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Sustainability indicators for the food supply chain

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Abstract: The chapter provides an overview for evaluating sustainability performance of a supply chain. It introduces a new methodology for sustainability assessment of a food supply chain, and demonstrates it using a case of a potato supply chain in the UK. The framework identifies indicators within three dimensions of sustainability (economic, social and environmental) and applies them to stages of agriculture, food processing, wholesale, retail and catering. The framework assigns importance ratings, determined with help of an expert, for the sustainability indicators using Analytic Network Process. The chapter discusses possible application of the framework and discusses further trends of sustainability benchmarking.

Key words: sustainability indicators, food supply chain, sustainability performance, benchmarking.

16.1 Introduction

Considering sustainability implications beyond the organisation and across the supply chain, including wider lifecycle influences of products and processes, is becoming an important element of corporate social responsibility (CSR) under growing pressures from organisational stakeholders. Stakeholders are increasingly expecting corporate responsibility to go beyond product quality and extend to areas of labour standards, health and safety, environmental sustainability, non-financial reporting, procurement, supplier relations, product lifecycle effects and environmental practices (Bakker and Nijhof, 2002; Waddock and Bodwell, 2004; Teuscher *et al*., 2006; Welford and Frost, 2006).

Nearly all Fortune Global 250 companies have subscribed to certain supply-chain codes of conduct and the majority report on their supply chain relations. Retailers have been working especially hard on building supply-chain compliance with various social and environmental standards and codes. Management of and reporting on supply-chain risks and implications is now seen as a response to the growing demand for greater responsibility and transparency (KPMG International, 2008; Waddock and Bodwell, 2004; Teuscher *et al.*, 2006).

Major retailers and brand manufacturers that are often considered to be focal companies within supply chains, are held responsible for environmental and social performance of their suppliers and products, and are forced to restructure supply-chain performance in relation to mounting sustainability concerns (Hughes, 2001; Welford and Frost, 2006; Seuring and Müller, 2008). If these focal companies are to assume their extended responsibility and are prepared to demonstrate accountability for sustainability implications of their operations and engage in effective management of sustainability issues, they need to measure and benchmark sustainability performance of their supply chains. However, currently methodologies and frameworks for effective and sustainable supply-chain performance evaluation and benchmarking are not well advanced in the literature (Hervani *et al.*, 2005). To partially address this gap we provide a framework to help organisations and policy makers measure sustainability performance of supply chains. The focus is on a food supply chain, a critical supply chain where sustainability issues are very prominent and sustainability performance is important to operation in the modern food production and consumption system.

Following Stevens (1989), the food supply chain is a sequence of stages that represent economic activities through which resources, materials and information flow downstream and upstream for the production of food products and services for ultimate consumption by consumers. The food supply chain is also a network of organisations, often integrated businesses encompassing several stages of production and distribution (Fine *et al.*, 1996). In this chapter, we adopt a definition of a food supply chain that comprises the following stages: agricultural production, food processing, food wholesaling, food retailing and food catering; the approach used by the United Kingdom Department for Environment, Food and Rural Affairs (DEFRA, 2006).

Environmental, social and ethical concerns and growing negative impacts of globalised food supply chains have contributed to increased interest in evaluation of sustainability performance within product lifecycles from ‘farm to folk’ and assessment of sustainability impacts of food supply chain, companies and individual food products (Marsden *et al.*, 1999; Courville, 2003; Weatherell *et al.*, 2003; Ilbery and Maye, 2005; Maloni and Brown, 2006; Matos and Hall, 2007). The operations of the food supply chain are seen in terms of the production and consumption system, with broad sustainability implications for economy, health, development, communities and the natural environment (Marsden *et al*., 1999; Hinrichs and Lyson, 2008; Roth *et al*., 2008).

Food organisations and businesses are increasingly making claims in relation to sustainability, promoting alternative food supply-chain models and marketing specific agricultural/craft products or individual places/regions through labelling and accreditation schemes (Ilbery and Maye, 2007; Holt and Watson, 2008). Many focal companies in the food supply chain (such as large supermarket retailers and brand food manufacturers and caterers) demonstrate ethical concerns through adoption and reporting on ethical codes of conduct, labour codes of conduct, or labelling of products that regulate social, environmental and ethical issues within the supply chains (e.g. Tesco Ethical Trading Code). In order to make sense of these schemes, for organisations to manage their food supply chains more sustainably, and for consumers to build trust in these supply chains, tools to help audit, assess and control these chains are needed. Measuring and benchmarking sustainability performance of food supply chains will be crucial for governments, businesses and communities.

This chapter aims to demonstrate how sustainability measurement can be applied to the food supply chain and proposes a new methodology for assessment of 'triple bottom line' performance of food supply-chain stages using the Analytical Network Process (ANP). First, the chapter reviews the principles of sustainability measurement, and of benchmarking and its application in the supply chain context. Second, it presents a framework for sustainability assessment of the food supply chain and demonstrates the new methodology using 2002 data for the potato supply chain in the United Kingdom (UK). Finally, the chapter discusses future trends on sustainability indicators in the food sector and includes recommendations for further sources of advice on the subject of sustainability measurement and benchmarking of supply chains.

16.2 Sustainability indicators and sustainability benchmarking in the supply chain

Assessing sustainability performance of supply chains and their subsystems is an emergent topic which has received some attention in the literature, but it is not as advanced as traditional evaluation of financial, inventory, and general operations and business performance measurement. Most of the work within assessment of sustainability performance has been focused on environmental performance or a single link (or stage) in a value chain (e.g. Veleva *et al*., 2003). Corporate environmental management systems (EMS) can be used as a tool for internal benchmarking of environmental performance (Matthews, 2003), but the EMS frameworks (such as ISO 14001) require adjustment to enable effective benchmarking beyond internal operations of an organisation. Economic input–output life-cycle analysis (EIO-LCA) may also perform high level benchmarking (Matthews and Lave, 2003) and could be used by individual firms (or plants) to gauge their performance *vis-à-vis* other firms (or plants) within their own or a related industry.

Some companies, such as Sony and Philips, have tried to evaluate and benchmark environmental performance of their products (Boks and Stevels, 2003), and the results of such benchmarking can help change product and process design practices as part of environmental improvement. Generally, benchmarking is an evaluation of organisational products, services and processes in relation to the best practice. This activity is devoted to improving organisational performance, quality and competitive advantage (Camp, 1995; McNair and Leibfried, 1995; Zairi and Youssef, 1995, 1996; Sarkis, 2001a; Manning *et al.*, 2008). Benchmarking could be successfully applied for purposes of sustainability evaluation and improvement.

Several tools have been developed for execution of benchmarking at various levels (either single process within a link or entire supply chain) such as: flowcharts, cause-and-effect diagrams, radar/spider charts, and Z charts (Camp, 1995), the European Foundation for Quality Management (EFQM) business excellence model, the balanced scorecard, service quality (SERVQUAL) framework, gap analysis, the Analytic Hierarchy Process (AHP), scatter diagrams (Min and Galle, 1996; Ahmed and Rafiq, 1998), computational geometry (Talluri and Sarkis, 2001), data envelopment analysis (DEA) (Zhu, 2002), combination of dependency analysis approach and software tool (TETRAD) with DEA (Reiner and Hofmann, 2006) and the Operational Competitiveness Ratings Analysis (OCRA) (Jayanthi *et al.*, 1999; Oral, 1993; Parkan, 1994).

Sustainable development indicators are widely used in industry and are popular with private and public bodies at various levels. Developed frameworks for analysis of sustainability parameters in a supply chain usually cover economic and environmental dimensions (e.g. Faruk *et al.*, 2001) and to a lesser extent incorporate three dimensions of sustainability (economic, environmental and social), as pointed out by Seuring and Müller (2008) in their review of sustainable supply-chain management frameworks. The three dimensions of sustainability have seen some integration into supply-chain analysis for a number of years (New, 1997; Kärnä and Heiskanen, 1998; Sarkis, 2001b).

There is a growing need for methodologies and tools for implementation of performance analysis across the supply chain for benchmarking purposes (Hervani *et al.*, 2005). Yet, some challenges arise from the difficulty of measuring performance across organisations, for example due to non-standardised data. Other challenges arise from the difficulty of tying performance results to one particular party in a multi-tiered supply chain. Finally, measuring sustainability performance itself raises challenges.

16.2.1 Triple bottom line benchmarking

The major trends for sustainable indicator creation have been: the construction of aggregate indices (such as ecological footprint and environmental sustainability index); formation of headline indicators; and the emergence of goal-oriented indicators such as Millennium Development Goals Indicators. Significant work has been completed on development and application of sustainability indicators (Bell and Morse, 1999; Pintér *et al.*, 2005). Most sustainability indicators have been targeted to the country or firm level of analysis.

Sustainability indicators may take on a number of perspectives, sometimes depending on the definition of sustainability. One such definition and indicator categorisation is the triple bottom line. The triple bottom line accounting of business operations refers to the assessment of corporate implications for 'planet, people and profit'; it has received a lot of consideration within business and industry (Elkington, 1997). Triple bottom line accounting aims to measure and balance economic, social and environmental aspects of organisational performance. The concept extends from sustainable development debate as it captures three dimensions of sustainability. It has been widely applied to reporting practices within the industry and is promoted by voluntary initiatives such as the Global Reporting Initiative and AA1000 Assurance Standard. Many organisations now use the triple bottom line as a basis of their sustainability reports (Kolk, 2004; KPMG International, 2008).

There is an extensive literature on assessment of sustainability impacts of food production, concentrating on effects of single or several stages of the food supply chain, although not many analyse the entire extent of the food supply chain from agricultural production to retail. The studies assign various boundaries of assessment (supply chain, production system, country or region) and focus on different units of assessments (single food commodity or food product, production system, or several food products) (Faist *et al.*, 2001; Courville, 2003; Biffaward, 2005; Collins and Fairchild, 2007; Van Hauwermeiren *et al.*, 2007). With reference to food supply chains, the focus of many sustainability assessments has been traditionally on agricultural production (McNeeley and Scherr, 2003; Filson, 2004); however, there are many assessment frameworks developed that incorporate stages of food processing, food retailing and transportation (Heller and Keoleian, 2003; Green and Foster, 2005).

Various approaches have been introduced to measure sustainability of food supply chains, selecting multiple levels of analysis including regional, industrial, and firm levels. Some specific sustainability assessment frameworks developed for the food sector include:

- lifecycle assessment (LCA) of environmental impacts of food products (Andersson, 2000; Hagelaar and van der Vorst, 2002);
- lifecycle related approach to sustainability impacts (Heller and Keoleian, 2003);
- farm economic costing (Pretty *et al.*, 2005);

- food miles (Garnett, 2003; AEA Technology Environment, 2005);
- energy accounting in product lifecycle (Dutilh and Kramer, 2000; Carlsson-Kanayama *et al.*, 2003);
- material flow and energy use of food products (Faist *et al.*, 2001);
- economically extended material flow analysis (Kytzia *et al.*, 2004);
- ecological footprints (Gerbens-Leenes *et al.*, 2002; Collins and Fairchild, 2007);
- mass balance of food sectors (Linstead and Ekins, 2001; Biffaward, 2005); and
- farm sustainability indicators (OECD, 2001).

In the United Kingdom, public bodies have produced several sustainability measures and guidelines for the food supply chain (MAFF, 1999, 2000; DEFRA, 2002a, 2002b, 2005, 2006), and the private sector has also made attempts to measure its sustainability impacts (FDF, 2002; J Sainsbury Plc, 2005; Marks and Spencer, 2005; Tesco, 2005; Unilever, 2005).

In summary, there has been an emergent set of investigations related to benchmarking and performance measurement of sustainability. Most of the research is oriented toward individual firms or processes rather than toward analysis of entire supply chains. The efforts to measure supply-chain performance have primarily centred on economic performance such as efficiency, whilst attempts to measure sustainability mostly assess firm- or product-level performance with a strong emphasis on environmental performance. There is a significant need to measure sustainability across the supply chain incorporating economic, social and environmental performances; however, methodologies for incorporating stakeholder aspects and additional sustainability dimensions are rare. In the next section, we describe a methodology to do a complete assessment of the food supply chain using sustainability indicators, applying it to a sector level, rather than a firm level, that enables comparison of stages in the food supply chain and could be applied further to benchmark food supply chains between each other.

16.3 Sustainability indicators for the food supply chain

This section outlines a methodology for assessing sustainability performance within the supply chain utilising data for a potato supply chain in the UK. We propose to use data for general industrial level analysis (that can be applied to commodities or products such as potatoes or flowers or other general agricultural products such as beef, chicken, etc.). Although strategic information can be obtained from product-level measurement and benchmarking (Wever *et al.*, 2007), we use a higher level perspective for our analysis. We aim to compare stages in the food supply chain to identify problem areas, and inform and improve cooperation in the food sector for enhanced sustainability performance.

Firstly, the assessment aims to reflect the current food supply chain by including stages of agriculture, food processing, food wholesaling, food retailing and food catering, and secondly, it aims to assess the complete triple bottom line and measures the effects of the supply chain operations on three dimensions: economic, social and environmental.

Our proposed methodological framework for sustainability benchmarking of the supply chain consists of four major stages:

(i) Identification of sustainability indicators (see Section 16.3.1).
(ii) Raw data gathering and data transformation using performance rescaling (Section 16.3.2).
(iii) Data gathering and adjustment using ANP (Section 16.4.1).
(iv) Sensitivity analysis of results, Section 16.4.2).

16.3.1 Identification sustainability indicators

The proposed sustainability indicators were identified on the basis of sustainable development objectives and principles that are applicable for the food sector. Specifically, the indicators were developed on the basis of objectives for sustainable development, outlined by the United Nations Commission for Sustainable Development (UNCSD, 1998) for business and industry, and those stated in Agenda 21 (UN, 1992) that could be applied for business and industry operations. UNCSD (1998) recognised that sustainable industrial policy and responsible entrepreneurship are at the heart of sustainable development. Industry, including the food industry, can contribute to a variety of interrelated economic, social and environmental objectives for sustainable development including the: (i) promotion of economic growth and encouragement of an open, competitive economy (economic objectives); (ii) creation of productive employment, gender equality, improvement of labour standards, increased access to education and health care (social objectives); and (iii) protection of natural environment and improvement of environmental performance (environmental objectives).

Then, appropriate criteria for measuring the progress towards these objectives were selected, followed by a final choice of indicators (see Table 16.1). Selected indicators are deliberately generic as they could be applied to various food products and compared between the stages in the supply chain. Chosen indicators enable assessment of sustainability objectives at a national level. For example, the sequence for selection of an indicator within the economic dimension could be demonstrated as follows. Economic objective of sustainable development such as promotion of economic growth could be measured by productivity within an industry at a national level. A specific indicator is selected then to measure productivity such as Gross Value Added per workforce, data for which are readily available with statistical services. Although initially, more than 50 indicators were drawn for the assessment of the food system (Yakovleva and Flynn, 2004); the number of indicators was reduced, accommodating the data collection process based on secondary sources (research reports, market reports and statistical data). Only 9 indicators were selected for assessment of five stages of the supply chain, three indicators per each dimension of sustainability, amounting to 45 units of measurement (Yakovleva, 2007) (Table 16.1).

16.3.2 Data gathering and data rescaling

The second stage of the proposed methodological framework includes the collection of raw data for calculation of chosen indicators. The data were collected for the potato supply chain in the UK for 2002 from DEFRA and Office for National Statistics (see Table 16.2). Potatoes represent an important product for the UK domestic production and consumption; this product penetrates various stages in the food supply chain including fresh and processed production routes (see Fig. 16.1).

The third stage of our methodological framework involves rescaling and normalisation of data to enable analysis and comparison the data for various stages in the supply chain. Indicators were allocated scores on a scale of 1 and 6 using linear interpolation. '0' stands for no available information,

Table 16.1 Identification of sustainability indicators

Sustainable development objective	Measurement criteria	Sustainability indicator
Economic dimension		
• Promotion of economic growth	○ Productivity	▪ Indicator 1: GVA per workforce, £ (A)
• Encouragement of open and competitive economy	○ Diversity and structure of the industry	▪ Indicator 2: Share of large enterprises, % (B)
• Changing consumption pattern	○ Reducing transportation of imported products	▪ Indicator 3: Import dependency, % (C)
Social dimension		
• Creation of productive employment	○ Employment volumes	▪ Indicator 4: Number of employees per enterprise (D)
	○ Quality of employment	▪ Indicator 5: Average wages per person per year, £ (E)
• Achieving equality	○ Gender balance at workplace	▪ Indicator 6: Female vs. male employment, % (F)
Environmental dimension		
• Reduction in resource use	○ Energy consumption	▪ Indicator 7: Purchase of energy for own consumption per enterprise, £ (G)
	○ Water consumption	▪ Indicator 8: Purchase of water for own consumption per enterprise, £ (H)
• Protection of natural environment	○ Waste disposal	▪ Indicator 9: Cost of sewage and waste disposal per enterprise, £ (I)

Table 16.2 Sustainability indicators for the potato supply chain in the UK (data for 2002) (Adapted from Yakovleva, 2007) Note: This work contains statistical data from ONS which is Crown copyright and reproduced with the permission of the controller of HMSO and Queen's Printer for Scotland. The use of the ONS statistical data in this work does not imply the endorsement of the ONS in relation to the interpretation or analysis of the statistical data

Stage of the food supply chain/Dimension of sustainability/Indicators				
Agricultural production	Units	Potato	Agriculture	Total UK economy
Economic indicators				
Number of enterprises		4581	142 840	1 619 195
Total output	£'000	544 000	15 508 000	1 948 458 000
Total output	'000 tonnes	6663	n/a	n/a
Output per enterprise	£'000	118	108	1203
Output per enterprise	'000 tonnes	1.45	n/a	n/a
GVA	£'000	n/a	7 137 000	926 275 000
Labour productivity (GVA per workforce)	£	n/a	12 976	35 600
Large enterprises	%	16%[1]	14%[2]	2%[3]
Imported products vs. domestic	%	9%	38%	n/a
Social indicators				
Total employment, average per year	people	n/a	550 000	26 000 000
Employee per enterprise	people	n/a	3.8	16.1
Average gross wages per employee (min)	£ per year	n/a	15 735[4]/3 467[5]	21 685
Male vs. female employment full time labour	%	n/a	n/a	63%
Environmental indicators				
Purchase of energy for own consumption per enterprise	£'000	n/a	n/a	n/a
Purchase of water for own consumption per enterprise	£'000	n/a	n/a	n/a
Cost of sewage and waste disposal per enterprise	£'000	n/a	n/a	n/a
Food processing	Units	Potatoes	Food & drink manufacturing	Total UK industry
Economic indicators				
Number of enterprises		60	7535	164 366
Total output	£'000	1 400 000	67 576 000	531 081 000
Total output	'000 tonnes	1940	n/a	n/a
Output per enterprise	£'000	23 333	896	3238
Output per enterprise	'000 tonnes	32.33	n/a	n/a
GVA	£'000	585 000	19 643 000	179 061 000
Labour productivity (GVA per workforce)	£	53 182	40 252	45 160
Large enterprises, turnover £5m+	%	27%	15%	7%

Table 16.2 Continued

Food processing	Units	Potatoes	Food & drink manufacturing	Total UK industry
Imported products vs. domestic	%	7%	15%	26%
Social indicators				
Total employment, average per year	people	11 000	488 000	3 965 000
Employee per enterprise	people	183.33	64.76	24.1
Average gross wages per employee	£ per year	19 273	18 193	20 635
Male vs. female employment full time labour	%	62%	70%	63%
Environmental indicators				
Purchase of energy for own consumption per enterprise	£'000	1535	634	484
Purchase of water for own consumption per enterprise	£'000	208	67	27
Cost of sewage and waste disposal per enterprise	£'000	299	133	43

Food wholesaling	Units	Potatoes	Agri-food wholesale	Total UK wholesale
Economic indicators				
Number of enterprises		880	17 218	113 812
Total output	£'000	2 245 700	70 032 000	388 989 000
Output per enterprise	£'000	2552	4067	3412
GVA	£'000	349 400	7 678 000	52 643 000
Labour productivity (GVA per workforce)	£	47 216	34 124	42 834
Large enterprises, turnover £5m+	%	13%	7%	7%
Imported products vs. domestic	%	21%	38%	n/a
Social indicators				
Total employment, average per year	people	7400	225 000	1 229 000
Employee per enterprise	people	8.4	13.1	10.8
Average gross wages per employee	£ per year	13 888	16 876	19 129
Male vs. female employment full time labour	%	71%	73%	73%
Environmental indicators				
Purchase of energy for own consumption per enterprise	£'000	75	21	161
Purchase of water for own consumption per enterprise	£'000	5	1	8
Cost of sewage and waste disposal per enterprise	£'000	18	3	16

Table 16.2 Continued

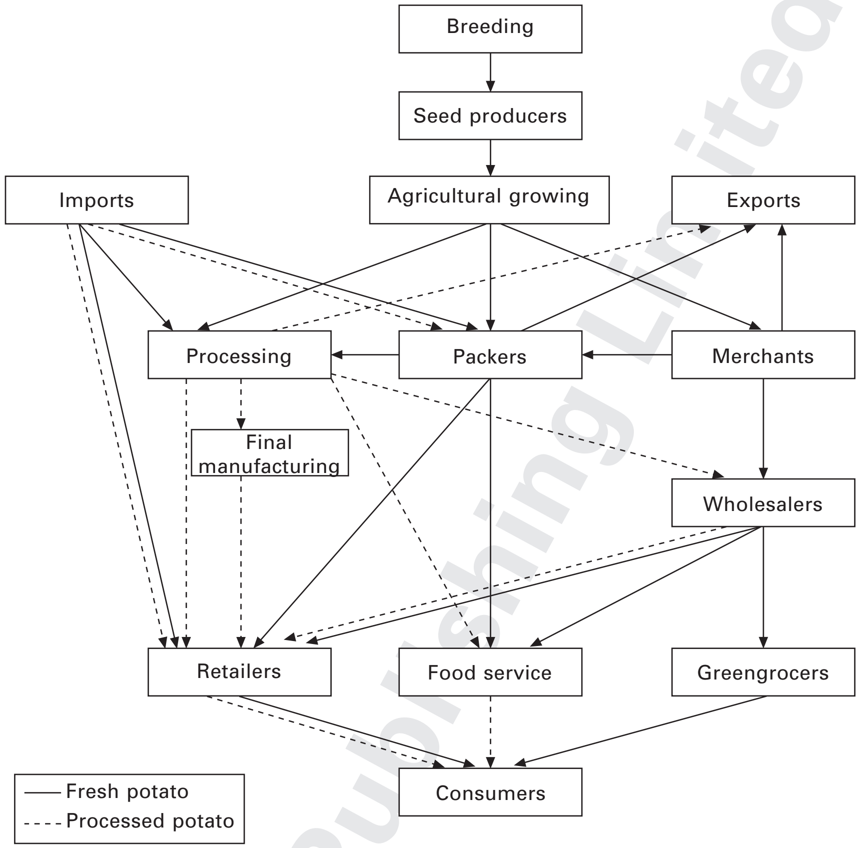
Food retailing	Units	Potatoes	Food and drink retail	Total UK retail
Economic indicators				
Number of enterprises		1400	66 703	207 513
Total output	£'000	3 415 000	71 000 000	265 211 000
Total output	'000 tonnes	3338	n/a	n/a
Output per enterprise	£'000	2439	1064	1275
Output per enterprise	'000 tonnes	2.38	n/a	n/a
GVA	£'000	86 800	17 510 000	53 185 000
Labour productivity (GVA per workforce)	£	12 765	13 820	17 285
Large enterprises, turnover £5m+	%	0.2%	1%	1%
Imported products vs. domestic	%	21%	38%	n/a
Social indicators				
Total employment, average per year	people	6800	1 267 000	3 077 000
Employee per enterprise	people	4.9	18.9	14.8
Average gross wages per employee	£ per year	4840	7812	8798
Male vs. female employment full time labour	%	54%	54%	50%
Environmental indicators				
Purchase of energy for own consumption per enterprise	£'000	13	477	173
Purchase of water for own consumption per enterprise	£'000	1	32	13
Cost of sewage and waste disposal per enterprise	£'000	2	28	12

Food catering (non-residential)	Units	Potatoes	Non-residential catering	Total UK economy
Economic indicators				
Number of enterprises		8500	107 739	1 619 195
Total output	£'000	700 000	46 436 000	1 948 458 000
Total output	'000 tonnes	3141	n/a	n/a
Output per enterprise	£'000	82	431	1203
Output per enterprise	'000 tonnes	0.36	n/a	n/a
GVA	£'000	324 000	18 002 000	926 275 000
Labour productivity (GVA per workforce)	£	12 226	12 221	32 200
Large enterprises, turnover £5m+	%	1%	1%	2%
Imported products vs. domestic	%	21%	38%	n/a
Social indicators				
Total employment, average per year	people	26 500	1 473 000	26 000 000

Table 16.2 Continued

Food catering (non-residential)	Units	Potatoes	Non-residential catering	Total UK economy
Employee per enterprise	people	3.1	13.7	16.1
Average gross wages per employee	£ per year	6327	6327	21 685
Male vs. female employment full time labour	%	49%	49%	63%
Environmental indicators				
Purchase of energy for own consumption per enterprise	£'000	124	124	n/a
Purchase of water for own consumption per enterprise	£'000	22	22	n/a
Cost of sewage and waste disposal per enterprise	£'000	15	15	n/a
Total food supply chain	**Units**	**Potatoes**	**Food and drink**	**Total UK economy**
Economic				
Number of enterprises		15 421	342 035	1 619 195
Total output	£'000	8 304 700	270 552 000	1 948 458 000
Total output	'000 tonnes	6479	n/a	n/a
GVA	£'000	1 345 200	69 950 000	926 275 000
Labour productivity (GVA per workforce)	£	26 019	17 474	32 200
Large enterprises	%	11%	7%	2%
Imported products vs. domestic	%	16%	30%	n/a
Social				
Total employment, average per year	people	51 700	4 003 000	26 000 000
Average gross wages per employee	£ per year	8866	9842	21 685
Male vs. female employment full time labour	%	59%	61%	63%
Environmental				
Purchase of energy for own consumption per enterprise	£'000	437	314	n/a
Purchase of water for own consumption per enterprise	£'000	59	30	n/a
Cost of sewage and waste disposal per enterprise	£'000	83	45	n/a

[1]Potato holdings with 20 ha of land and over.
[2]Agricultural holdings with 100 ha of land and over (data from DEFRA (2003), *Agriculture in the United Kingdom 2002).*
[3]Enterprises with a turnover of more than £5m.
[4]Average wages per person per year, full-time labour.
[5]Average wages per person per year, gross wages in agriculture divided by total employment in agriculture in 2002.



Note:

- Breeding – the process of developing new varieties of potatoes;
- Seed selection – the stage where potato seeds are selected and improved for better potato production. Potato seeds are produced and later supplied to the farms.
- Agricultural growing – the stage where potatoes grow from seed to the stage of their harvesting. Potatoes are gathered and then transported to the distribution or processing stage.
- Imports – potatoes and potato products brought from abroad.
- Exports – potato products send to foreign countries for trade.
- Merchants – are engaged in exports and imports, supply for processing, packing and wholesale of potatoes at the stages of distribution.
- Packing – the stage when potatoes are cleaned, graded, weighed, packed and priced and later supplied to retailers. This stage refers to either primary processing or commonly distribution stages of the supply chain.
- Processing – the stage of value adding, such as peeling, pre-cooking, cooking, seasoning, preparation of various products.
- Final manufacturing – the stage for value adding leading to chilled production, where potatoes are used as ingredients for the preparation of soups, ready meals, salads, etc.
- Wholesale – the stage at which wholesalers acquire potatoes and potato products and distribute them amongst retailers and market outlets.
- Green grocery sale – the stage of retail through green-grocers, who are supplied by the wholesalers.
- Retail – includes supermarkets and other outlets, except for green-grocers.
- Food service – includes fast food service, restaurants, takeaways, work canteens, etc.
- Consumption – refers to household consumption of potatoes and potato products, including purchasing, storing, cooking, consuming and disposing of food.

Fig. 16.1 Potato supply chain in the United Kingdom.

score '1' reflects low benefit to sustainability and score '6' represents a high level of sustainability benefit. The scale for each indicator was developed based on general notions of a maximum desirable sustainability benefit or value and a minimum unacceptable or undesirable sustainability value. The indicator score ranges are defined in Table 16.3. The actual scores for each supply chain stage and food type are reported in Table 16.4.

If applied to a firm level, score '6' can represent sustainability targets at a firm level and within public policy context, score '6' can represent sustainability objectives or policy targets. Thus, the proposed assessment framework can be applied to monitor sustainability performance of supply chains over time either at a national level or at a firm level using policy goals or corporate sustainability targets. The framework can be used to make relative comparisons between various commodities, but most importantly can be applied to make relative comparisons between various models of supply chain configuration and methods of production (e.g. organic, slow food and conventional, etc) for same product or products produced by different supply chains (companies or retailers). If applied to a company level, the

Table 16.3 Scoring sustainability indicators (Adapted from Yakovleva, 2007)

Indicators *Mark*	0 n/a	1 Very poor	2 Poor	3 Fair	4 Average	5 Good	6 Excellent
Productivity (GVA per workforce, thousand pounds)	n/a	0	12.0	24.0	36.0	48.0	60
Market concentration (% of large enterprises)	n/a	40	32.0	24.0	16.0	8.0	0
Trade importance (import dependency, %)	n/a	100	80.0	60.0	40.0	20.0	0
Employment (employees per enterprise, number of people)	n/a	0	4.0	8.0	12.0	16.0	20
Wages (average gross wages per employee per annum, thousand pounds)	n/a	0	5.4	10.8	16.2	21.6	27
Gender balance (male vs. female employment full time labour, %)	n/a	100	90.0	80.0	70.0	60.0	50
Energy use (purchase of energy for own consumption per enterprise, thousand pounds)	n/a	1000	800.0	600.0	400.0	200.0	0
Water use (purchase of water for own consumption per enterprise, thousand pounds)	n/a	80	64.0	48.0	32.0	16.0	0
Waste (cost of sewage and waste disposal per enterprise, thousand pounds)	n/a	100	80.0	60.0	40.0	20.0	0

Note: 0-information not available, 1-lowest score, 6-highest score

Table 16.4 Indicator scores for each stage of the potato supply chain (Adapted from Yakovleva, 2009)

	Indicators								
	Economic			Social			Environmental		
Supply Chain Stage	A	B	C	D	E	F	G	H	I
Agriculture									
Potato	0.00	4.00	5.55	0.00	0.00	0.00	0.00	0.00	0.00
Benchmark: Food production	2.08	4.25	4.10	1.95	1.64	0.00	0.00	0.00	0.00
Food processing									
Potato	5.43	2.63	5.65	6.00	4.57	4.80	1.00	1.00	1.00
Benchmark: Food and drink processing	4.35	4.13	5.25	6.00	4.37	4.00	2.83	1.81	1.00
Food wholesale									
Potato	4.93	4.38	4.95	3.10	3.57	3.90	5.63	5.69	5.10
Benchmark: Agro-food wholesale	3.84	5.13	4.10	4.28	4.13	3.70	5.90	5.94	5.85
Food retail									
Potato	2.06	5.98	4.95	2.23	1.90	5.60	5.94	5.94	5.90
Benchmark: Food and drink retail	2.15	5.88	4.10	5.73	2.45	5.60	3.62	4.00	4.00
Food catering									
Potato	2.02	5.88	4.95	1.78	2.17	6.00	5.38	4.63	5.25
Benchmark: Non-residential catering	2.02	5.88	4.10	4.42	2.17	6.00	5.38	4.63	5.25

Note: A = Labour productivity (GVA per workforce); B = Large enterprises, turnover £5m+; C = Imported products vs. domestic; D = Employees per enterprise; E = Average gross wages per employee; F = Male vs. female employment full time labour; G = Purchase of energy for own consumption per enterprise; H = Purchase of water for own consumption per enterprise; I = Cost of sewage and waste disposal per enterprise.

development benchmarking framework could assist consumers to evaluate sustainability performance of equivalent product lines.

16.4 Application of analytical network processing (ANP) to sustainability scores

16.4.1 Adjustment of sustainability scores using ANP

The fourth stage of our methodological framework is the most intricate. The values in Table 16.4 represent adjusted scores based on ranges as defined in Table 16.3. This rough estimate may not be adequate as it does not consider the relative importance of each of these factors with respect to each other, nor does it consider the interrelationships amongst various factors and indicators. To further this methodology we introduce a weighting scheme based on multi-attribute rating technique, ANP, to more accurately represent the performance of these actual supply chains.

ANP is a generalised form of the multi-criteria decision making technique, the Analytical Hierarchy Process (AHP) (Saaty, 1980). ANP offers a solution to scoring methods (Sarkis and Sundarraj, 2000). In the context of sustainability, the complexity of evaluating sustainability and assigning scores arises from multiple relationships and interlinkages amongst the sustainability factors within and between the sustainability dimensions (Sarkis, 2003). ANP modelling is a method that can incorporate interdependencies amongst factors and indicators included in the sustainability evaluation through utilisation of pairwise comparisons made by decision makers. The pairwise comparisons used as the inputs to ANP can allow sustainability evaluators to integrate the perception of relative importance amongst sustainability factors or parameters. ANP can structure the sustainability factors in a hierarchical (or network) relationship and thus help evaluators to assign weights for sustainability factors in the performance evaluation exercise (following Dou and Sarkis, 2008).

For this sustainability assessment, a general ANP model is constructed (illustrated in Fig. 16.2) that considers the relationships and interrelationships amongst a variety of sustainability factors such as:

(i) Interrelationships amongst the general sustainability factors or sustainability dimensions (external interdependency). For these relationships we can argue that economic factors are influenced by both social and environmental factors; and the social factors are influenced

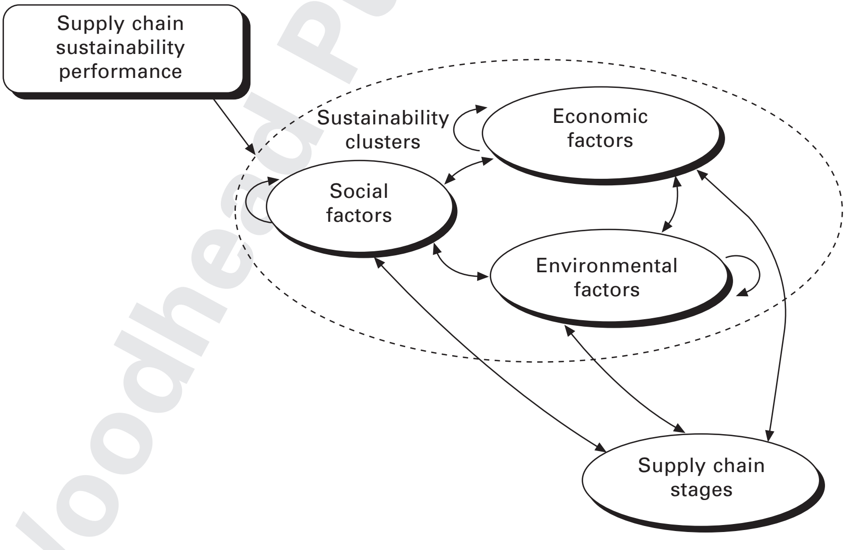


Fig. 16.2 A high-level schematic of the ANP network decision model for evaluating a supply chain's performance.

by the environmental and economic factors, etc. These relationships are shown in Fig. 16.2 by the double-arrowed lines that go between the clusters of factors.

(ii) Within each sustainability dimension, there is an internal interdependency between sustainability factors or indicators. For example, for environmental factors there are influencing relationships amongst factors of Water Consumption, Energy Consumption and Waste Generation (similar to the interdependencies of the general sustainability factors). We can evaluate these interdependencies and they are represented by the 'looped' arcs on each of the general sustainability factors.

(iii) In the hierarchical structure, the relative importance of the three general clusters (sustainability dimensions) influences the overall objective (sustainability performance evaluation of the supply chain), which is the goal of this model. This relationship is represented by the arrow from the objective to the overall cluster. Relative importance weights will also be determined for these general clusters.

(iv) There are also relative importance weights for each of the sustainability factors within their respective sustainability dimensions. These are not shown on the high level diagram but appear in the initial supermatrix (see Table 16.5) in the last nine rows of the supermatrix underneath columns labelled 'Env', 'Social' and 'Eco'.

(v) There are hierarchical representations of the supply chain stages' influence on each of the general sustainability dimensions and the influence of each of the specific sustainability factors on each of the supply-chain stages. These relationships are represented by the double-arrowed lines between the supply chain stages and sustainability factors.

For this study, we determine relative importance weights partly using opinions of an expert with an in-depth knowledge of the potato supply chain in the UK and partly using our opinions as an illustrative example. It is important to mention that the view of experts on sustainability issues in the supply chain is significant in determining the relative importance weights, which affects the final scores for the selected indicators and the overall index. Therefore, we selected a knowledgeable specialist with a substantial experience on sustainability aspects of the potato supply chain. As part of the weight evaluation process, a questionnaire was developed. An excerpt from the full questionnaire is shown in Table 16.6. All questions in the questionnaire are formulated as pairwise comparisons and are used to construct pairwise comparison matrices. These pairwise comparison matrices are used to determine the relative weights for the factors that are compared.

Pairwise comparison questions (105) are used to fully acquire the information for the three clusters of sustainability factors, each with three sub-factors, for the five stages of the food supply chain. For example, with respect to the first level of interrelationships in the ANP mode, the following three questions were posed:

Table 16.5 Initial supermatrix for ANP network decision model

	Obj	Env	Social	Eco	Agri	Proc	Whole	Retail	Cater	EnCon	WatCon	Waste	Employ	Wages	Gender	LabProd	Markcon	ImpDep
Obj	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Env	0.177	**0.500**	**0.084**	**0.375**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Social	0.304	**0.084**	**0.500**	**0.125**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Eco	0.519	**0.417**	**0.417**	**0.500**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Agri	0.000	0.535	0.233	0.078	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Proc	0.000	0.264	0.342	0.302	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Whole	0.000	0.035	0.041	0.033	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Retail	0.000	0.134	0.218	0.466	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cater	0.000	0.032	0.166	0.121	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EnCon	0.000	**0.785**	0.000	0.000	0.567	0.319	0.778	0.333	0.333	**0.500**	**0.250**	**0.375**	0.000	0.000	0.000	0.000	0.000	0.000
WatCon	0.000	**0.066**	0.000	0.000	0.323	0.460	0.111	0.333	0.333	**0.417**	**0.500**	**0.125**	0.000	0.000	0.000	0.000	0.000	0.000
Waste	0.000	**0.149**	0.000	0.000	0.110	0.221	0.111	0.333	0.333	**0.084**	**0.250**	**0.500**	0.000	0.000	0.000	0.000	0.000	0.000
Employ	0.000	0.000	**0.761**	0.000	0.715	0.460	0.742	0.633	0.701	0.000	0.000	0.000	**0.500**	**0.375**	**0.375**	0.000	0.000	0.000
Wages	0.000	0.000	**0.191**	0.000	0.218	0.221	0.203	0.304	0.204	0.000	0.000	0.000	**0.375**	**0.500**	**0.125**	0.000	0.000	0.000
Gender	0.000	0.000	**0.048**	0.000	0.067	0.319	0.055	0.063	0.095	0.000	0.000	0.000	**0.125**	**0.125**	**0.500**	0.000	0.000	0.000
LabProd	0.000	0.000	0.000	**0.701**	0.701	0.429	0.685	0.685	0.726	0.000	0.000	0.000	0.000	0.000	0.000	**0.500**	**0.417**	**0.084**
Markcon	0.000	0.000	0.000	**0.097**	0.202	0.143	0.234	0.234	0.198	0.000	0.000	0.000	0.000	0.000	0.000	**0.125**	**0.500**	**0.417**
ImpDep	0.000	0.000	0.000	**0.202**	0.097	0.429	0.080	0.080	0.076	0.000	0.000	0.000	0.000	0.000	0.000	**0.375**	**0.084**	**0.500**

Note:
In grey – weights determined by potato supply chain expert, in bold – weights determined by the authors.

Table 16.6 Extract from the questionnaire on comparative importance of sustainability indicators in the food supply chain

On the scale of one to nine please rate the significance of one issue over the other issue. Please mark with X one of the nine boxes provided for each answer.

No.	Questions	Extremely less important	Very much less important	Less important	Slightly less important	Equal	Slightly more important	More important	Very much more important	Extremely more important
		1	2	3	4	5	6	7	8	9
1	*In terms of SUSTAINABILITY OF THE FOOD SUPPLY CHAIN*									
A	How significant are environmental factors when compared to economic factors?									
B	How significant are environmental factors when compared to social factors?									
C	How significant are social factors when compared to economic factors?									
2	*In terms of their ENVIRONMENTAL IMPACT*									
A	How much more important are agricultural activities when compared to food processing activities?									
B	How much more important are agricultural activities when compared to food wholesale activities?									
C	How much more important are agricultural activities when compared to food retail activities?									
D	How much more important are agricultural activities compared to food catering?									

Table 16.6 Continued

No.	Questions	Extremely less important	Very much less important	Less important	Slightly less important	Equal	Slightly more important	More important	Very much more important	Extremely more important
		1	2	3	4	5	6	7	8	9
E	How much more important are food processing activities when compared to food wholesale activities?									
F	How much more important are food processing activities when compared to food retail activities?									
G	How much more important are food processing activities when compared to food catering activities?									
H	How much more important are food wholesale activities when compared to food retail activities?									
I	How much more important are food wholesale activities when compared to food catering activities?									
J	How much more important are food retails activities when compared to food catering activities?									
3	*In terms of their SOCIAL IMPACT*									
A	How much more important are agricultural activities when compared to food processing activities?									

B	How much more important are agricultural activities when compared to food wholesale activities?									
C	How much more important are agricultural activities when compared to food retail activities?									
D	How much more important are agricultural activities compared to food catering?									
E	How much more important are food processing activities when compared to food wholesale activities?									
F	How much more important are food processing activities when compared to food retail activities?									
G	How much more important are food processing activities when compared to food catering activities?									
H	How much more important are food wholesale activities when compared to food retail activities?									
I	How much more important are food wholesale activities when compared to food catering activities?									
J	How much more important food retails activities when compared to food catering activities?									

- How much more important is the influence of social factors on economic factors when compared to environmental factors in the food supply chain?
- How much more important is the influence of economic factors on environmental factors when compared to social factors in the food supply chain?
- How much more important is the influence of environmental factors on social factors when compared to economic factors in the food supply chain?

The responses were represented on a 1–9 Likert-type scale with a '1' response representing the 1/9 value for standard AHP, meaning extremely less important, and a '9' response meaning extremely more important. Table 16.5 reports the importance ratings derived from the responses of a potato supply chain expert (highlighted in grey are the weights determined by the potato expert and in bold are the weights determined by the authors).

Using these numbers as inputs, ANP determines the relative importance weights of each of the factors. The relative importance weights are calculated from each set of pairwise comparisons. An example pairwise comparison matrix comparing the relative importance of each of the sustainability factor groups, environmental, social, and economic, on the overall benchmarking exercise is shown in Table 16.7. The results of this pairwise comparison matrix show that economic factors (0.519) represent the greatest importance on the supply chain performance on sustainability by this decision maker. The relative importance is followed by social factors (0.304), then by environmental factors (0.177).

Each of these relative importance weights computed by a pairwise comparison matrix is then used to populate the initial supermatrix. The supermatrix is used to generate the final weightings after all the interdependencies, and relationships amongst the factors are integrated. The results of the example pairwise comparison matrix from Table 16.7 are shown as a vector of three weights in the first column of Table 16.5, under the 'obj' heading. After completing populating the supermatrix, we then have to make it 'column stochastic'. That is, the supermatrix is computed by normalising the summation of all the weights in a column to a sum of 1. The next step is to arrive at a convergent (stable) set of weights. One way of arriving at a convergent set of weights is to raise the matrix to a sufficiently high power where the

Table 16.7 Pairwise comparisons and ratings of general sustainability clusters on the overall objective

Cluster	*Environmental*	*Social*	*Economic*	Importance Rating
Environmental	1	1	1/5	0.177
Social	1	1	1	0.304
Economic	5	1	1	0.519

scores are no longer changing to a specified number of decimal places. For our example, we stopped when the weights stabilised to the 10^{-4} power.

The final converged ANP scores for the potato supply chain are displayed in the converged supermatrix in Table 16.8. Highlighted in bold in the grey area are the global weights for each of the sustainability factors (indicators) that sum to 1. Final sustainability indicators are computed by weighting the indicator scores reported in Table 16.4 by the global ratings of Table 16.8 for each stage in the potato supply chain (see Table 16.9).

16.4.2 Sensitivity analysis

As a final stage of the proposed supply-chain sustainability indicator framework, a sensitivity analysis can be performed to evaluate the robustness of the obtained weights. To evaluate the sensitivity of the final values or relative influence weights of the various sustainability factors, a simple perturbation approach may be applied. That is, one vector of weights within a supermatrix (usually an influential vector such as the overall sustainability dimension weights) can be selected. The perturbations may occur by changing the weight structure of the vector. Many approaches may be used. One extreme approach is to give all the weight within a vector of weights a given factor and then calculate the converged weights of the supermatrix. This process then can be repeated for each factor within a vector. For example, initially we give all the weight 1.000 to the economics factor from the three major sustainability grouping factors and determine the final scores. Then we can see what happens to these final scores when we shift the full weighting to the environmental factor, and so on. An alternative mechanism is to change the weights over a range of 0 to 1 for a given factor in a vector, while the relative importance ratio of the other factors remains constant. The process will require recalculation of the converged supermatrix for each point within that range.

After determining the relative importance of the sustainability factors (indicators), the hierarchy of sustainability factors according to their weights in descending order is as follows: (i) market concentration; (ii) labour productivity; (iii) employment; (iv) import dependency; (v) wages; (vi) energy use; (vii) water use; (viii) waste; (ix) employment gender ratio. According to the opinion of the potato expert, the economic dimension of sustainability has a larger weight (0.5191) than the social (0.304) and environmental (0.177) dimensions.

Since sustainability factors for each stage have the same weights, we can compare the sustainability performance according to these factors between the stages in the supply chain. According to the final (weighted) sustainability scores, considering that we have no complete data for the stage of agricultural production, the stage of food wholesaling scored the highest in terms of sustainability performance with a sustainability index of 4.6, followed by the stage of food retailing (index of 4.3) and the stage of food

Table 16.8 Converged supermatrix for ANP network decision model

	Obj	Env	Social	Eco	Agri	Proc	Whole	Retail	Cater	EnCon	WatCon	Waste	Employ	Wages	Gender	LabProd	Markcon	ImpDep
Obj	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Env	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Social	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Eco	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Agri	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Proc	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Whole	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Retail	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cater	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
EnCon	**0.105**	0.217	0.072	0.086	0.125	0.125	0.125	0.125	0.125	0.375	0.375	0.375	0.000	0.000	0.000	0.000	0.000	0.000
WatCon	**0.105**	0.217	0.072	0.086	0.125	0.125	0.125	0.125	0.125	0.375	0.375	0.375	0.000	0.000	0.000	0.000	0.000	0.000
Waste	**0.070**	0.145	0.048	0.057	0.083	0.083	0.083	0.083	0.083	0.250	0.250	0.250	0.000	0.000	0.000	0.000	0.000	0.000
Employ	**0.131**	0.079	0.245	0.081	0.143	0.143	0.143	0.143	0.143	0.000	0.000	0.000	0.429	0.429	0.429	0.000	0.000	0.000
Wages	**0.113**	0.068	0.212	0.070	0.124	0.124	0.124	0.124	0.124	0.000	0.000	0.000	0.371	0.371	0.371	0.000	0.000	0.000
Gender	**0.061**	0.037	0.114	0.038	0.067	0.067	0.067	0.067	0.067	0.000	0.000	0.000	0.200	0.200	0.200	0.000	0.000	0.000
LabProd	**0.142**	0.081	0.081	0.198	0.114	0.114	0.113	0.114	0.114	0.000	0.000	0.000	0.000	0.000	0.000	0.341	0.341	0.341
Markcon	**0.144**	0.082	0.082	0.201	0.115	0.115	0.115	0.115	0.115	0.000	0.000	0.000	0.000	0.000	0.000	0.346	0.346	0.346
ImpDep	**0.130**	0.075	0.075	0.182	0.104	0.104	0.104	0.104	0.104	0.000	0.000	0.000	0.000	0.000	0.000	0.313	0.313	0.313

Note: In grey-global weights for each of the sustainability indicators that sum to 1.

Table 16.9 Weighted sustainability scores for each stage in the potato supply chain

Indicator/Stage	Agriculture	Processing	Wholesale	Retail	Catering
EnCon	0	0.105	0.591	0.624	0.565
WatCon	0	0.105	0.597	0.624	0.486
Waste	0	0.070	0.357	0.413	0.368
Employ	0	0.786	0.406	0.292	0.233
Wages	0	0.516	0.403	0.215	0.245
Gender	0	0.293	0.238	0.342	0.366
LabProd	0	0.771	0.700	0.293	0.287
Markcon	0.576	0.379	0.631	0.861	0.847
ImpDep	0.722	0.735	0.644	0.644	0.644
Total	1.298	3.759	4.567	4.306	4.040

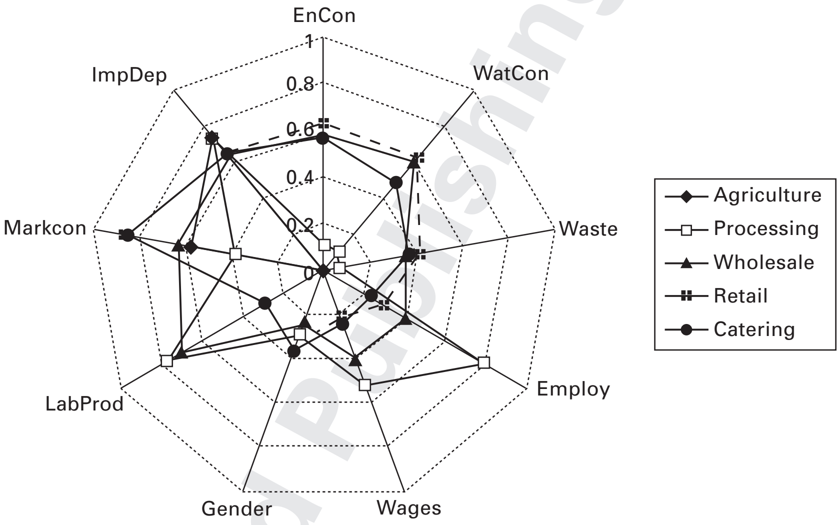


Fig. 16.3 Weighted sustainability factors for the potato supply chain.

catering (index of 4.0) (see Table 16.7). The higher the score (maximum of 6), the better the stage is performing in terms of sustainability within the three dimensions economic, social and environmental as determined by the range of scores in Table 16.3. The final scores for each supply chain stage are illustrated in a spider diagram (see Fig. 16.3). This method includes the interrelationships between the sustainability dimensions and sustainability factors (chosen sustainability criteria) within their respective sustainability dimensions. An advantage of this scoring and weighting scheme is that we can arrive at a single sustainability index score for each stage and compare the stages between each other. Policy makers or supply chain managers seeking to improve performance should see what aspects of a particular food supply chain stage make it more sustainable.

The overall sustainability index of the potato supply chain is 3.594, and is an arithmetic mean of five indices for the potato supply chain stages. As the stage indices already reflect the interrelationships between stages and sustainability factors, there is no need for weighting supply chain stages when computing the overall supply chain index. For further applications of the proposed assessment method, the calculation of an overall sustainability index for the entire food supply chain could be useful for benchmarking different food supply chains or production models.

The method uses statistical data for the food supply chain, in combination with expert opinion, to construct an overall index of sustainability. In this chapter we utilised the opinion of a potato expert together with the authors' opinion; however, for further application of the method, the opinion of several experts on particular supply chains could be utilised. Since we constructed and ranged indicators between 1 and 6, where score '6' is the desirable sustainability performance, we can say that the closer the overall sustainability score to score '6', the closer is the supply chain stage to conforming to set sustainability objectives or targets within the three dimensions of sustainability.

16.5 Future trends

Potential users of the framework may wish to consult stakeholders when selecting sustainability indicators for the assessment, and consult them on what would be the desirable sustainability values before ranging the indicators from 1 to 6. Furthermore, potential users (such as policy makers and individual organisations) may set the maximum scores as planned targets for sustainability performance (either policy targets or individual corporate performance targets) and use the framework to measure supply chain performance over time or between product lines. The higher the score, the closer the supply chain overall is to achieving sustainability targets or maximum set desirable sustainability values within three dimensions: economic, social and environmental. The framework can be used to make relative comparisons between various commodities, but most importantly can be applied for comparison of various configurations of the supply chain. In this study we used three dimensions of sustainability; however, more themes or dimensions could be utilised for the development of sustainability indicators.

Reporting on supply chain relations in the food sector has increased; large supermarket chains now publish sections on supply-chain operations in their sustainability or corporate social responsibility reports, and place similar information on corporate websites (see for example, Tesco's policy on Responsible Buying and Selling on Tesco's corporate website and CSR report). Monitoring, measuring and reporting on sustainability effects of supply chains will be growing as the demand for regulation of supply chain relations is increasing.

Since supply-chain relations are now seen within the merit of sustainability, CSR and corporate citizenship, various concepts will be applied to the formulation of supply-chain relations and their monitoring. We have applied the triple bottom line concept to measuring sustainability performance in the supply chain. Other concepts for evaluation of performance in the supply chain could be applied that may cover more aspects of sustainability or CSR, such as ethical dimensions, organisational effectiveness, human rights, animal welfare and so on. Since the use of ethical, social and environmental labelling is growing, there will be an increasing need for consumers to find their way through these claims.

The development of sustainability indicators needs to take into account the relative importance of sustainability measures and trade-offs between sustainability dimensions or individual sustainability factors. Moreover, since various groups perceive sustainability differently, it is important to involve stakeholders in developing sustainability measures for the supply chain, their importance, ranges and metrics.

16.6 Sources of further information and advice

16.6.1 Assessments of environmental and social impacts of food production and distribution

Andersson K (2000), 'LCA of food products and production systems', *International Journal of LCA*, 5(4), 239–248, doi: 10.1007/BF02979367

Barrett H R, Ilbery B W, Browne A W and Binns T (1999), 'Globalisation and the changing networks of food supply: The importation of fresh horticultural produce from Kenya into the UK', *Transactions of the Institute of British Geographers*, 24(2), 159–174, doi: 10.1111/j.0020-2754.1999.00159.x

Carlsson-Kanyama A (1997), 'Weighted average source points and distances for consumption origin – tools for environmental impact analysis?' *Ecological Economics*, 23, 15–23, doi: 10.1016/S0921-8009(97)00566-1

Dewick P, Foster C and Green K (2007), 'Technological change and the environmental impacts of food production and consumption: The case of the UK yogurt industry', *Journal of Industrial Ecology* 11 (3), 133–146, doi: 10.1162/jiec.2007.1241

Fritz M and Schiefer G (2008), 'Food chain management for sustainable food system development: A European research agenda', *Agribusiness*, 24(4), 440–452. doi: 10.1002/agr.20172

Gerbens-Leenes P W, Moll H C, Schoot Uiterkamp J M (2003), 'Design and development of a measuring method for environmental sustainability in food production systems', *Ecological Economics*, 46(2), 231–248, doi:10.1016/S0921-8009(03)00140-X

16.6.2 Sustainability reporting standards

AccountAbility (2008), *AA 1000 Series*, http://www.accountability21.net/aa1000series

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16.6.3 Supply chain measurements and benchmarking for sustainability

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