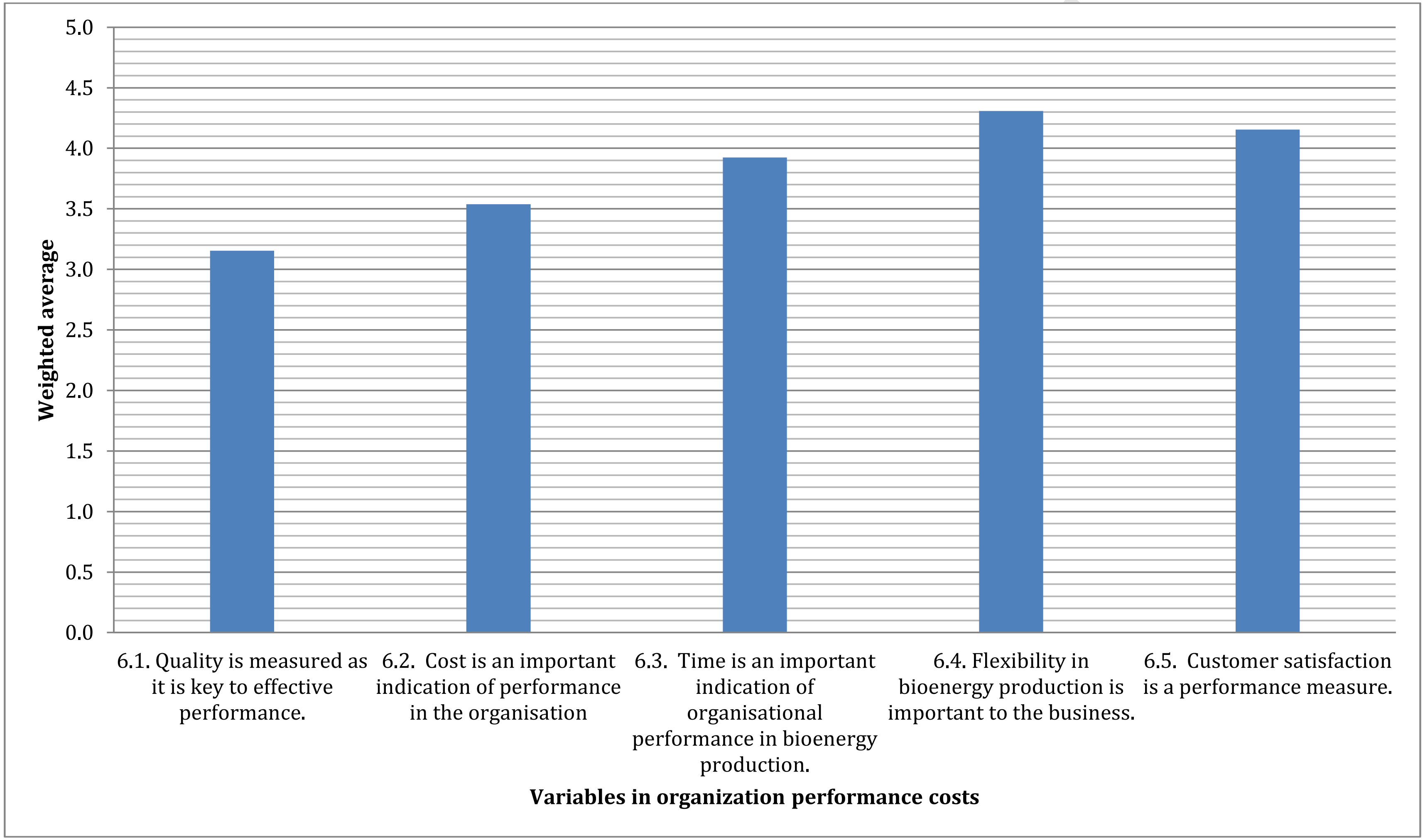


Fig. 7: IT Applications

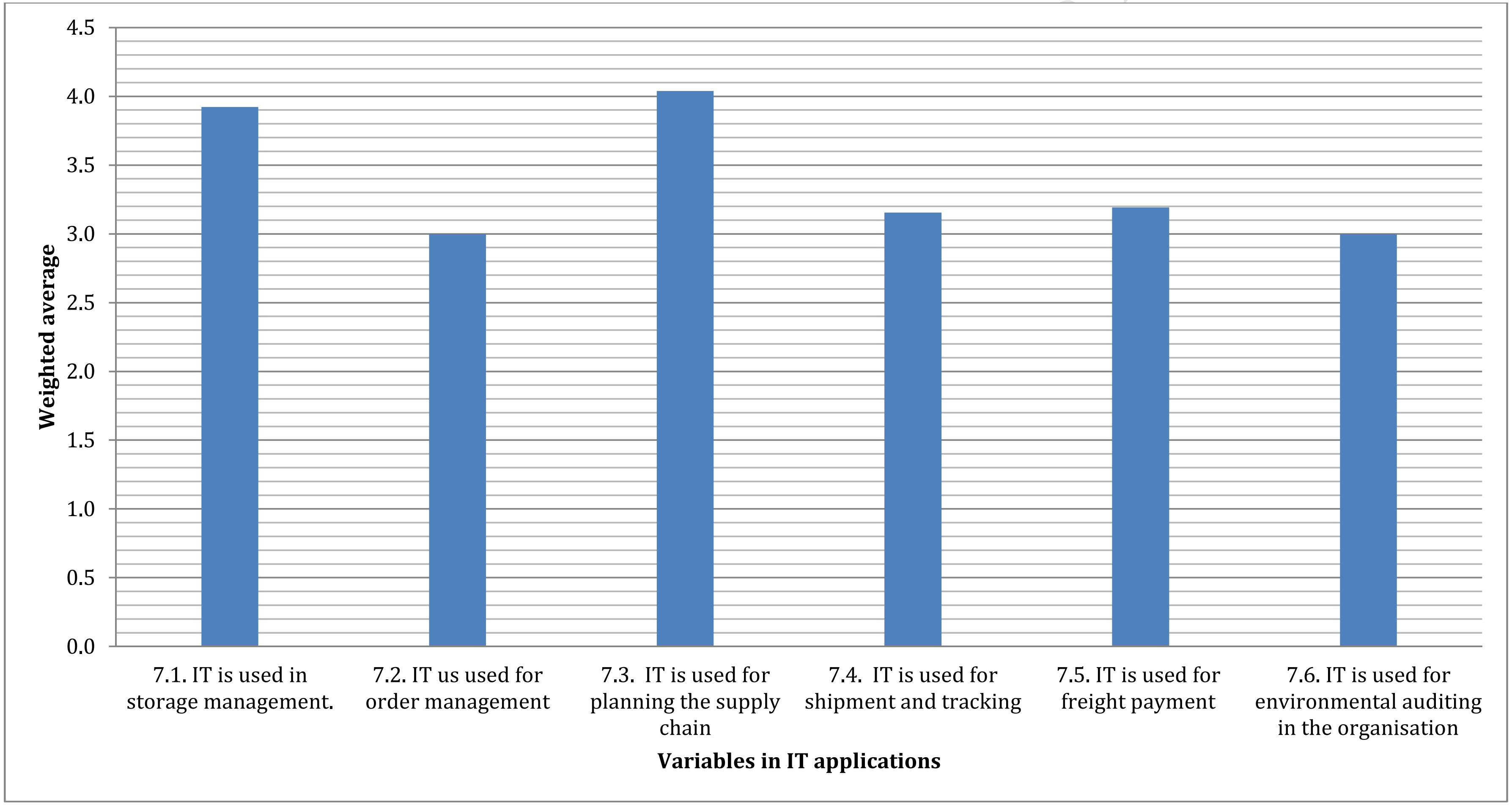
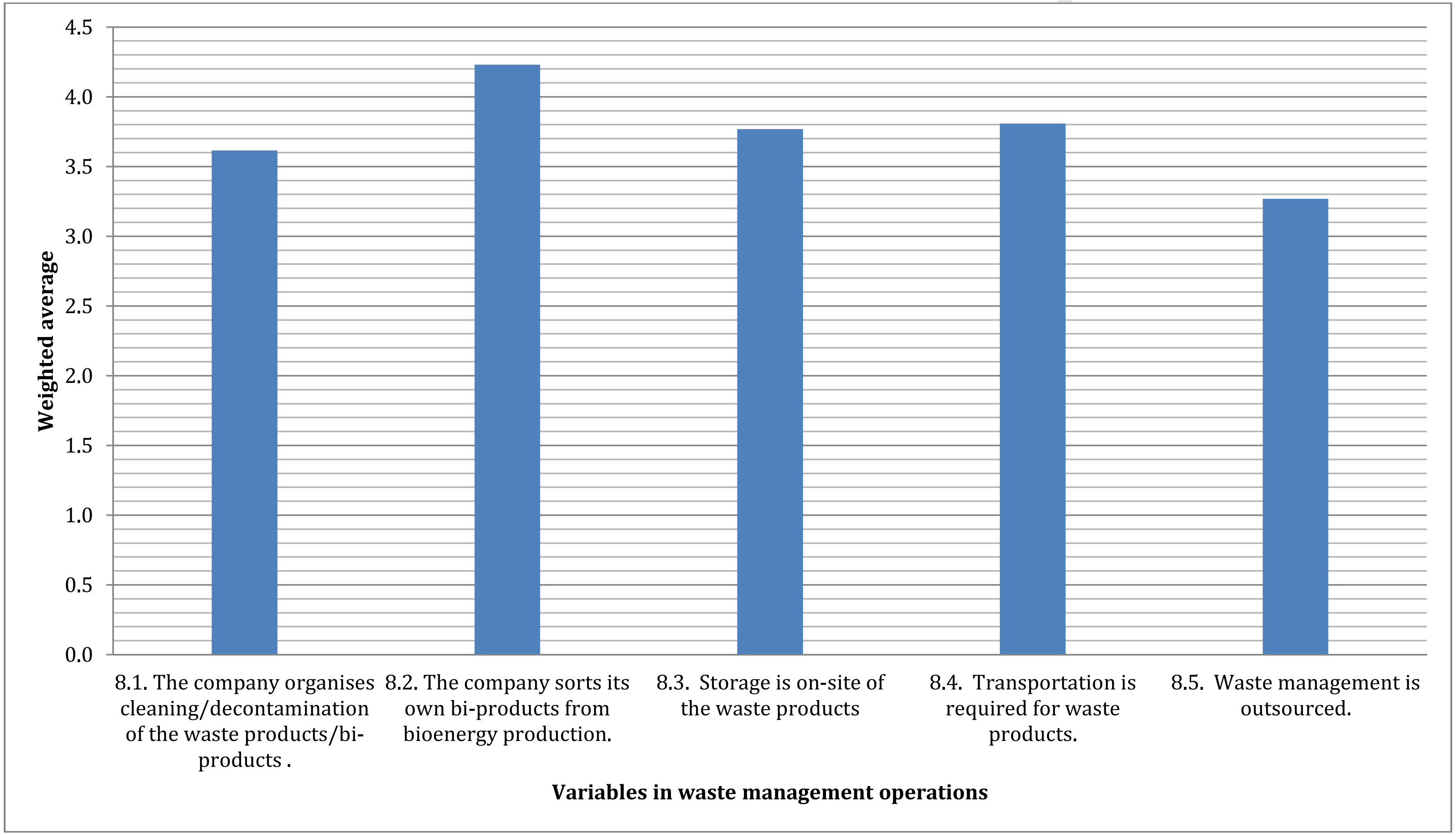


Fig. 8: Waste Management Operations



Highlights

- Purpose to identify key characteristics of bioenergy supply chains in the UK.
- A questionnaire was distributed to bioenergy.
- Out of 100 questionnaires there were 26 responses.
- Study reveals supply chain integration constructs for the UK bioenergy industry.

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Appendix 1: Pilot Study Questionnaire

Pilot Study Questionnaire

Supply Chain Integration in Bioenergy Pilot Study

The questionnaire is divided into eight sections and is part of a pilot study for research in supply chain integration in the bioenergy industry within the UK. The responses and suggestions you provide will be extremely valuable for designing the full scale study. In order to complete the questionnaire which should not take more than 20 minutes of your time please indicate in order of importance your responses to each question using the scale of 1-5 by placing a tick in the box of your main choice: ☑

Please return the questionnaire to: christine.lloyd@bcu.ac.uk/lloydce@aston.ac.uk

Thank you for taking time to complete the questionnaire

Scale

5 Highly important to the bioenergy industry
4 Important to the bioenergy industry
3 Not applicable to the bioenergy industry
2 Partially important to the bioenergy industry
1 Not at all important to the bioenergy industry

Appendix 1: Pilot Study Questionnaire

	5	4	3	2	1
Supply Chain and Logistics Planning (SCLP)					
Supplier selection, including energy companies is important to ensure security of supply of resources					
Inventory replenishment is important to ensure effective operations of bioenergy production.					
Carrier selection is important to bioenergy supply chain planning and logistics.					
Direct transport services is important to bioenergy supply chain planning and logistics.					
Logistics Functions (RLF)					
The collection of bio-fuel/mass resources is an important feature in the logistics operations of the bioenergy organisation.					
Storage of bio-fuels/mass is a feature of the logistics operations.					
Sorting is part of the logistics operations in the organisation.					
Transitional processing is part of the logistics operations in the logistics operations.					
Our company outsources all of the above.					
Organisational Role (OR)					
Co-ordination and organisation of delivery is undertaken by the organisation.					
Decontaminating and cleaning is part of the operational role in the organisation.					
Waste management is critical to the operations of our organisation.					
Waste management is outsourced and passed on to 2nd customers in terms of the management of waste and/or bi-product from biomass.					
Location is taken into consideration in the decision-making process of choice of site.					
Partnerships and responsibility to Project Mgt Team, Funding Bodies are an important feature in the overall organisational strategic aims and objectives.					
User Satisfaction (US)					
Effective communications is important to user satisfaction in the organisation.					

Appendix 1: Pilot Study Questionnaire

Overall working relations is necessary to effective operations in the organisation.					
Cost saving enables the organisation to be more competitive.					
Marketing and brand image is important to competitive strategy of the organisation.					
Service improvement is necessary to gain better user satisfaction ratings.					
Impact of Use (IU)					
Customer satisfaction is measured by the organisation.					
Profitability is a key indicator of usage of bioenergy in our organisation.					
Employee morale is a measure of effective operations in our organisation.					
Organisation Performance Costs (OPC)					
Quality is measured as it is key to effective performance.					
Cost is an important indication of performance in the organisation					
Time is an important indication of organisational performance in bioenergy production.					
Flexibility in bioenergy production is important to the business.					
Customer satisfaction is a performance measure.					
IT Applications (IT)					
IT is used in storage management.					
IT is used for order management.					
IT is used for planning the supply chain.					
IT is used for shipment and tracking.					
IT is used for freight payment					
IT is used for environmental auditingin the organisation.					
Waste Management Operations (WMO)					
The company organises cleaning/decontamination of the waste products/bi-products .					
The company sorts its own bi-products from bioenergy production.					
Storage is on-site of the waste products.					

Appendix 1: Pilot Study Questionnaire

Transportation is required for waste products.					
Waste management is outsourced.					
Please add further information should you wish to do so:					