DAVID B GRANT, ALEXANDER TRAUTRIMS, CHEE YEW WONG

SUSTAINABLE LOGISTICS AND SUPPLY CHAIN MANAGEMENT

REVISED EDITION

PRINCIPLES AND PRACTICES FOR SUSTAINABLE OPERATIONS AND MANAGEMENT

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Sustainable Logistics and Supply Chain Management

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Introduction

This revised first edition of our book discusses issues pertaining to sustainable logistics and supply chain management (SCM), and is different from other books as it takes a holistic view across the supply chain from point of origin through to point of consumption. Logistics and supply chain activities permeate almost every aspect of our lives and thus their abilities to impact the natural environment are of significant importance. This revision was prepared in response to feedback requesting additional guidance and suggestions for using the book in classroom and seminar settings. Hence, this revision includes updated tables where applicable and a set of additional teaching resources available at the Kogan Page website.

The objective of this book is to introduce principles and practices that facilitate responsible SCM and sustainable logistics operations, and consider factors of logistics and SCM affecting the natural environment beyond the usual factors of road miles, fuel use and carbon dioxide (CO_2) emissions that have been well discussed in freight transportation; see for example *Green Logistics: Improving the environmental sustainability of logistics* by McKinnon *et al* (2012), which is a good complement to this book. As an example of wider factors, business globalization has meant that many products are not manufactured in national markets anymore; they are outsourced and manufactured in lesser-developed countries, particularly in Asia, and then shipped all around the world. How then does a national firm ensure sustainability in its global supply chain? Further, most seasonal fresh food such as fruit and vegetables are now available all year round due to sourcing in foreign markets or the use of sophisticated chilled storage and transport to prevent premature spoiling or ageing. Thus, should consumer markets return to more seasonal goods to reduce the effects of continuous product availability on the environment?

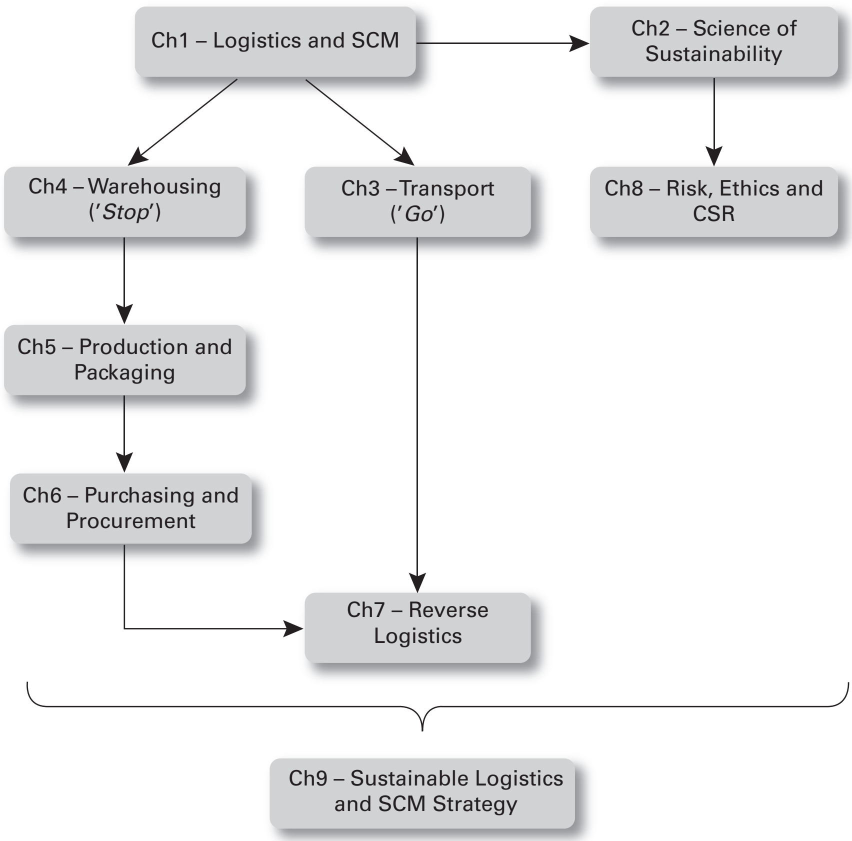
These types of activities and factors have increased the effects that logistics and SCM have on the natural environment. Accordingly, logistics and supply chain strategies and operations are discussed in this book in the context of raising awareness of, and shifting an emphasis to, responsible, ethical and sustainable practices. It is important for firms, consumers and societies to do so and be proactive in considering these issues. Otherwise, legislation may emerge to limit the impact of logistics and SCM on the environment that may be more draconian than these three stakeholders would wish.

For example, the UK government considered and then abandoned a scheme of personal or individual 'carbon credits' in 2008 (BBC News, 2013). Under the scheme individuals would have an annual CO_2 emission limit for fuel and energy use, which they could only exceed by buying credits in a secondary carbon-trading market from those who were under limit. The scheme was considered more progressive than taxation as it would redistribute wealth from rich to poor, be transparent and easy for everyone to understand, and fair as everyone would get the same annual CO_2 limit. However, the government's initial studies found that the cost of introducing the scheme would be between £700 million and £2 billion and cost a further £1–2 billion a year to operate. There were also practical difficulties identified in deciding how to set annual limits taking into account a person's age, location, health and activities such as business and personal travel. From a different sustainability perspective, many Members of Parliament admitted that the public were likely to be opposed to the scheme, but urged the government to be courageous in going ahead with it. With a General Election less than two years away the government decided to discontinue further taxpayer-funded research on the scheme while noting that the concept of personal carbon limits and trading had not been completely abandoned.

But, there is recent evidence that individual attitudes may be changing. Only 57 per cent of US citizens believed climate change was real in 2010; that number increased to 70 per cent in September 2012 (Porter, 2012). Thus, circumstances in the United States may be right for the introduction of a carbon tax and values being mooted at the end of 2012 were for a tax of US \$20 per US ton of CO_2 emitted, beginning in 2013 with an escalator of 4 per cent per annum. It is estimated that such a tax would raise US \$1.25 trillion by 2023 and reduce CO_2 emissions by 14 per cent below 2006 levels.

Today, individuals can calculate their own CO_2 emissions or 'carbon footprint' through websites such as www.carbonfootprint.com. Factors for this calculation include energy use in the home, personal and public transport including aeroplane flights, and lifestyle preferences such as in-season or organic food, packaging, recycling and recreation. What this discussion about CO_2 emission limits and carbon taxes has highlighted is that

FIGURE 0.1 Chapter pathways in this book



environmental issues are complex, involve elements of logistics and SCM in many facets of everyday life, and are not easy to solve.

The pathways for the nine chapters in this book are shown in Figure 0.1. Each chapter is designed to be read and considered on its own, but the flow of the chapters is based on two basic premises in logistics and supply chain activities: transportation or 'Go' and storage/production or 'Stop' (Grant, 2012), which are discussed in Chapter 1.

Chapter 1 provides an overview of logistics and SCM activities and contemporary thought about sustainability as it pertains to logistics and SCM, including the impact of logistics and SCM activities on the natural environment and ecosystem, and vice versa. Topics include the nature of various logistical and supply chain activities, the increase in globalization that has lengthened supply chains, and the debate on being more lean and efficient versus a need to compress time and be more agile and responsive.

Chapter 2 discusses the science of sustainability, the environmental and climate change debate, the nature of the Earth as an ecosystem that must be in balance but also make sense for people and business, ie a 'triple bottom line' approach. Topics here include the Earth's climate and sustainability as an ecosystem, the greenhouse effect and related gases such as carbon monoxide, sulphur dioxide and methane, and the impact of human activity on sustainability affecting the use of natural resources such as minerals, oil, gas and water, as well as population growth and food production.

The following five chapters consider sustainability issues in depth as they relate to the main functional 'Go' and 'Stop' activities of logistics and SCM. Chapter 3 leads off by considering freight transport as the major contributor to the logistics and SCM environmental debate due to its overwhelming importance in the supply chain and its very visible presence. Topics include the nature of various freight transport modes, trends in global freight issues of emissions, fuel consumption and congestion, and the evolution of technology to assist greener transport alternatives.

Chapter 4 discusses sustainable warehousing; after transportation storage facilities in the form of factories, warehouse and distribution centres contribute the second largest logistical and supply chain impact on the natural environment. Topics here include designing green warehouses and inherited emissions from construction materials, reducing resources consumption in existing warehouses, location of warehouses and network design, and LEED and BREEAM certifications for sustainable facilities.

Chapter 5 takes the storage discussion further by considering issues related to product design, cleaner production and packaging that are the underlying tenets in producing goods in factories. Topics here include environmental product design to use less materials, ie design for the environment and being lighter and easier to transport; novel production methods that consume less energy/natural resources and produce less pollution; and packaging for logistics versus the environment, ie reusable packaging and recycling of packaging materials.

The next two chapters go one step beyond production and logistics and supply chain activities. Chapter 6 considers sustainable purchasing, procurement and supplier relationships that are important antecedents for the production process. Topics here include drivers and barriers for environmental or green purchasing, procurement frameworks and a product whole-lifecycle assessment. A product's lifecycle assessment naturally includes a reverse element to recycle or dispose of unwanted products or components.

Chapter 7 discusses reverse logistics and recycling that are important factors for transportation or 'Go' and storage or 'Stop' functions. Topics discussed include reverse-loop product recovery options such as refurbishing, remanufacturing, cannibalization and recycling, current regulatory frameworks and issues surrounding these topics.

Chapter 8 then returns to a more holistic approach to consider risk, corporate social responsibility (CSR) and ethics relating to logistics and SCM. Topics include the wider scope of CSR including environmental sustainability and social responsibility, the different risks affecting a global supply chain including environmental disasters, ethical models and the notion of 'greenwash,' and global and industrial initiatives that promote economic, environmental and social sustainability.

Finally, Chapter 9 provides an overview of sustainable logistics and SCM strategy and firms can incorporate environmental considerations in such strategies, including accounting for the related costs and benefits. Topics include strategic planning for sustainability, the redesign of supply chain networks, sustainable logistics and supply chain performance measurement, and environmental cost trade-offs in logistics systems and supply chains.

It has been our pleasure to write this book and we sincerely hope you find it informative and inspiring on holistic environmental concerns as they apply to logistics and SCM.

David B Grant, Alexander Trautrims and Chee Yew Wong

Logistics and supply chain management

01

The nature of logistics and supply chain management

Logistics and supply chain management (SCM) are far-reaching activities that have a major impact on a society's standard of living. In Western developed societies we have come to expect excellent logistics services and only tend to notice logistical and supply chain issues when there is a problem. To understand some of the implications to consumers of logistics activities, consider:

- The difficulty in shopping for food, clothing, and other items if logistical and supply chain systems do not conveniently bring all of those items together in one place, such as a single store or a shopping centre.
- The challenge in locating the proper size or style of an item if logistical and supply chain systems do not provide for a wide mix of products, colours, sizes and styles through the assortment process.
- The frustration of going to a store to purchase an advertised item, only to find the shipment is late in arriving.

These are only a few of the issues that highlight how we often take for granted how logistics touches many facets of our daily lives. However, the various activities associated with logistics and SCM also have an impact on environmental sustainability and this chapter provides an overview of logistics and SCM and such impacts.

We first need to define what is meant by logistics and SCM. The Council of Supply Chain Management Professionals (CSCMP) in the United States defines logistics management as (2012):

> that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverses flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers' requirements.

Logistics management activities typically include inbound and outbound transportation management, warehousing, materials handling, order fulfilment, logistics network design, inventory management, supply/demand planning, and management of third-party logistics (3PL) service providers. To varying degrees, the logistics function also includes sourcing and procurement, production planning and scheduling, packaging and assembly, and customer service.

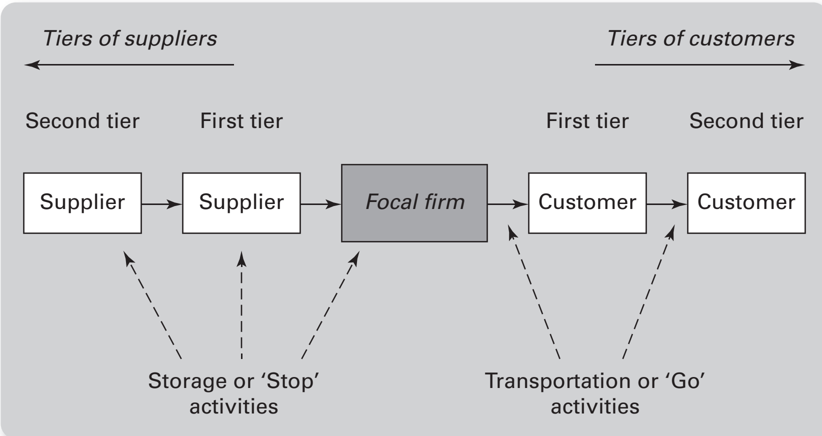
The term 'supply chain management' or SCM was introduced by consultants in the 1980s and since then academics have attempted to give theoretical and intellectual structure to it. CSCMP (2012) defines SCM as encompassing:

> the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies.

SCM is thus considered an integrating function with a primary responsibility for linking major business functions and business processes within and across companies into a cohesive and high-performing business model. It includes all of the logistics management activities noted above, as well as manufacturing operations, and drives the coordination of processes and activities with and across marketing, sales, product design, finance, and information technology, and is thus a more holistic view of a firm.

Nevertheless, there are some overlaps, which have prompted some authors (Larson and Halldórsson, 2004) to consider whether SCM is merely a relabelling of logistics due to a lack of understanding by academics and practitioners of what supply chains are and what supply chain managers do. Is it an intersection between logistics and SCM as SCM represents a broad strategy across all business processes in the firm and the supply chain, or a union whereby logistics is a sub-set of SCM due to a wider supply chain and business process perspective of SCM? The CSCMP definitions above represent

FIGURE 1.1 A simplified supply chain



a unionist view and this book adopts them as they appear intellectually sound and bring clarity to the sustainability debate.

A firm's simplified supply chain and its relevant features are shown in Figure 1.1. The immediate customer and supplier of the firm under consideration, or the focal firm, are known as 'first tier' customers and suppliers. The first tier customer's first tier customer and the first tier supplier's first tier supplier are the focal firm's second tier customer and supplier respectively, and so on. Between each supply chain node, where a node is the focal firm, a supplier or a customer, goods are moved by transportation or 'Go' activities. Further, goods are stored and/or processed at each node in storage or 'Stop' activities. Essentially, logistics and SCM are about 'Go' or 'Stop' activities, although details of each of them can be quite complex (Grant, 2012). However, it will be useful to consider this simple 'Go' or 'Stop' concept when discussing sustainability issues as they really occur during transportation or storage activities.

Logistics and SCM activities have a significant economic impact on countries and their societies. For example, these activities accounted for 8.5 per cent or US $1.28 trillion of US gross domestic product (GDP) in 2011 (Wilson, 2012) and 7.2 per cent of or €850 billion GDP across the 27 European Union countries in 2008 (A T Kearney and European Logistics Association, 2009). Thus, a small percentage decrease in these activities would see major environmental impacts from reductions in the use of fuel, water and other natural resources and decreases in waste and emissions. An example of such an impact, together with the associated problems in measuring this impact, is discussed in the following box.

How should we reduce food miles?

What are the correct measures to use when assessing sustainability and logistics and SCM generally, or 'food miles' in particular? A UK study of food miles has determined that the globalization of the food industry, with increasing food trade and wider geographical sourcing of food within the UK and overseas, has led to a concentration of the food supply base into fewer, larger suppliers, partly to meet demand for bulk year-round supply of uniform produce; major changes in delivery patterns with most goods now routed through supermarket regional distribution centres (RDCs) and a trend towards use of larger heavy goods vehicles (HGVs); and a switch from more-frequent food shopping on foot at small local shops to a concentration of sales at supermarkets by weekly shopping, using cars. This rise in food miles has led to increases in environmental, social and economic impacts such as CO_2 emissions, air pollution, traffic congestion, accidents and noise, and a growing concern over these impacts has led to a debate on whether to try to measure and reduce food miles.

The UK study also estimated that the annual amount of food tonne kilometres moved in the UK by HGVs has increased by over 100 per cent since 1974 and the average distance for each trip has increased by over 50 per cent. UK food transport, export, import and internal, accounted for 19 million tonnes of CO_2 emissions in 2002 with estimated direct costs of £9 billion, £5 billion of which related to traffic congestion.

Yet a US study, conducted by Carnegie Mellon University in the mid-2000s and using a lifecycle assessment, found that transportation accounts for only 11 per cent of the 8.1 million tonnes of greenhouse gases generated by an average US household every year from food consumption – over 83 per cent comes from agricultural and industrial activity in growing and harvesting food. The differences in these two emissions numbers suggests different factors are taken into account in each calculation. Also, the UK study found that the increase in UK food tonne kilometres has not been accompanied by an increase in HGV food vehicle kilometres due to increases in vehicle operating efficiencies and improvements in vehicle load factors.

The US study found that greenhouse gases from food miles per food product in the United States are as follows:

red meat – 30 per cent;

dairy products – 18 per cent;

cereals, carbohydrates and fruit and vegetables – 11 per cent each;

chicken, fish and eggs – 10 per cent;

beverages, oils, sweets, condiments and others – the remaining 21 per cent.

The US study's authors also found that switching to a totally local diet saves about 1,000 miles per year, but that the following dietary trade-offs are almost as effective in reducing food miles: replacing red meat once a week with chicken, fish or eggs saves 760 miles per year and eating vegetables one day a week saves 1,160 miles per year.

The UK study concluded that a single indicator based on total food kilometres is an inadequate indicator of sustainability; the impacts from food transport are complex and involve many trade-offs between different factors. The study's authors recommended a suite of indicators be developed to take into account transport modes and efficiency, differences in food production systems and wider economic and social costs and benefits.

Shaw *et al* (2010) concluded that while logistics and supply chain performance measurement is a well-established area of research, green or environmental logistics and supply chain performance measurement are relatively under-researched in both the logistics/supply chain and environmental management literature. Despite being an important and topical subject, the lack of clear direction and legislation on environmental management makes it difficult for firms to know exactly what they should measure and how, whether it is food miles, emissions or recycling. More theoretical and empirical research needs to be undertaken to give firms and other stakeholders the tools to do so.

Sources: AEA Technology (2005); Shaw *et al* (2010); Whitty, J (2012)

Logistics and SCM trends affecting sustainability

Environmental issues have been an area of growing concern and attention for businesses on a global scale. Transportation, production, storage and the disposal of hazardous materials are frequently regulated and controlled. In Europe, firms are increasingly required to remove and dispose of packaging materials used for their products. These issues complicate the job of logistics and SCM, increasing costs and limiting options. Important logistics and SCM trends for this millennium have been discussed in the literature (see for example Bowersox *et al*, 2000; Christopher, 2011; Straube and Pfohl, 2008) and some of these trends significantly affect sustainability. Following is a discussion of these key trends and their impacts.

Globalization

Globalization has increased tremendously since the 1970s primarily due to the development and widespread adoption of the standard shipping container, international trade liberalization, the expansion of international transport infrastructure such as ports, roadways and railroads, and production and logistics cost differentials between developed and developing countries. However, the geographical length of supply chains has increased along with their attendant environmental issues of fuel use and emissions.

The impact on logistics and SCM from globalization has been significant over the past several decades. For example, global container trade has increased on average 5 per cent a year over the last 20 years and at its peak in the mid-2000s comprised 350 million 20-foot equivalent units (TEU) a year (Grant, 2012). However, the impact of globalization doesn't only affect sea-borne containers: worldwide demand for smart phones and tablets has led to an increase in air freight volumes and prices.

For example, Apple sold a record 5 million iPhone 5s in the first three days after product launch, and sales in the last three months of 2012 were about 50 million units. Air freight rates were at their lowest in 2009 during the depths of the recession, but the rate from China to Europe/North America rose over 7 per cent between August and September 2012 to US $3.56 per kilogramme, and was predicted to rise to over US $5.00 per kilogramme by the end of 2012 in the run-up to the Christmas season (Neate, 2012).

Relationships and outsourcing

In concert with the logistics and SCM issues above, there has been a need for increased collaboration and mutually beneficial relationships among customers, suppliers, competitors and other stakeholders in an increasingly interconnected and global environment, which can have positive benefits for sustainability.

For example, two competitors could share transportation and warehousing facilities in an effort to avoid the empty running of trucks and also provide return or reverse logistics opportunities. On the other hand, many firms have outsourced their logistics and SCM activities to 3PL specialists, such as DHL or Norbert Dentressangle, to perform activities that are not considered part of a firm's core competencies. The outsourcing/3PL market is now worth over US $125 billion in the United States and over €70 billion in Europe. Across the globe, over 80 per cent of domestic and 75 per cent of international transportation or 'Go' and 74 per cent of warehousing or 'Stop' activities are outsourced, as is over 35 per cent of reverse logistics and product labelling, packaging and assembly activities (Langley and Capgemini Consulting, 2012).

Outsourcing can be very cost-effective for firms as they can efficiently concentrate on their core competencies, reduce capital expenditures and fixed assets related to transportation and storage infrastructure, cut labour and internal operating costs, and enjoy the expertise and economies of scale of the 3PL service provider. However, firms lose control of those operations that they outsource, despite service level agreements and contracts, and thus may not have control over sustainability efforts of 3PLs or their sub-contractors.

Technology

Technology is also an important factor in modern, global supply chains as it enables better, faster and more reliable communication. Logistics and SCM has interfaces with a wide array of functions and firms, and communication must occur between the focal firm, its suppliers and customers and various members of the supply chain who may not be directly linked to the firm, and the major functions within the firm such as logistics, engineering, accounting, marketing and production. Communications are thus a key to the efficient functioning of any integrated logistical or supply chain system.

The use of communications technology has increased remarkably during the last few decades due to increases in computing power and storage that have fostered the invention of personal and laptop computers, global positioning systems, 'smart' mobile phones and 2014's desirable Christmas gifts: tablets and iPads. Such technology has become increasingly automated, complex and rapid, and has enabled firms to develop faster and longer supply chains due to their ability to trace and track goods in production, storage or transit.

Order processing entails the systems an organization has for getting orders from customers, checking on the status of orders and communicating to customers about them, and fulfilling the order and making it available to the customer. Increasingly, organizations today are turning to advanced order-processing methods such as electronic data interchange (EDI) and electronic funds transfer (EFT) to speed the process and improve accuracy and efficiency, and advanced scanning technology such as radio frequency identifications (RFID) to track and trace products.

Lean versus agile

Time compression refers to ways of 'taking time out' of operations. Longer lead times and process times create inefficiencies; require higher inventory levels, greater handling, storage and transportation, more monitoring; incur a greater chance for error; and thus decrease the efficiency of the supply chain as a whole. Advanced logistics and supply chain activities and technology help compress a firm's time by developing better relationships with suppliers and customers to share more real-time information and improve its accuracy. Thus, many firms have initiated time compression strategies to significantly reduce manufacturing time and inventory.

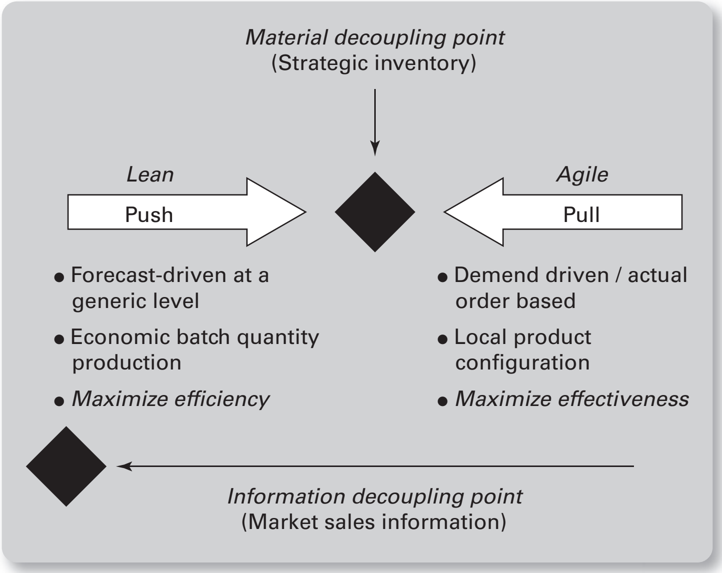
Retailers, particularly in the grocery sector where perishability is an issue, have been leaders in time compression, relying heavily on advanced computer systems involving bar coding, electronic point-of-sale (EPOS) scanning, and EDI to develop quicker responses for order processing. In fact, the grocery sector across the globe established efficient consumer response (ECR) in the 1990s to do just that (Fernie and Grant, 2008).

As a result of a need to be more efficient in production and manufacturing at an operational level and reduce times at a logistical and supply chain level, two different logistics and supply chain paradigms, 'lean' and 'agile', emerged during the 1990s. The lean paradigm is based on the principles of lean production in the automotive sector where a 'value stream' is developed to eliminate all waste, including time, and ensure a level production system (Jones *et al*, 1997). Firms make to order and therefore speculate on the number of products that will be demanded by forecasting such demand. Thus, a firm assumes inventory risk rather than shifting it through developing economies from large-scale production, placing large orders that reduce the costs of order processing and transportation, and reducing stock-outs and uncertainty and their associated costs. Speculation very much fits a lean strategy.

The agile paradigm has its origins in principles of channel postponement (Christopher, 2011). Under postponement, costs can be reduced by postponing changes in the form and identity of a product to the last possible point in the process, ie manufacturing postponement, and by postponing inventory locations to the last possible point in time since risk and uncertainty costs increase as the product becomes more differentiated from generic form, ie logistical postponement. Being agile means using market knowledge and information in what is known as a virtual corporation to exploit profitable opportunities in a volatile marketplace inventory (Christopher, 2011).

The lean approach seeks to minimize inventory of components and work-in-progress and to move towards a just-in-time (JIT) environment wherever possible. Conversely, firms using an agile approach are meant to respond in shorter time-frames to changes in both volume and variety demanded by customers. Thus, lean works best in high-volume low-variety and predictable

FIGURE 1.2 A hybrid lean and agile supply chain



environments, while agility is needed in less predictable environments where the demand for variety is high (Christopher, 2011; Jones *et al*, 1997).

While the paradigms appear dichotomous, in reality most firms are likely to need both lean and agile logistics and supply chain solutions, suggesting a hybrid strategy. Such a strategy has also been called 'leagile' (Naylor *et al*, 1999); Figure 1.2 illustrates a hybrid solution. The 'material decoupling point' represents a change from a lean or 'push' strategy to an agile or 'pull' strategy. The 'information decoupling point' represents the point where market sales or actual order information can assist forecasting efforts within the lean approach of this hybrid solution.

The impact of time compression on sustainability includes increased transportation or 'Go' and storage or 'Stop' activities in an agile supply chain, along with their associated environmental effects, to achieve levels of responsiveness and flexibility. Further, the location of transportation hubs and ports or storage and production sites may also be detrimental to the environment. For example, it has been estimated that 70 per cent of shipping emissions occur within 400 kilometres of land; thus ships contribute significant pollution in coastal communities. Shipping-related particulate matter (PM) emissions have been estimated to cause 60,000 cardiopulmonary and lung cancer deaths annually, with most deaths occurring near coastlines in Europe, East Asia and South Asia (Corbett *et al*, 2007).

The 'one-way flow' of logistics and SCM

The logistical or supply chain flow of products is predominantly one way, from raw materials/resources and producers to consumers. Reverse or return networks and systems are woefully under-developed and, for those mature networks that exist, the vagaries of the economy have significant effects.

For example, the United Kingdom was sending a lot of mixed paper and cardboard waste to China in the 2000s for reprocessing and reuse as new product packaging. However, the price of this waste fell from over £90 per tonne to £8 per tonne in late 2008 as a result of the economic recession (Sutherland and Gallagher, 2013). Consumer demand and thus Chinese production of new products slowed, with a knock-on effect that demand for mixed paper and cardboard waste as well as container shipping, particularly from West to East, also fell precipitously. At that point, none of Britain's 80 paper mills was accepting new stock and it was estimated that there were about 100,000 tonnes of local authority waste sitting in warehouses, set to double by March 2009. Another concern was that if paper is stored for longer than three months it will rot and attract vermin, rendering it worthless, and will then have to be incinerated or sent to landfill. The demand situation eased and by 2010 prices returned to around £75–£80 per tonne. However, the market remains weak due to the lingering recession and by December 2012 prices had again fallen and were around £45–50 per tonne (letsrecycle.com, 2013).

Thus, globalization, technology, lean and agile techniques and a 'one-way flow' have all contributed to increased standards of living around the world, including developing nations, which benefit from better economic activity. However, parallel increases in logistical and supply chain activities related to this prosperity have been detrimental to the natural environment in terms of increased resource use, waste and pollution as well as inefficient movement and storage of goods.

Sustainable logistics and supply chains

Abukhader and Jönson (2004) posed two interesting questions regarding logistics and SCM and the natural environment: 1) what is the impact of logistics on the environment, and 2) what is the impact of the environment on logistics?

The impact of logistics on the environment is the easier question to answer but the second question is a bit more difficult to conceptualize. However, an example should illustrate their point. Cotton does not grow naturally in many countries in northern latitudes. Thus, if people living in northern European countries or Canada desire cotton clothing or other cotton goods, some form of logistics activity such as transportation and/or warehousing will be required to bring cotton to these markets. However, the main logistical/supply chain issue here is whether the cotton should be in the form of raw materials or finished goods. The answer will depend on the design of the particular logistical system and supply chain.

Abukhader and Jönson (2004) also posited that there are three main 'themes' regarding sustainable or 'green' logistics and supply chain management:

1. reverse logistics;
2. assessment of emissions; and
3. the 'greening' of logistical activities and supply chains.

When Abukhader and Jönson wrote their article there was little use of lifecycle assessment (LCA) in logistics and supply chain management and there was little consideration of environmental impacts beyond cost-benefit analysis. That situation has improved since then (Curran, 2013) (and will be discussed further in Chapters 6 and 9), but it is important to remember that the sustainability agenda in general and its application to logistics and SCM in particular are still fairly recent and under-developed. However, some insights in this area were developed in the 1990s, as discussed in the following box.

The early days of sustainable logistics and SCM

While sustainability, 'green' and environmental issues are reasonably new to the logistics and SCM domain, early research in the 1990s considered both transportation processes in the lifecycle of a product, concentrating on the activities of the manufacturer, and reverse logistics.

An article by Stefanie Böge in 1995 was one of the first discussions on the impact of 'food miles' on consumer products and her research also quantified the environmental impact of transport. Her study of a food manufacturer in southern Germany examined all constituent parts of its strawberry yogurt in 150-gram recyclable glass jars, including the ingredients (milk, jam and sugar) and packaging of the glass container, paper label, aluminium cover, cardboard box and cardboard sheets, and glue and foil.

Böge found that the transport intensity to deliver 150-gram yogurt pots across German supply chains meant that 24 fully-packed trucks each had to travel 1,005 kilometres to distribution centres, collectively using over 10,200 litres of diesel fuel in the process. She further broke that down and noted that each yogurt pot moved a total of 9.2 metres, comprised of 5.1 metres of movement related to sub-contractors, 3.1 metres for the manufacturer, and 1.0 metres for trade distribution, and used 0.004 litres of diesel.

She concluded that there were three basic options for manufacturers: use inputs from nearer sub-contractors, improve existing vehicles, and shift to more environmentally sound freight shipment vehicles. These themes of closer sourcing, less environmentally intrusive vehicles and modal shift now have currency among those responsible for logistics and supply chain activities. However, at the time Böge's work was not considered extensively by either academics or practitioners. Her article was published in a journal outside the mainstream logistics and SCM domain; today it is an open access internet journal published by Eco-Logica Ltd. in the UK (see http://www.eco-logica.co.uk/index.html).

In 1998, Dale Rogers and Robert Tibben-Lembke at the University of Nevada Reno and James Stock at the University of South Florida wrote a monograph and book respectively on reverse logistics. Notions of recycling consumer products such as bottles and cans and product recovery management in the manufacturing domain for remanufacture or cannibalization (see Thierry *et al*, 1995) had been around since the 1950s, but little previous work existed on issues related to reverse logistical flows. The next section and Chapter 7 consider these issues more fully, but the Rogers/Tibben-Lembke and Stock works were pioneering in this area.

Sources: Böge, S (1995); Rogers and Tibben-Lembke (1998); Stock (1998); Thierry *et al* (1995)

Reverse logistics

Reverse logistics is not a new concept, as noted above. The return, recovery and recycling of products have been practised for decades. However, it is a growing area in logistics and SCM, and work by Rogers and Tibben-Lembke and Stock in 1998 set the stage for this impetus. Reverse logistics has been defined as:

> the process of planning, implementing, and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal. (Rogers and Tibben-Lembke, 1998: 2)

Note that this definition is very similar to the CSCMP definition of logistics above, with only the latter part changed. Reverse logistics encompasses all of the activities in the CSCMP definition; the difference is that reverse logistics activities occur in the opposite direction. Reverse logistics also includes processing returned merchandise due to damage, seasonal inventory, restock, salvage, recalls, and excess inventory.

There are four primary questions regarding reverse logistics from a strategic perspective:

1. What types of materials may be returned, recovered or recycled?
2. How are responsibilities defined in a reverse logistics supply chain?
3. What is it reasonably possible to return, recover or recycle?
4. How are economic value and ecological value determined?

There are also some key differences between new product and reverse logistics supply chains:

- There is uncertainty in the recovery process regarding reverse product quality or condition, quantity and timing.
- Return forecasting is an even greater problem than demand forecasting.
- There is uncertainty in consumer behaviour:
  - the consumer has to initiate the return as opposed to simply disposing of the products;
  - the consumer has to accept and purchase recovered and refurbished products;
  - the price offered and value placed by consumers on returning or recycling goods is not clear.
- The number of collection points, their location or viability are uncertain and there may be delayed uplift of products as time is not critical, ie no time compression.
- Returned products often have poor packaging and small consignment sizes, and the information, traceability and visibility may be poor.
- Inspection and separation of products are necessary and are very labour-intensive and costly.

However, providing proper refurbished or remanufactured goods can give a competitive advantage to firms and brand credibility and quality for consumers. For example, Fujifilm launched single-use cameras in 1986 under the brand name QuickSnap after market research determined that a growing segment of Japanese consumers only wanted to take pictures on an occasional basis (Grant and Banomyong, 2010). QuickSnap quickly became a popular consumer convenience product and 1 million cameras were sold in its first six months in the marketplace. However, at the beginning of the 1990s several stakeholder groups attacked the product's disposable nature that resulted in a negative impact on the brand's image and sales. Consumers began to refer to QuickSnap as 'disposables' or 'throwaways' and the media reported environmental groups' concern regarding their wastefulness.

In response to these environmental pressures, Fujifilm initiated a voluntary take-back programme and began recycling the cameras by utilizing a highly developed and original recycling system. They also redesigned the camera to use various techniques of product recovery management such that it cannot be reused or resold. Waste management is almost non-existent in the QuickSnap 'inverse manufacturing system' as a near 100 per cent recycling rate can be achieved, even with components such as packaging for the product. In doing so Fujifilm established one of the first, fully-integrated closed-loop or reverse logistics systems for FMCG products and has since negated much of the poor environmental image of QuickSnap.

The topics of reverse logistics and product recovery management are dealt with further in Chapter 7; the use of recycled products can also be used to achieve other sustainable goals, as discussed in the following box.

Recycling rubber to meet other environmental objectives

As traffic grows around the globe there is a commensurate increase not only in the use of rubber tyres but also in road noise, which is one external form of pollution affecting people's wellbeing. One noise abatement technique is the use of roadside barriers, but they are expensive (up to US $600,000 per kilometre), can create wind tunnels, and may not be aesthetically pleasing.

However, two Swedish scientists are among several across Europe who are investigating the use a poroelastic road surface (PERS) in an attempt to reduce traffic noise. PERS is a wearing course or layer that has a porous structure and has several advantages over normal 'rubberized' asphalt or tarmac; it contains 'rubber crumbs' recycled from used tyres as an additive to the bitumen and crushed stone.

The Swedish experiments used a PERS made up of rubber particles bound with polyurethane as an additive to create a 30 mm thick structure that contained 30–35 per cent interconnecting air voids. Laboratory experiments on test specimens indicated very low wear from exposure to studded tyres and emissions particles in the air, but showed rolling resistance comparable to that of a conventional asphalt surface. Adhesion to a base asphalt course and skid resistance received particular attention and the laboratory experiments indicated satisfactory performance.

Field tests conducted on a Stockholm street carrying a mixture of light and heavy traffic indicated road noise was reduced by 8–11 dB(A), rolling resistance and braking resistance were the same as normal asphalt, and there was no significant wear on the PERS surfaces even with winter studded tyres. However, there were some technical issues beyond the cost, which was five times that of asphalt: the PERS materials significantly absorbed water, which would necessitate better drainage under the surfaces, and wear through the use of snow ploughs was significant. If cost and technical issues can be resolved, then surfaces like PERS offer some unique sustainability benefits: reducing traffic road noise and using recycled materials instead of virgin asphalt.

Sources: The Economist (2012); Sandberg and Kalman (2005)

Assessment of emissions

How do transportation and storage activities compare to other activities in society in terms of their environmental impact? Both are users of energy, for example fuel and electricity, and both produce carbon dioxide (CO_2) emissions as a result of using this energy. The World Economic Forum (2009) estimates that logistics activity accounts for 2,800 mega-tonnes of CO_2 emissions annually or about 6 per cent of the total 50,000 mega-tonnes produced by human activity, so it is not surprising that non-energy companies are beginning to assess the energy consumption of their supply chains as a way of reducing their overall carbon emissions.

The United Kingdom's domestic CO_2 emissions, excluding international aviation and shipping, are generated from four main sectors: energy supply at 40 per cent, transportation at 23 per cent, industry including manufacturing, retailing, service and warehousing at 18 per cent, and residential at 15 per cent (Commission for Integrated Transport, 2007).

Examining the transportation sector's 23 per cent of emissions in more detail, private automobiles are the primary source of CO_2 emissions at 54 per cent, followed by heavy goods trucks or lorries and vans at 35 per cent. Thus, road freight transportation accounts for just over

8 per cent of the UK's total CO_2 emissions. This is consistent with the World Economic Forum's (2009) findings.

On the energy input side, vehicle engines are becoming more efficient in terms of fuel use and emissions and there are ongoing efforts to consider alternative fuels such as biodiesel or bioethanol, hydrogen, natural gas or liquid petroleum gas, and electricity. However, these developments are still in their infancy and also have their own environmental impacts. For example, the growth of crops for biofuels requires the use of arable land, which displaces the growing of crops for food, and could lead to more forests and grasslands being cultivated for food, thus possibly negating the positive effects of greenhouse gas emissions reductions from using biofuels.

Turning to warehousing as one aspect of the industrial sector, the World Business Council for Sustainable Development (2013) notes that buildings account for 40 per cent of worldwide energy use. Initiatives to increase the efficiency of buildings in using energy and reducing emissions have been developed by the Leadership in Energy and Environmental Design certification program (LEED) in the United States and the Building Research Establishment Environmental Assessment Method (BREEAM) in the United Kingdom.

Aspects of transportation emissions assessment and performance measurement will be discussed further in Chapter 3 and 9 respectively, while further consideration of warehouses and buildings, including LEED and BREEAM, will be discussed in Chapter 4.

The 'greening' of logistical activities and supply chains

The greening of logistics activities and supply chains means ensuring that these activities are environmentally friendly and not wasteful, and particularly focus on reducing carbon emissions across the entire supply chain. The World Economic Forum (2009) argued that a collaborative responsibility for greening the supply chain resides with three groups: logistics and transport service providers, shippers and buyers as recipients of such services, and both government and non-government policy makers. They presented specific recommendations for these three groups, as follows.

Transportation, vehicles and infrastructure networks

Logistics and transport service providers should increase adoption of new technologies, fuels and associated processes where there is a positive business case, deploy network reviews of large closed networks to ensure efficient hierarchies and nodal structures, look to integrate optimization efforts across multiple networks, enable further collaboration between multiple shippers and/or between carriers and look to switch to more environmentally friendly modes within their own networks. Shippers and buyers should build environmental performance indicators into the contracting process with logistics service providers, work with consumers to better support their understanding of carbon footprints and labelling where appropriate and make recycling easier and more resource efficient. They should also support efforts to make mode switches across supply chains and begin to 'de-speed' the supply chain. Policy makers should promote further expansion of integrated flow management schemes for congested roads and make specific investments in infrastructure around congested road junctions, ports and rail junctions, mode switches to rail, short sea and inland waterways, and consider re-opening unused rail lines, waterways and port facilities with government support.

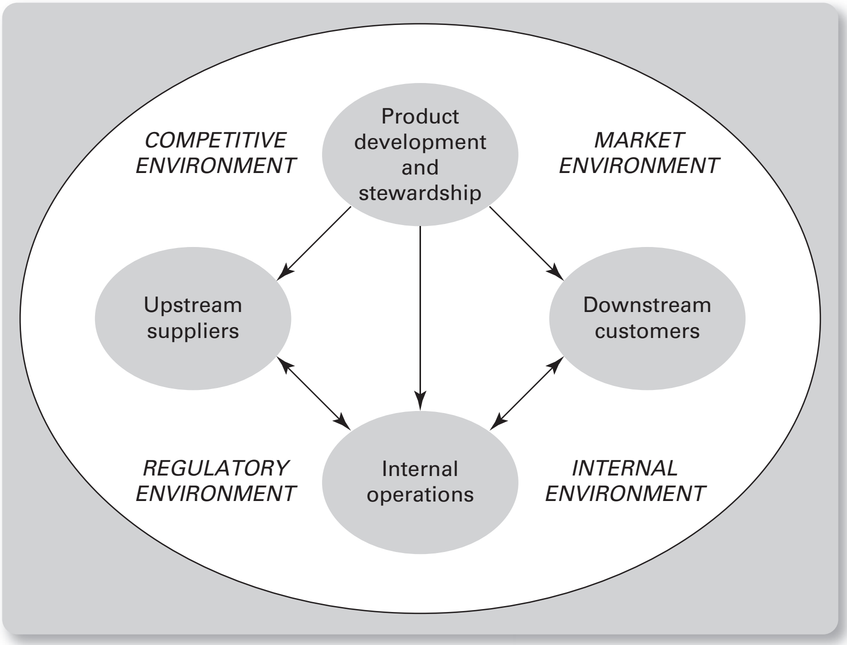
Green buildings

Logistics and transport service providers should encourage wider industry commitment to improve existing facilities through retrofitting green technologies and work towards industry-wide commitments to boost investment in new building technologies, and develop new offerings in recycling and waste management, working collaboratively with customers. Policy makers should encourage industry to commit to improvements that consider the boundaries of possibilities with current and future technologies, through individual and sector-wide actions.

Sourcing, product and packaging design

Shippers and buyers should determine how much carbon is designed into a product through raw material selection, the carbon intensity of the production process, the length and speed of the supply chain, and the carbon characteristics of the use phase. Shippers and buyers can take decisions that actively drive positive change up and down the supply chain. Shippers and buyers should agree additional standards and targets on packaging weight and elimination, and seek cross-industry agreements on modularization of transit packaging materials. They should also develop sustainable sourcing policies that consider the carbon impact of primary production, manufacturing and rework activities, and integrate carbon emissions impact into the business case for near-shoring projects.

FIGURE 1.3 A framework for a sustainable supply chain



Administrative issues

Logistics and transport service providers should develop carbon offsetting solutions for their own operations and clients as part of a balanced suite of business offerings. Policy makers should work with them to develop universal carbon measurement and reporting standards, build an open carbon trading system, review tax regimes to remove counter-productive incentives, and support efforts to move towards further carbon labelling. They should also ensure that the full cost of carbon is reflected in energy tariffs across all geographies and all modes of transport.

Another view on 'greening' the supply chain was provided by Mollenkopf (2006). She argued there are four aspects of eco-efficiency, based on earlier work by the World Business Council on Sustainable Development, that provide strategic guidance for firms operating in knowledge-based economies. These aspects, along with related supply chain applications, are shown in Table 1.1. Mollenkopf (2006) also presented a framework for creating a sustainable supply chain from the Global Environmental Management Initiative's supply chain tool, as shown in Figure 1.3.

TABLE 1.1 Four aspects of eco-efficiency and supply chain initiatives

Aspect	Description	Supply chain applications
Dematerialization	Substitution of material flows with information flows	Substituting information for inventory so as to avoid premature deployment of goods before demand is known
	Product customization	Any form of production or logistics postponement allows firms to meet more closely actual demand with less anticipatory stock, therefore less use of materials and energy
Production loop closure	Closed-loop systems and zero-waste factories, ensuring that every output can be returned to become an input into the production of another product, or returned to natural systems as a nutrient	Closed-loop supply chains are being increasingly adopted as firms look to recapture their products for refurbishment, remanufacture, and sales in primary or secondary markets; this requires a product recovery strategy and facilitated by design-for-disassembly or design-for-environment strategies
Service extension	In demand-driven economies firms need to develop customized responses to customer needs; this is increasingly being accomplished through leasing goods rather than outright purchase	Asset recovery programmes are employed to manage the return of products at the end of lease; this requires reverse logistics and reprocessing capabilities upon receipt

(*Continued*)

TABLE 1.1 (*Continued*)

Aspect	Description	Supply chain applications
Functional extension	'Smarter' products with enhanced functionality; associated services further enhance products' functional value	Product design initiatives to enhance product life with upgrades and service enhancements

The approach to using this framework begins with a firm considering why it should develop a sustainable supply chain strategy. The major factors might include regulatory changes, market demand and competitive pressures, such as Wal-Mart Canada's development of a sustainable warehouse, discussed in the following box.

Techniques for 'greening' a warehouse

Wal-Mart Canada opened a 400,000 square-foot fresh and frozen food warehouse in Balzac, Alberta in November 2010 to serve about 100 retail outlets in Western Canada. The facility is expected to reap CDN $4.8 million in energy cost savings through 2015, but will also become the model for the company's future warehouse and DC design and development.

The warehouse generates electricity from a combination of on-site wind turbine generators and roof solar panels. The refrigerated building uses low-energy, solid-state light-emitting diode (LED) lights, an advantage for the retailer because solid-state illumination keeps the facility cooler than does traditional incandescent lighting. Even though the LED lights cost an additional CDN $486,000, Wal-Mart expects annual savings of CDN $129,000 from that approach.

Wal-Mart has also custom-designed dock doors to minimize the loss of cool air from the refrigerated warehouse, monitoring cooling loss from the dock doors daily with the use of thermal imaging cameras to ensure that dock doors are not opened unnecessarily. The facility is also using hydrogen fuel cells to power its fleet of lift trucks and material handling equipment. The hydrogen-powered vehicles cost Wal-Mart CDN $693,000 more than conventional vehicles, but they are expected to generate nearly CDN $269,000 a year in operational savings. Lift trucks powered by hydrogen fuel cells are also considered more efficient because they don't have to be taken out of service for battery replacement and recharging. Warehouse workers can refuel a hydrogen fuel cell vehicle as it moves around the warehouse in as little as two minutes.

Source: CSCMP's Supply Chain Quarterly (2011)

Product development and stewardship impacts all stages of logistics and SCM. Suppliers may need to get involved in the product development process in order to design appropriately for the environment. An understanding of the lifecycle of the product is critical as to when it reaches end of use and end of life as well as the costs and environmental impacts of the product at each stage. Figure 1.3 suggests that the four external environments may act as drivers to developing a sustainable supply chain as well as providing the context in which the supply chain operates. Therefore, a solid understanding of these factors and the ability to monitor them as they change over time is paramount to developing successful sustainable strategies. For example, the EU Waste Electrical and Electronic Equipment (WEEE) Directive has caused many manufacturers to reassess their production and supply chain activities in order to be compliant with the changes in the regulatory environment.

A sustainable supply chain must also consider both upstream and downstream firms. Supplier requirements and codes of conduct can be employed to ensure that suppliers and customers behave in socially and environmentally responsible ways. Further, sustainability is also about proving the source of the product. For example, do wood products that consumers purchase come from certified, sustainable forests as endorsed by Forest Stewardship Council (FSC) guidelines? Traceability and chain of custody capabilities are necessary to ensure this is the case, and this must be demonstrable to customers.

Internal operations are at the core of a firm's activities. Transformation and logistics activities provide a plethora of opportunities for firms to reduce their environmental footprint through better waste management, reduction of hazardous substances, packaging reduction, efficient reverse logistics, and appropriate transportation. Many firms are now using design for the environment programmes so that the environmental impact of their products at end-of-life will be minimized. Product stewardship means that a supply chain must increasingly accommodate the reacquisition of product and the return flow of product/parts up the supply chain for further disposition. These activities need to be designed into a sustainable supply chain from the earliest stages of product development.

Summary

Logistics and SCM have a major impact on the global economy as well as everyday life. The concepts of transportation or 'Go', and storage or 'Stop' activities enables the right products to be in the right place in an efficient and effective manner. However, while the trends of increased globalization, outsourcing and deeper relationships, more use of technology, lean and agile supply chain processes, and a one-way flow in the supply chain have assisted logistics and SCM activities, they have also been detrimental from a sustainability perspective. Emissions of greenhouse gases, use of fuel and other natural resources, other forms of pollution, and increased levels of waste from packaging are just some of these detriments.

There are several recurring themes regarding sustainable logistics and SCM that stem from works discussed above that tie-in to these current trends for logistics and SCM. First, firms need to recognize that sustainability needs to form part of their logistics and supply chain strategies and for the right reasons; this theme is developed further in Chapters 8 and 9. Second, internal operations including transportation, warehousing and production need to be conducted as efficiently as possible; these elements of this theme feature in Chapters 3, 4 and 5 respectively. Third, relationships with upstream suppliers and downstream customers need to embrace sustainability; Chapter 6 discusses relationships with suppliers in the context of sustainable purchasing and procurement. Finally, what goes downstream in the supply chain must also come back upstream; hence reverse logistics is important and will be discussed in Chapter 7.

Some issues of sustainable logistics and supply chain activities have been examined over the past 15 years. However, they are becoming more important due to a realization that economic and environmental sustainability issues require urgent attention and that logistics and supply chain activities have a significant impact on the natural environment. The science of sustainability and its relationship to logistics and SCM will be discussed in Chapter 2. This domain is growing rapidly and many initiatives are under way to increase efficiencies in sustainability, particularly energy use and emissions. However, it is still under-developed and under-researched, particularly regarding trade-offs between a sustainable supply chain and current logistical and supply chain practices that involve long, global one-way supply chains dependent on technology, outsourcing and time compression to meet ever-increasing customer demand for more and better products in a timely manner.

Science of sustainability

02

Concepts of sustainability

Collins English Dictionary (1998) provides two definitions for sustainability: 1) capable of being sustained, ie of economic development, energy sources, etc, and 2) capable of being maintained at a steady level without exhausting natural resources or causing severe ecological damage, ie sustainable development. These two separate meanings highlight an important point that 'green is green', ie a firm's sustainability initiatives for the natural environment, or being green, need to be considered in conjunction with the economic case for long-term corporate sustainability, ie green being the colour of money.

Further, the second definition for sustainability relating to development raises the issue of consumption not only today but also for tomorrow. The philosopher John Rawls termed this issue 'intergenerational equity' whereby societies must justly determine how much of the Earth's resources they will sacrifice or not use today so that future generations will be able to access and enjoy such resources. This view helped shape a more widely-used definition of sustainable development by Brundtland (1987) as development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Sustainability is linked to corporate social responsibility (CSR) as a socially responsible firm should ensure its impact on the natural environment is minimized. But, CSR goes beyond the natural environment to include aspects of fair trade, good employment practices, and appropriate relationships with customers, suppliers and other stakeholders (CSR is discussed further in Chapter 8). The linkage with sustainability is manifested in

Elkington's (1994) 'triple bottom line' or TBL concept encompassing profits, the planet and people. The TBL posits that firms should focus on maximizing shareholder wealth or economic value they create while ensuring that they also add environmental and social value to achieve long-term natural environment security and proper working and living standards for all human beings. The TBL concept has found wide acceptance in firms, governments and non-governmental organizations (NGOs).

The natural environment has been receiving attention since the first UN Conference on the Human Environment at Stockholm in 1972. Since then there have been a number of events and meetings to raise the profile of the environment and climate change around the world including, among others, the Brundtland (1987) Commission, the initial UN Earth Summit at Rio de Janiero in 1992 that declared that polluters should pay the cost of pollution, the 1997 Kyoto Protocol which determined greenhouse gas emissions reduction targets for the world, and follow-on events such as the 2000 New York Millennium summit, the 2002 Johannesburg summit, the 2009 Copenhagen climate change conference and the 2012 Rio+20 conference.

Brundtland (1987) defined five key areas related to sustainability: species and ecosystems, energy, industry, food, and population and urban growth. These areas plus the topic of fresh water form a holistic view of sustainability and will now be discussed in turn, including their respective relationship to logistics and SCM.

Species and ecosystems

Brundtland (1987) noted that the conservation of living natural resources – plants, animals, micro-organisms and the non-living elements of the environment on which they depend – is crucial for development and that the conservation of wild living resources is now on the agenda of governments.

The climate system is a complex, interactive system consisting of the atmosphere, land surface, snow and ice, oceans and other bodies of water, and living things. For example, humans and animals require oxygen to breathe and live and exhale CO_2; plants absorb CO_2 and convert it into oxygen in a process known as photosynthesis. This activity should maintain an ecosystem balance, but the removal of plants and trees or the extinction of species put the ecosystem into imbalance.

Climate change can occur as a result of internal variability within the climate system and external variability (natural or anthropogenic). Natural variability includes phenomena such as volcanic eruptions and solar variations.

Anthropogenic variability includes human-induced changes in the composition of the atmosphere, for example a change in the concentration of greenhouse gases (GHGs).

The greenhouse effect is a naturally occurring phenomenon and without it, life on Earth would not exist as it acts as a natural thermostat for the Earth's atmosphere. Without a natural greenhouse effect, the temperature of the Earth would be 0° F (–18° C) instead of its present 57° F (14° C) and a decline of 8–10° C would plunge Europe and North America into an ice age. Climatic observations over the past 150 years have shown that temperatures at the Earth's surface have risen globally, with important regional variations. Most of the observed increase in global average temperatures since the mid-20th century is considered to be due to an observed increase in GHG concentrations (Shaw *et al,* 2010).

An article in an issue of *Nature* (Farman *et al,* 1985) documented a large seasonal disappearance of ozone from the Earth's atmosphere over Antarctica. Immediately following the *Nature* publication, 20 nations signed the Vienna Convention, which established a framework for negotiating international regulations on ozone-depleting substances. In 1988, the Intergovernmental Panel on Climate Change (IPCC) was set up jointly by the World Meteorological Organization and the United Nations Environment Programme (UNEP) to provide an authoritative international statement of scientific understanding of climate change. This action and subsequent work have determined that the need to reduce GHG emissions is the greatest long-term ecosystem challenge facing the world today.

The six major GHGs (Shaw *et al,* 2010) include CO_2, methane (CH_4), nitrous oxides (N_2O), hydrofluorocarbons (HFC), perfluorocarbons (PFC) and sulphur hexafluoride (SF_6); CO_2 is the most significant of these greenhouse gases and is the main contributor to global warming. The 1997 Kyoto Protocol legally bound industrialized nations to reduce emissions of GHGs, particularly CO_2, to an average of 5.2 per cent below 1990 baseline levels by 2012. The aim of this legislation as well as various climate change bills in the EU and UK is to maintain global CO_2 levels below 450 parts per million and limit the temperature rise to no more than 2 degrees Celsius by 2012. The UK government committed to reduce GHG emissions to at least 12.5 per cent below baseline by the same date and has also set a tougher long-term goal of reducing CO_2 emissions by 80 per cent by 2050.

Concern about increased GHGs from pollution, traffic congestion, global warming, disposal and the clean-up of hazardous materials has led to a number of environmental laws and EU directives that affect logistics systems design and strategies. GHG emissions, particularly CO_2, have been the focus of much work in logistics and SCM, especially consumer and freight transport. The UK's domestic CO_2 emissions, excluding international aviation and shipping, are generated from four main sectors (Commission for Integrated Transport, 2007): the energy supply sector (40 per cent), all modes in the transport sector (23 per cent), the industrial sector including manufacturing, retailing, services and warehousing (18 per cent) and the residential sector (15 per cent).

Examining the transport sector in more detail, private automobiles are the primary source of CO_2 emissions (54 per cent) followed by heavy goods trucks or lorries (22 per cent) and vans (13 per cent). Thus, truck and van freight transportation in the UK accounts for less than 9 per cent of total CO_2 emissions. This is consistent with worldwide estimations of 8 per cent for transport; warehousing and goods handling worldwide are estimated to add about 4 per cent to that total (McKinnon *et al,* 2012).

However, the United Kingdom's total transportation emissions have risen 11 per cent from the Kyoto baseline of 1990, faster than any other sector despite efficiencies in fuel use and emissions. This situation is primarily due to the growth in freight transport activity and is again consistent with predicted growth in freight transport, particularly road freight, all over the globe (World Business Council for Sustainable Development, 2012). (Freight transport issues are discussed in depth in Chapter 3 while warehousing and manufacturing and production are discussed in Chapters 4 and 5 respectively.)

Climate change due to GHGs is continually being discussed by the media and at international conferences, and major reports are issued regularly on the steps necessary to combat it by organizations such as the IPCC. However, proper and accurate measurement, particularly regarding alternative trade-offs and decisions, remains difficult. A recent study to determine an economic value for carbon storage and CO_2 is discussed in the following box.

Banking on carbon: The economic impact of the natural environment

A report by the David Suzuki Foundation based in Vancouver, Canada has demonstrated the economic value of maintaining a massive carbon storehouse of trees and plants to reduce carbon through the photosynthesis process. A massive greenbelt in southern Ontario, Canada encompasses some 750,000 hectares (1.8 million acres) around the western end of Lake Ontario in an area known as the Greater Golden Horseshoe (GGH). The GGH greenbelt contains natural features such as Niagara Falls and the adjacent Niagara Escarpment that runs north towards Lake Huron and the Oak Ridges Moraine system north of Toronto.

Within and surrounding these natural features are farms, forests and wetlands. The forests comprise about 24 per cent of the greenbelt and are estimated to ‘bank’ 40 million tonnes of carbon or the equivalent of 147 million tonnes of CO_2 while the wetlands ‘bank’ about almost 7 million tonnes of carbon or 25 million tonnes of CO_2. The total amount of CO_2 from both these sources is equivalent to the annual emissions of 33 million car and trucks.

The study in the report estimated there are about 87 million tonnes of carbon being stored in the GGH greenbelt. Using an average peer-reviewed estimate of CDN $53 per tonne of carbon, this greenbelt’s carbon value is about CDN $4.5 billion. Considered as an annuity over 20 years, the carbon value is CDN $370 million per year. Further, the GGH greenbelt’s ‘natural capital’ produces CDN $2.6 billion a year in critical ecosystem services, for example water storage and filtration, and plant pollination, or about CDN $3,470 per greenbelt hectare.

These values allow for cost trade-offs to be considered when alternative land use is proposed. Removing any parts of the GGH greenbelt for other use such as industry or housing will release its banked or stored carbon into the atmosphere and thus have a negative impact on the natural environment. The GGH region is under tremendous pressure for growth; the report notes that by 2031 the population is expected to increase from 9 million currently to 11.5 million and an additional 107,000 hectares (257,000 acres), or just over 14 per cent of the current GGH greenbelt will be urbanized.

Conversely, any attempt to increase the GGH greenbelt’s ability to store carbon also represents a positive environmental value that can be accounted for as ‘carbon offsets’ and traded against carbon release or generation. For example, there are around 7,100 farms in the greenbelt that generate CDN $1.5 billion in annual earnings. If the Ontario provincial government introduces a carbon cap and carbon trading system, farmers could create carbon offsets by planting more trees or adopting no-till farming techniques to plant crops and control weeds without turning the soil and thus releasing carbon.

However, caution must be used when considering any such initiatives. Although golf courses provide carbon capture and storage through their vegetative land cover, ongoing maintenance operations including cutting regularly and applying fertilizers and pesticides generate CO_2 emissions. Golf courses also use large amounts of water for irrigation, often drawing this resource directly from rivers, streams or groundwater. Such water use puts strain on existing hydrologic systems. The Oak Ridges Moraine system, which serves as an essential groundwater discharge and recharge area for millions of Ontarians and a direct drinking water source for over 250,000 residents, already has 41 golf courses in place and plans for more would exacerbate ecological issues.

The David Suzuki Foundation report is useful as it provides a methodology to enhance discussions about the measurement of carbon and CO_2 and alternative strategies in order to provide an economic and ecological balance in southern Ontario society, as well as provide a framework for application in other areas around the globe.

Sources: Kidd (2012); Tomalty (2012)

Energy

Energy is necessary for daily survival as it provides heat for warmth, cooking and manufacturing, or power for transport and mechanical work. Conventional energy sources for these services have included fossil fuels such as oil and gas, coal, nuclear, wood and other primary sources such as solar, wind, or water power. Primary energy sources used around the globe continue to be mainly non-renewable: oil, natural gas, coal, peat and nuclear power. The resources used for such sources, ie crude oil, coal, peat and uranium, will eventually run out through depletion.

An important question that relates to Rawls' 'intergenerational equity' is when will we reach the point where these resources are used up? Certainly, as these resources become scarcer the cost to extract them and thus market prices costs for users will both increase, prompting what economists call a 'threshold price' or the point where users will switch to a lower-cost alternative. There has been a concern over the past 40 years that daily production of oil and natural gas will soon be exceeded by daily demand, ie the concept of 'peak oil'; however, the following box suggests otherwise.

When will we run out of oil?

The concept of peak oil argues that global oil production will peak relative to increasing demand such that supply will be insufficient for all needs, which would trigger massive price increases and perhaps rationing. However, while recent oil price increases and widespread oil reservoir depletion suggested that the globe has passed the peak oil point, it is not clear if that is in fact the case.

Some argue that we have seen this all before: in 1975 M K Hubbert, a Shell geoscientist, successfully predicted a decline in US oil production and suggested that global supplies would peak in 1995, while in 1997 the petroleum geologist Colin Campbell estimated it would happen before 2010. And now, a report by Leonardo Maugeri published by the Harvard Kennedy School argues that a new oil boom is taking place.

Maugeri's thesis is that recent price rises have stimulated exploration in higher-cost, marginal oil fields and that a net additional capacity of over 17 million barrels of oil per day (mbd) to around 110 mbd will be added to global supplies by 2020. Average supplies in 2011 were 93 mbd, which was about 107 per cent of daily demand. The economic prerequisite to justify investment for this increase is a price greater than US $70 per barrel; the average price has hovered around US $95 per barrel since July 2011. Over US $1 trillion was invested in oil production in 2010–11 and a record US $600 billion was projected for 2012.

Conventional oil production is thus growing throughout the world at an unexpected rate, although some areas of the world such as the United States, Canada and the North Sea are witnessing an apparently irreversible decline of conventional production. These areas are, however, enjoying a boom in unconventional oil production from tar sands and shale oil. It is estimated that the Bakken shale oil reservoir in the state of North Dakota contains almost as much oil as Saudi Arabia, although much of it cannot be extracted. Nevertheless, North Dakota oil production has increased from 100,000 barrels of oil per day (bopd) in 2005 to 550,000 bopd in early 2012. Further, the application of shale oil extraction technologies, such as horizontal drilling and hydraulic fracturing to conventional oilfields could further increase the world's oil production.

However, Maugeri argues that a 'revolution' in environmental and emission-curbing technologies is required to sustain the development of most unconventional oils along with strong enforcement of existing rules. Without such a revolution, a continuous clash between the oil industry and environmental groups will force governments to delay or constrain the development of new projects. Some of the major geopolitical consequences of this include Asia becoming the reference market for the bulk of Middle East oil, with China becoming a new protagonist in the political affairs of the whole region. At the same time the Western Hemisphere could return to a pre-World War II status of theoretical oil self-sufficiency and the United States could dramatically reduce its oil import needs. However, quasi oil self-sufficiency will not insulate the United States from the rest of the global oil market and world oil prices. Further, Canada, Venezuela and Brazil may decide to export their oil and gas production to markets other than the United States for purely commercial reasons, making the notion of Western Hemisphere self-sufficiency irrelevant.

Thus, Maugeri concludes that oil is not in short supply from a purely physical point of view; there are huge volumes of conventional and unconventional oils still to be developed with no ‘peak oil’ in sight. He suggests instead that real problems concerning future oil production are ‘above the surface, not beneath it, and relate to political decisions and geopolitical instability’. While the age of ‘cheap oil’ is over it is still uncertain what the future level of oil prices may be as technology could turn today’s expensive oil into tomorrow’s cheap oil.

However, George Monbiot worries that the automatic environmental correction mechanism – resource depletion destroying the machine that was driving it – is not going to happen. The problem of too much instead of too little oil generates a conflict between the planet’s natural systems and industrial and consumer capitalism as there are no obvious means or reasons to prevail upon governments and industry to leave oil in the ground to prevent climate breakdown, as evidenced by the collapse of multilateral discussions at the UN Conference on Sustainable Development (Rio +20) in June 2012. In summary, when will the Earth run out of oil but more important, how will that uncertainty affect environmental issues going forward?

Sources: Maugeri (2012); Monbiot (2012)

Renewable sources include wood, plants, dung, falling or gravity-fed water for hydroelectric or mechanical energy, geothermal sources, solar, offshore and onshore wind, biomass or biofuels, and tidal and wave energy. The latter five sources are relatively new, with only about 20–30 years of operational experience at the most, and are still higher-cost alternatives until economies of scale take effect.

Each source has its own economic, health and environmental costs, benefits and risk factors that interact strongly with other governmental and global priorities. Key factors for energy sustainability include sufficient growth of energy supplies to meet human and industrial needs, energy efficiency and conservation measures so that the waste of primary resources is minimized, public health by recognizing safety risks inherent in energy sources such as radiation from nuclear sources, and protection of the biosphere by prevention of pollution.

The growth of global primary energy demand in response to industrialization, urbanization and societal affluence has led to greater than 50 per cent increase in total consumption from all sources of 8,616 million tons of oil equivalent (Mtoe) in 1990 to 13,078 Mtoe in 2011 (Enerdata Global Energy Statistical Yearbook, 2012). There is also an uneven distribution of energy consumption across the globe, as shown in Table 2.1. The highest

TABLE 2.1 Highest and lowest energy consuming countries in 2011

Country	Energy Consumption (Mtoe)
Highest energy consuming countries in 2011	
China	2,648
United States	2,225
India	759
Russia	725
Japan	469
Germany	317
Brazil	268
Canada	266
France	257
South Korea	257
Lowest energy consuming countries in 2011	
Algeria	43
Czech Republic	42
Colombia	35
Kuwait	35
Romania	35
Finland	34
Norway	32
Chile	31
Portugal	24
New Zealand	19

energy consuming countries by far in 2011 were China with 2,648 Mtoe and the United States with 2,225 Mtoe. The lowest consuming countries were New Zealand with 19 Mtoe and Portugal with 24 Mtoe.

Halldórsson and Svanberg (2013) note that energy has two purposes. One is to power various operations processes such as storage (or 'Stop') and production and transportation of goods (or 'Go') for use and consumption. On the energy input side of logistics and SCM, trucks and vans use fuel-burning engines as their motive source. However, vehicle engines are becoming more efficient in terms of fuel use and emissions and there are ongoing efforts to consider alternative fuels such as biodiesel or bioethanol, hydrogen, natural gas or liquid petroleum gas, and electricity (McKinnon *et al,* 2012). Some of these developments are still in their infancy, just like newer sources of renewable energy, and also have their own environmental impacts. For example, the growth of crops for biofuels requires the use of arable land, which displaces the growing of crops for food, and could lead to more forests and grasslands being cultivated for food, thus possibly negating the positive effects of greenhouse gas emissions reductions from using biofuels.

The second purpose (Halldórsson and Svanberg, 2013) is energy that is embedded in physical products, eg electricity through assembly such as energy consumption for vehicle production, or via their material content such as oil used in consumer products. These purposes also affect service provision. For example, energy includes mobility – transport, heating – households and warehouse facilities, and cooling – storing of drugs and food.

The World Business Council for Sustainable Development (2013) notes that commercial buildings, including warehouses, account for 40 per cent of worldwide energy use; this was discussed in Chapter 1. Initiatives to increase the efficiency of buildings in using energy and reducing emissions consider the following categories of sustainability: the indoor environment quality including lighting, the materials and resources used in construction, the energy source and building atmosphere including electricity use, sustainable building sites, and water use efficiency. The ultimate goal for a sustainable building is a net-zero operation where a building uses little or no outside energy or resources at all, for example by generating its own electricity through solar power, recycling and reusing waste water.

Industry

Industry is central to economies of modern societies and is an important engine of growth. It is also essential for developing countries to widen their development base and meet growing needs, for example China and India in the last decade. Essential human 'needs' such as food, shelter clothing and white goods or appliances, as well as non-essential 'wants' such as luxury goods and holidays, can be met only through goods and services provided by industry.

Economic development is fundamentally a process of structural transformation and involves the transformation of productive factors from traditional to modern agriculture, industry and services, and the reallocation of those factors among industrial and service sector activities. This process involves shifting resources from low- to high-productivity sectors to be successful in accelerating economic growth (UN Department of Economic and Social Affairs, 2007). Essentially, sustained economic growth is associated with the capacity to diversify domestic production structure, ie to generate new activities, strengthen economic linkages within the country, and create domestic technological capabilities.

Since the end of World War II, modern industrial policies and have led to rapid growth in the developing world through such diversification of production into manufacturing and services. The business management mantra of outsourcing manufacturing to low-cost, global producers during the 1960s and 1970s, coupled with a reduction in transportation and communication costs combined with corresponding increases in technological power, especially computing and data processing power, has led to a physical disintegration of production. Because of lower transaction costs, different components of final products are now manufactured in several different countries. The product may then be assembled in yet another country and finally distributed worldwide. This means that, to get products or services to the market, it is important to tap into the global production and supply chains operating in the 21st century (UN Department of Economic and Social Affairs, 2007). This structural transformation is also known as the two great 'unbundlings.'

The first unbundling is the end of the need to produce goods close to consumers. This transformation has been accelerated by the rapid decline in transportation regulation and costs during the last four decades, particularly with the widespread use of containers and bulk carriers. Thus, the impact has been that much manufacturing production, especially of more standard and labour-intensive goods, transferred to developing countries with lower labour costs. The second unbundling is the end of the need to perform most manufacturing stages near each other. This has been made possible by rapidly falling costs of telecommunications, the possibility of codifying and digitizing tasks and increasing data processing power to turn

TABLE 2.2 Comparison of 2013 estimated gross domestic product (CIA, 2014)

Country	GDP US $ trillion	Percentage World GDP
World	74.31	100.0
European Union 28	17.20	23.2
United States	16.72	22.5
China	9.33	12.6
Japan	5.01	6.7
Brazil	2.19	2.9
Russia	2.11	2.8
India	1.67	2.2

such data into information. The resultant impact has been that many service tasks supporting manufacturing as well as other services, such as back office accounting and customer service support, have been sent offshore to countries with lower labour costs.

The shift to offshore facilities has led to significant growth in developing countries such as China, India and Southeast Asia. Total gross domestic product (GDP) estimated across the globe in 2013 was US $74.31 billion at official exchange rates as shown in Table 2.2 (CIA, 2014). The three major geographic regions that account for the bulk of this economic activity are the US with 22.5 per cent of world GDP, the 28 member states of the European Union (EU) with 23.2 per cent, and the two western Pacific Rim countries of China and Japan with 19.3 per cent. However, three other countries worthy of note are Brazil (2.9 per cent), Russia (2.8 per cent) and India (2.2 per cent). These three plus China make up the so-called 'BRIC' group considered to be rapidly developing countries.

A method to compare the logistics performance of various countries to their GDP performance is the World Bank Logistics Performance Index (2014) or LPI. The LPI is a multidimensional assessment of logistics performance

TABLE 2.3 World Bank logistics performance index 2014

Country	Rank	LPI Score
Germany	1	4.12
Netherlands	2	4.05
Belgium	3	4.04
United Kingdom	4	4.01
Singapore	5	4.00
Sweden	6	3.96
Norway	7	3.96
Luxembourg	8	3.95
United States	9	3.92
Japan	10	3.91
China	28	3.53
India	54	3.08
Brazil	65	2.94
Russian Federation	90	2.69

rated on a scale from one (worst) to five (best). In 2014, the top five countries as shown in Table 2.3 were Germany (4.12 LPI score), the Netherlands (4.05), Belgium (4.04), the United Kingdom (4.01) and Singapore (4.00). In comparison, the four BRIC countries were ranked as follows: China twenty-eighth (3.53), India fifty-fourth (3.08) Brazil sixty-fifth (2.94), and Russia ninetieth (2.69).

One way of considering these differences is that those countries that have both high GDP and LPI values are highly efficient in terms of production, logistics and SCM. However, that does not necessarily translate into efficient or better sustainability. The countries emitting the most CO_2 in 2009 according to the US Energy Information Administration were China and the United States at 7.7 and 5.4 billion tonnes respectively. Russia, India and Japan were all between 1 and 1.5 billion tonnes each (Grant, 2012).

Industrial processes themselves remain very much the same, albeit enhanced by recent manufacturing techniques such as lean production and just-in-time (JIT). Industry extracts materials from the natural resource base, such as minerals and energy resources and, with financial and human resources, develops products for market. However, coupled with this activity is the production and distribution of pollution into the environment.

Issues of depletion also affect non-energy inputs for industry, such as iron, copper and rare earth elements, and the concept of 'peak' also applies to them. The British Geological Survey (2012) publishes an annual risk list for chemical elements or element groups that possess economic value and are necessary to maintain our economy and lifestyle. The numerical ranking value on the risk list is an index score reflecting these criteria: scarcity, production concentration, reserve distribution, recycling rate, substitutability, and governance of both the top producing and reserve-hosting nations.

In 2012 those elements considered at high or very high risk, ie index scores greater than 8.5, were rare earth elements, tungsten, antimony, bismuth, molybdenum, strontium and mercury. The top reserve holder and leading producer for all these elements is China, with the exception that Mexico is the top reserve holder for mercury. In fact, China is now the leading global producer of 22 of the 41 elements or groups on the risk list.

The risk list gives an indication of which elements or groups may be subject to supply disruption resulting from human factors such as geopolitics, resources nationalism, strikes, accidents and lack of sufficient reserves. The British Geological Survey's message for firms and countries is to develop diversified supplies of primary resources and make full use of secondary or substitute resources and recycling to reduce intensity of resource use. Such activities will also impact current logistics and supply chain designs and operations.

Food

The UN's Food and Agriculture Organization (2012) reported that about 870 million people in the world suffered from undernourishment in the period 2010–12, representing 12.5 per cent of the global population or one in eight people. While still unacceptably high, this overall amount is a decrease from the turn of the millennium figures. However, there are considerable differences among regions and individual countries: about 852 million undernourished people live in developing countries. For the periods between 1990–92 and 2010–12, the shares of south eastern and eastern Asia have seen the most marked decline, from 13.4 to 7.5 per cent and from 26.1 to 19.2 per cent respectively, while Latin America also declined from 6.5 to 5.6 per cent. Meanwhile, shares have increased from 32.7 to 35.0 per cent in Southern Asia, 17.0 to 27.0 per cent in sub-Saharan Africa, and 1.3 to 2.9 per cent in Western Asia and Northern Africa.

However, the effects of climate change may prevent further declines in undernourishment due to crop failures, drought and rising prices. World cereal production declined in 2012 and will result in a significant reduction in world inventories by the close of seasons in 2013, even with world demand falling as a result of higher prices. Crop production estimates for corn, soybeans, sorghum and hay declined in the United States throughout the summer of 2012 as drought intensified. By harvest time in late 2012 the US Department of Agriculture estimated that the production of corn, soybeans, sorghum and hay was down 27, 16, 26.5 and 9 per cent, respectively.

The most severe and extensive drought in 25 years seriously affected US agriculture in 2012, with impacts on the crop and livestock sectors, and with the potential to affect food prices at the retail level (USDA Economic Research Service, 2012). The drought destroyed or damaged a significant portion of US agriculture in 2012, about 80 per cent of agricultural land and 60 per cent of farms, which was more extensive than any drought since the 1950s. This drought led to increased retail prices for beef, pork, poultry and dairy products well into 2013. But in the short term, drought conditions also led to herd culling in response to higher feed costs with resulting short-term meat supply increases.

Stuart (2009) noted that approximately 40 million tonnes of food are wasted by households, retailers and food services each year. This amount of food would be enough to satisfy the hunger of all of the people worldwide suffering from undernourishment. Further, irrigation water used globally to grow food that is wasted would be enough for the domestic needs of 9 billion people at 200 litres per person per day, or the number expected on the planet by 2050. Trees planted on land currently used to grow unnecessary surplus and wasted food would theoretically offset 100 per cent of GHG emissions from fossil fuel combustion.

Stuart (2009) argues that the United States and Europe, including the UK, have nearly twice as much food as is required by the nutritional needs of their populations and that up to half the entire food supply is wasted between the farm and the fork; UK households waste 25 per cent of all the food they buy. The fishing industry is also not immune to waste according to Stuart. Around 2.3 million tonnes of fish are discarded in the North Atlantic and the North Sea each year; 40 to 60 per cent of all fish caught in Europe are discarded either because they are the wrong size or species, or because of the European quota system.

While Stuart is an activist the facts behind his arguments have cogency and are voiced by others. One element of waste that is not discussed in depth is the inefficiency of logistics and supply chain activities to deal with this food. One way of using food for people in poverty that would otherwise be wasted in the supply chain is discussed in the following box.

Social supermarkets to prevent food waste and poverty

Nearly 80 million people or 16 per cent of the European Union's population live below a 'poverty line' where their monthly resources do not allow them to afford basic goods for living, including sufficient amounts of nutritious food. The Austrian government has defined its national poverty threshold as a monthly net income of €900 for a one-person household; about 13 per cent of its population belongs to that group. One development undertaken to address the food issue are social supermarkets (SSMs), the first of which was opened in Linz in 1999 as a private initiative of four families.

The objective of an SSM is to prevent consumable food and household products from turning into waste, help people who are financially at risk or in poverty, and support the re-integration of unemployed people into society. SSMs are similar to traditional supermarkets as they sell food and consumer products and offer similar in-store services, as opposed to 'food banks' that simply give food away. However, there are three main differences between an SSM and a traditional supermarket.

First, SSMs provide a very limited assortment of food and household goods such as cosmetics or cleaning products. Their offered merchandise is surplus products given free by food producers, processors and retailers. These products are still consumable, but are no longer merchantable as they are too close to an expiry date, have wrong labelling, or have slightly damaged packaging. Second, access to an SSM is limited to people at risk of poverty or who are already below the poverty threshold; this access is controlled with the help of identification cards that are issued according to the official income status. Card holders are only able to purchase a maximum of €30 over a maximum of three visits per week. Lastly, shelf prices are significantly lower, with approximately 50–70 per cent off regular supermarket prices.

Services in an SSM are provided by volunteers as well as employees who are part of specific employment programmes; the key objective with the latter is to re-integrate people who are long-term unemployed. The training and knowledge needed to run a supermarket operation is provided by suppliers and retailers, who later welcome employees of SSMs in their internal training programmes. The number of SSMs has increased to 80 located in every major Austrian city, with about 20 mobile SSMs supplying rural areas; the seventh SSM opened in Vienna in early 2012. SSMs represent a 1.5 per cent national share when compared to the 5,600 mainstream supermarkets in Austria.

From a sustainability perspective, large amounts of food and consumer products end up in Austria's public waste system. The Austrian Institute of Ecology has found that some 70 tonnes of food, or about 40 kilograms per capita, are thrown away every year in Vienna alone. Food waste stemming from private households comprises leftovers from preparing meals. However, the majority of food waste is products in original packaging or broken-up packaging. Food waste from food producers or supermarkets usually comes in very large quantities of one kind, eg milk products, fruit or vegetables. It has been estimated that between 3 and 8 per cent of the value of food products along the entire food supply chain has the potential to be rescued for further consumption.

From a supply chain management point of view, SSM activity takes place at the very end of the supply chain process; it represents onward distribution to a new location for the further use of products and waste reduction, rather than reverse logistics. However, the process involves a complex logistical redistribution of goods and many of the reverse logistics issues discussed in Chapter 7 will apply in this context.

SSMs have merit from a corporate and socially responsible perspective: they allow people in or near poverty a real opportunity to eat healthily and maintain dignity while reducing the vast amount of perfectly consumable food that goes to waste due to operational considerations.

Sources: austrian*times* (2012); Holweg and Lienbacher (2010)

Population and urban growth

The current world's population is almost 7 billion and the UN's median population forecast is 9.3 billion by 2050, with a variance range 2.5 billion – the total world population in 1950 – depending on the methodology used. Every new person on Earth requires additional food, water and energy and produces extra waste and pollution, thus increasing the total impact on the planet and decreasing everyone else's share (Martin, 2012).

The point is that indefinite population growth is physically impossible on a finite planet – it will certainly stop at some point. Maurice Strong, secretary general of the 1992 Earth Summit in Rio, noted that either we reduce our population numbers voluntarily or nature will brutally do it for us. On a finite planet, the optimum population providing the best quality of life for all is clearly much smaller than the maximum, which only permits bare survival. An expansion in population can also increase the pressure on resources and slow the rise in living standards in areas where deprivation is widespread. Though the issue is not merely one of population size but of the distribution of resources, sustainable development can only be pursued if demographic developments are in harmony with the changing productive potential of the ecosystem.

Growth has no set limits in terms of population or resource use, and beyond that ecological disaster lies in wait. There are different limits for the use of energy, other resources, water and land. Many of these will manifest themselves in the form of rising costs and diminishing returns, rather than any sudden loss of a resource base. Also, the accumulation of knowledge and the development of technology can enhance the carrying capacity of the resource base. But there are ultimate limits and sustainability requires that long before these are reached the world must ensure equitable access to constrained resources and reorient technological efforts to relieve bottlenecks through better management or substitution.

Urbanization, the demographic transition from rural to urban, is associated with shifts from an agriculture-based economy to mass industry, technology and service. For the first time ever, the majority of the world's population lives in a city, and this proportion continues to grow. One hundred years ago, 2 out of every 10 people lived in an urban area but, as of 2010, more than half of all people live in an urban area. By 2030, 6 out of every 10 people will live in a city, and by 2050 this proportion will increase to 7 out of 10 people, or 6.5 billion of the 9.3 billion predicted. Currently, around half of all urban dwellers live in cities with between 100,000 and 500,000 people, and fewer than 10 per cent of urban dwellers live in megacities, which are defined by UN Habitat as a city with a population of more than 10 million.

Almost all urban population growth during the next 40 years will occur in cities of developing countries. Between 1995 and 2005, the urban population of developing countries grew by an average of 1.2 million people per week, or around 165,000 people every day. By the middle of the 21st century, it is estimated that the urban population of these countries will more than double, increasing from 2.5 billion in 2009 to almost 5.2 billion in 2050 (World Health Organization, 2012).

The satisfaction of human needs and wants is the major objective of development. The essential needs of vast numbers of people in developing countries for food, clothing, shelter and jobs are not being met, and beyond their basic needs these people have legitimate aspirations for an improved quality of life. A world in which poverty and inequity are endemic will be prone to ecological and other crises, and sustainable development requires meeting the basic needs of all and extending to all an opportunity to satisfy their aspirations for a better life.

Meeting essential needs depends in part on achieving full growth potential, and sustainable development clearly requires economic growth in places where such needs are not being met. Elsewhere, it can be consistent with economic growth, provided the content of growth reflects the broad principles of sustainability and non-exploitation of others. Hence, sustainable development requires that societies meet human needs both by increasing productive potential and by ensuring equitable opportunities for all.

Water

Global water use grew at more than twice the rate of population growth in the last century: while the world's population tripled the use of fresh water grew sixfold. Water use is comprised of about 70 per cent for irrigation, about 22 per cent for industry and about 8 per cent for domestic use such as cleaning, cooking and bathing. With the world's population forecast to grow 40–50 per cent in the next 50 years, much more water will be needed to produce food and supply drinking water, particularly in heavily populated regions. Further, the volumes of fresh water needed to support the growth in energy production are not available with today's water management policies and practices, and ageing water-delivery systems compound these issues (International Council of Academies of Engineering and Technological Sciences, 2009).

The world's almost 7 billion people are appropriating 54 per cent of all the accessible freshwater contained in rivers, lakes and underground aquifers. And, water withdrawals are predicted to increase by 50 per cent by 2025 in developing countries and 18 per cent in developed countries. Over 1.4 billion people currently live in river basins where the use of water exceeds minimum recharge levels, leading to the desiccation of rivers and depletion of groundwater. By 2025, 1,800 million people will be living in countries or regions with absolute water scarcity, and two-thirds of the world population could be under stress conditions (UN Water, 2012).

On the supply side, climate change presents important challenges for local and global water resource management. Rainfall levels in many regions are already impacted, evidenced by increasing frequency and severity of floods and droughts that also have a serious impact on the aquatic ecosystems that support the sustainable supply of food and fresh water. The capability of global climate models to predict precipitation is poor, and the understanding of regional catchment scale impacts remains highly uncertain.

Since the Carbon Disclosure Project (CDP) launched its first global water report in 2010, water and its relationship with business have rarely been out of the news. For example, the Swedish retailer H&M reported a 30 per cent fall in profits for the first quarter of 2011, largely because the price of cotton doubled in the previous 12 months as a result of increased global demand and disruption to supplies caused by drought and floods in cotton producing countries like Pakistan. Also, about one-third of the world's hard disk drive production for computers is currently located in Thailand and severe floods in that region in late 2011 caused a shortage in the supply of hard disks around the world. Corporate responses to CDP's 2011 water disclosure questionnaire revealed that the supply chain is largely uncharted territory when it comes to water (CDP, 2012). Only 26 per cent of respondents require their key suppliers to report water use, risks and management plans while 38 per cent of respondents did not know if their supply chain is exposed to water-related risk.

However, there is recent evidence of corporate awareness for water issues, particularly in logistics and SCM. IGD, the UK food and grocery sector's trade association, formed a Water Stewardship Working Group (IGD, 2012) to run workshops exploring the impact of a drought crisis on the UK food and grocery industry. The workshops found that risks posed by changes in water availability and water quality, and their potential impacts on business, were a significant motivation for delegates to understand more about how to manage these risks. However, despite this motivation delegates agreed there were insufficient financial or legislative drivers for the industry to embrace a collaborative approach to managing these risks, and considered that a crisis was the most likely driver for a collaborative water stewardship approach to be developed. Core recommendations from the workshop were that the food and grocery industry needs a water resilience framework to facilitate increasing levels of collaboration and the adoption of a water stewardship approach across the industry embracing water users and stakeholders, as well as long-term planning and actions to ensure greater resilience in the industry.

Summary

Economic growth and prosperity are fundamental imperatives in today's competitive and globalized marketplace and aspirations for all citizens of the world. However, the science of sustainability has taken on a sense of urgency in recent years as mounting evidence suggests that climate change and its effects of drought and reduced agricultural yields, as well as the depletion of energy, other natural resources and water, is beginning to affect the quality of human existence and its own sustainability. All of these issues have logistics and supply chain management implications due to the impact these activities have on the natural environment.

It has been suggested that these issues must be addressed very soon to ensure that what Elkington (1994) defines as economic, environmental and human sustainability, ie his triple bottom line, are in balance. By doing so, the two dictionary definitions of sustainability presented at the beginning of this chapter will be met. Further, the intergenerational concepts posited by Brundtland (1987) and Rawls (1999) of development meeting present needs without compromising the needs of future generations provides for temporal equity and fairness.

However, there remains some confusion over what trade-offs and interdependent strategies must be employed to achieve such balance. An increase in economic growth suggests better standards of living across the globe, which in turn leads to increased and healthier populations, which will demand more food and water. These issues are not minor and at present are not insurmountable but the will to embrace and address them is sometimes lacking in government, business and society. However, it is important that logisticians and supply chain managers do so in order to be at the vanguard of sustainability and effect real change.

Freight transport 03

Freight transport is arguably the most visible issue in the discussion on making logistics activities in supply chains greener. Although the proportion of environmental impact of transport and transport intensity varies strongly between supply chains, every goods supply chain and almost every services supply chain contains transport activities. The World Economic Forum (2009) estimates that most of the carbon emissions from logistics activities are caused by freight transport. Nevertheless, other environmental costs and emissions from freight transport include wider issues such as noise, vibration and accidents.

With supply chains becoming increasingly global, freight transport disproportionately outgrew economic development over the last decade. Much of this can be related to offshoring and further specialization in supply chains leading to increased international trade. Even relatively simple products are now characterized by increasingly complex and long supply chains. The ongoing debate on supply chain risks and the higher responsiveness of local supply might mitigate this trend to some extent, but it can be expected that a growing world economy will lead to an even higher growth in transport services.

Impact of freight transport

The transport sector is the biggest single energy user in the United Kingdom with a share of 38 per cent of all energy consumption in the country. Although some transport modes reduced their energy intensity during the last decades, the overall growth of transport and the increase of energy consumption in road freight per tonne/km keep carbon emissions from transport on the rise (Department of Energy and Climate Change, 2009). There are ambitious governmental commitments to reduce greenhouse gas emissions in most developed countries, and the transport sector will undoubtedly need to contribute to this task.

Externalities

Although this chapter focuses on the greenhouse gas emissions, it is worth noting that transport has a wider environmental impact than only atmospheric emissions. We therefore have a brief look into the external pollution aspects of noise and accidents, before we re-focus on the greenhouse gas aspect.

Noise

The vast majority of the population today experiences traffic noise, using either objective measures of the decibel levels that citizens are exposed to (den Boer and Schraten, 2007) or citizens' subjective perception of traffic noise (Lambert and Philipps-Bertin, 2008). In 2000 more than 44 per cent of Europe's population experienced road traffic noise at a level of annoyance and 7 per cent were exposed to noise at such a level from rail transport. The exposure to noise results in a negative impact on citizens' health and the social costs from noise are conservatively estimated as at least €40 billion. A reduction of noise can be achieved through a mix of central (European) and local regulation, and the application of already available technology (den Boer and Schraten, 2007; Lambert and Philipps-Bertin, 2008). The FEHRL report (2006) recommends European regulation for tyres and road construction to reduce traffic noise, with improvement in tyres being seen as the most cost-effective measure. It also suggests that innovation in traffic noise reduction can be encouraged only through tightening regulation.

Accidents

An often ignored environmental impact of transportation is casualties from accidents. Road freight transport vehicles share roads and motorways with other road traffic, cyclists and pedestrians and are therefore more at risk of being involved in accidents than rail or water transport. Due to the heavy weight of road freight transport vehicles the severity of accidents is worse and the rate of fatal incidents is higher than for cars. The casualty rate varies a lot between countries due to road safety and vehicle maintenance standards, age of vehicles, etc (Cullinane and Edwards, 2010). A new aspect in road safety is the discussion on whether electric vehicles should be equipped with noise emitting devices as there is a fear that electric vehicles may be unnoticed by other road users because of how quiet they are at low speed (SWOV, 2011).

Transport modes

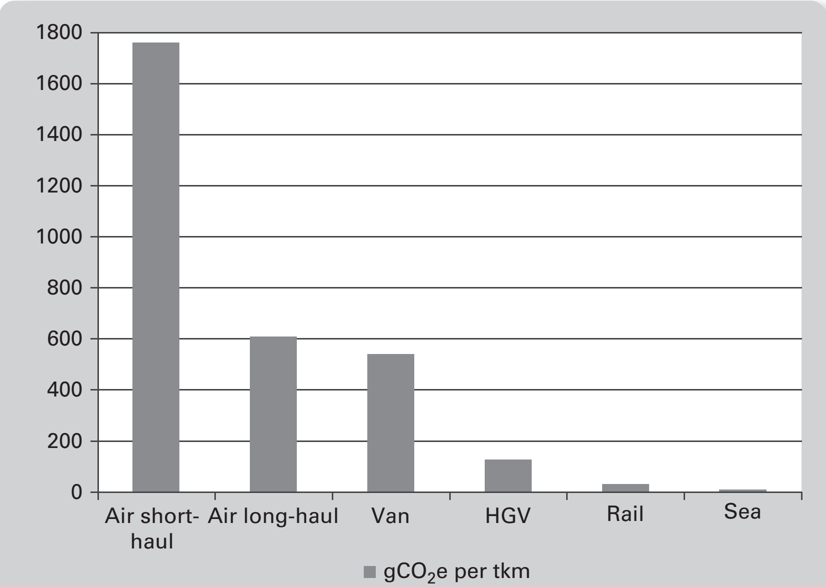
By far the most emissions in freight transport stem from road transport. However, this has to be seen in the light of road freight transport having by far the largest share in tonne kilometres of all inland transport modes. The choice of transport mode is influenced by the characteristic of the mode, operational factors and consignment factors, and cost and service requirements (Rushton *et al,* 2006).

Sea freight, whether in containers or in bulk, is generally a slow but cheap option for the transportation of mainly low-value high-volume items. Shipping rates can vary between busier and less busy routes. Usually there is always a need for double handling, as goods have to be brought to and away from the port. Although the emissions per tonne kilometre are low, journeys are usually long and most ships burn bunker fuel, which is considered one of the most polluting fuels.

Rail freight is considered a rather slow method of inland transport. It uses a fixed infrastructure, which makes it less prone to disruptions, but also means that goods have to be brought to a rail terminal if a site has no connection to the railway network. A common application for rail freight is steady and heavy bulk loads, for example coal for coal fire stations or steel mills. The expensive infrastructure is often provided by state-owned companies, which can lead to inefficiencies in the rail freight market. Trains can be powered by electricity or traditional fuels. It is usually considered as a 'greener' mode than road transport, but that depends on journey characteristics and backhauling.

Road freight is particularly popular for its accessibility and flexibility. The road network allows access to most industrial sites and is usually the first access mode that is constructed. It also requires little investment, which makes it popular for short- and medium-term solutions. The road freight market is also very competitive and fragmented, with few large logistics companies but many small haulage companies of three or fewer lorries (Department for Transport, 2011). Road freight is usually called Full-Truck-Load (FTL) or Less-Than-Truck-Load (LTL), and vehicles are classified by size. The European Union separates between Light Commercial Vehicles (LCVs) which weigh less than 3.5 metric tonnes and Heavy Goods Vehicles (HGVs) of over metric 3.5 tonnes.

FIGURE 3.1 CO_2e emissions by transport mode



Source: Based on Defra (2012)

Air freight is the fastest available transport mode over long distances. However, it is also the most carbon emitting one as aircraft burn a large amount of fuel per tonne kilometre. Due to the fuel consumption it is also relatively expensive, which makes it a more suitable transport mode for high-value items or when a short lead-time is of importance.

Pipelines are mainly used to transport large quantities of liquids or gas. Due to the high investment, it is used in situations of high volume and predictable demand. Not only do the production and maintenance of pipelines result in emissions, but the operation needs energy for pumping and sometimes temperature control.

Figure 3.1 shows the carbon emissions per tonne-km by transport mode. Particularly for air freight the assumed journey distance influences emissions drastically. One needs to be aware that the figures are averages based on many assumptions. The emission calculations depend on loading factors, engine efficiency, etc, which can vary hugely between countries and transport situations. Additionally, it is not uncommon for industry groups to issue their own studies, naturally portraying their own mode of transport in a more favourable light.

Factors to consider when choosing the transport mode

With some transport modes being more harmful to the environment than others, we need to understand the non-environmental considerations made by organizations in the selection process.

Operational factors

External factors affect the choice of transport mode. The availability and quality of infrastructure differs between countries and transport modes and so does the availability and quality of vehicles and logistics service providers. Also local law, regulations on transport and the price of transport will impact choice. Many developed countries try to encourage transport modes with lower emissions, for example through fuel taxation or aviation tax. Local climate becomes an issue when for example rainy seasons affect some modes of transport more than others.

The availability of infrastructure needs to be seen in the context of where the goods need to be delivered. Accessibility by water or rail determines whether these modes can be considered as options. Sea and rail transport very often need some road transport for the final leg of the journey.

Cost and service requirements

Customer requirements on cost and service impact the selection of transport mode. Larger order sizes and longer order cycles make the use of less flexible transport modes possible. An example would be white undershirts, which are a common low-value item sold in large quantities and are not subject to fashion changes or time constraints. They would usually be shipped in sea freight containers from the Far East to markets in Europe or North America, as this is relatively cheap.

Drivers for the growth of road freight transport in the past were the logistics strategies of 'just-in-time' (JIT) manufacturing and 'efficient consumer response' (ECR) in retailing. JIT reduces inventory holding by having items delivered to an assembly line when they are needed, thus avoiding storage. Deliveries will therefore be optimized from an assembly line perspective with sometimes short notice periods. This usually results in more frequent but smaller orders, and requires flexible transport that can usually only be provided by road.

ECR also requires high levels of flexibility and responsiveness. It is a common strategy in grocery retailing. It aims to replenish quickly what customers bought at the store. Customer demand can be volatile and ECR uses a high frequency of store deliveries in response. This way it increases the number of journeys and the proportion of less-than-truckload deliveries.

Product characteristics

The value density and weight of transported items as factors in the choice of the transport mode have already been mentioned; but other product characteristics influence this choice. Perishable products, such as food, will put a focus on speed of delivery if ripening cannot be delayed. Bananas exported to Western markets for example are harvested unripe and then transported in temperature-controlled ships to destination countries. The same is not possible for fresh flowers, which have to be transported by aeroplane. The transport of hazardous goods is usually regulated, affecting the speed of delivery and the choice of transportation mode to protect the public from potentially harmful accidents.

Consignment factors

Whether a consignment can actually fill the size of a standardized unit of transportation has a significant impact on the price for freight transport. The loading factor (or utilization) for a transport mode is also important for the environmental assessment. Whether the vehicle returns empty or other goods can be hauled back changes the calculation significantly. Loads may be incorporated into an already planned trip or may contribute to the utilization of an existing system, which may be financially and environmentally more attractive than setting up a new system. For example, much air freight arrives on passenger planes, which would be flying the route anyway, but this can make the allocation of emissions for freight transport on a passenger plane difficult.

The carbon emissions of transport modes depend on the type of fuel and engine used. Electrified transport modes – using electricity generated at a power station – such as the train services in many Continental European countries have lower carbon intensity than those transport modes run on fossil fuels.

Although sea transport is relatively low in energy intensity per tonne-kilometre, the bunker fuel burnt by ocean vessels is considered as being particularly polluting and can lead to a concentration of emissions and to respiratory health problems in port cities. One way of reducing the environmental impact on port communities is therefore to supply ships with energy from the grid while they are in port.

TABLE 3.1 Comparison of greenhouse gas emissions by transport mode

	gCO_2e per tkm			
	CO_2	CH_4	N_2O	Total
Van	537.0	0.16	3.71	540.9
HGV	127.2	0.4	1.91	129.2
Rail	28.5	0.05	3.06	31.6
Sea (general cargo, 100+ TEU)	11.0	0.00	0.08	11.1
Air (long-haul)	610	0.00	10	610
Air (short-haul)	1740	0.00	20	1760

SOURCE Defra (2012)

The emissions from individual fuel types differ hugely between various pollutants. To make the discussion more transparent and measures comparable, the guidelines for company greenhouse gas reporting use CO_2e (CO_2 equivalence) as a measure. The figures from this guideline are used to estimate the environmental impact of a company's logistics activities in the lifecycle assessment of a supply chain.

The figures in Table 3.1 were calculated based on average loading factors in the United Kingdom. The figures for air freight also considered the proportions of freight on passenger planes and on pure freight aircrafts. This means that the numbers are averaged across the entire country and individual performances may differ strongly. The guidelines are therefore quite detailed and provide numbers based on different fuel types, vessel size, vehicle type, etc.

Additional complexity is added by a report from PE International (2010) arguing that water and rail are not always greener than road freight transport. The study compares road and rail mode in several scenarios with various assumptions. When the comparison includes all factors like emissions from producing electricity and diesel, loading factors, type of goods to be transported, length of a train, proportion of the journey from factory to freight terminals etc, the comparison can in some scenarios show lower emissions for a lorry. In one scenario of light goods, river barge transport has the highest emissions of all three modes being compared. Since the study was conducted in Germany, where the government decided to shut down all nuclear power stations, comparisons in future also need to consider the reduction of nuclear energy in the electricity mix. If nuclear energy is replaced with energy from coal or other highly polluting ways of energy production the environmental performance of electricity-powered trains will decrease.

Options to reduce the environmental impact of transport operations are to reduce the emissions from the current mode of transport, shifting freight towards less polluting modes of transport, and the overall reduction of freight transport. These options are discussed in more detail below.

Strategies to reduce environmental impact of freight transport

The selection of a transport mode and the resulting emissions can differ significantly between individual circumstances. However, the considerations and thought processes between individual solutions are similar, although the feasibility and availability of greener options varies. In the following paragraphs we introduce the strategic decisions behind emission reductions in transport.

Change of transport mode

The move to other transport modes is subject to access to alternatives. Water and rail transport need heavy investment in infrastructure. Regardless of whether these investments are made by governments or private investors they need to make economic sense. The investment in greener transport infrastructure therefore requires a number of users to utilize it. Since water and rail freight are particularly suitable for heavy low-value items such infrastructure is mainly found in areas of manufacturing and heavy industry. With the move to a services-dominated economy and the consequent decline of sizeable manufacturing, the United Kingdom has reduced the share of freight moved by water and rail. In contrast to this the People's Republic of China for example invested more than US $200 billion from its 2008 stimulus package into the development of a rail, waterway and grid network to support the manufacturing sector (Park *et al,* 2012). To make use of these freight transport modes potential users who are not based in a port and have no rail terminal, need to apply multi-modal solutions, ie the use of more than one transport mode in a consignment's journey. Using several transport modes means that the freight is handled when moved from one mode to another; this can be made much easier with the right infrastructure and equipment.

Multi-modal transport became much more efficient through the widespread use and increasing standardization of pallets and containers. In earlier times general cargo vessels were loaded and unloaded manually in a slow and labour-intensive process. Today there are standardized containers for bulk loads and for liquids. Containers allow a faster transfer of larger quantities onto rail carriages or trucks with a suitable body. A major obstacle for multi-modal transport is whether a loading unit (eg a container) can be used for the entire journey avoiding double-handling of goods. The major unit in international container shipping is the TEU, a 20-foot equivalent unit, ie a container of 20 feet length. However, 40- and 45-foot container units also exist. In a similar way, work swap-bodies can be used for the road and rail mode. The swap-body's dimensions need to adhere to regulations of both modes and are therefore different than the shipping container. Unlike the shipping container it cannot be stacked. Slightly different to the swap-body is the road-rail trailer where an entire articulated semi-trailer is put onto a modified rail wagon, with the wheels pulled in to fit onto the rail wagon.

Another form is the use of intermodal vehicles. RORO (roll-on roll-off) ferries allow road vehicles (and sometimes trains) to use water transport. The land-based version of this are trains that can carry lorries; these are for example used for freight traffic through Switzerland.

Some of the intermodal applications require special handling equipment and facilities. Intermodal terminals are needed for road-rail transport with special cranes and ramps. Also, inland ports are built to connect waterway barges to the road and rail network; and ferries need terminals to connect with land transport modes.

Reduction of freight transport

Besides shifting freight to greener transport modes, emissions can be reduced by avoiding freight transportation in the first place. Much of the increase in emissions from freight transport is caused by globalization of trade. International trade grew through the reduction of trade barriers and the stronger participation of emerging economies. The availability of cheap and effective transportation across the globe, labour cost differences, and more specialization in the production of complex products supported the growth in international trade and the resulting increase in freight transport. As a consequence, much of the emissions was shifted abroad through offshoring manufacturing to developing countries (Peters *et al*, 2011) where environmental regulation is often less strict and enforced less rigorously.

The emissions from manufacturing would still occur if the product was manufactured closer to the point of consumption, but the emissions from freight transport could be minimized by sourcing locally. Although this doesn't allow taking advantage of lower labour wages elsewhere it reduces risks in the supply chain and makes supply chains more agile and responsive. The higher labour costs can sometimes be recouped through more efficient production, better quality, the savings achieved through the reduction of freight transport and the reduction in inventory caused by long lead times and necessary buffer stock in global supply chains (BCG, 2011; Roland Berger, 2011). A combination of the advantages of close-by suppliers and of low labour costs lead to the concept of 'nearshoring'. It locates manufacturing in low-wage countries near or next to the place of consumption. The main advantages are the reduction in lead times and uncertainties in the supply chain and the consequent freeing up of cash for other company activities (Chow, 2011).

The decision for local sourcing or nearshoring is strongly influenced by the costs of freight transportation. As discussed earlier in this chapter, the costs for freight transport differ between the various transport modes and are very volatile due to demand/supply mismatches and the cost of fuel.

In the recent economic slowdown overcapacities in global container shipping suddenly appeared. But since the shipping companies had already placed orders for new ships, capacity increased further despite falling freight charges. Capacity in this market could not be adjusted quickly enough to match the decline in demand and all major container liners announced financial losses. Overcapacity can also occur due to directional imbalances, for example if the shipment of a container from Europe to China is much cheaper than vice versa because there is much less demand for shipping goods in this direction.

A major cost for transport providers is fuel or the energy that goes into providing the transport service. The price for freight transport therefore depends heavily on global fuel and oil prices. With crude oil prices being higher than ever before, it can be assumed that transport costs will increase further in future, which makes transport more expensive and therefore offshoring a less attractive option. However, the proportion of transport costs of the overall product costs varies between products and – despite transport cost increases – may be negligible in some cases.

Reduction of emissions from current mode

In many cases a shift to more environmentally friendly transport modes may be impossible as the available infrastructure or product characteristics demand a particular mode of transport. But even if a shift to a greener mode is not possible there is still much scope for reducing the emissions from the mode in use.

The greenhouse gas emissions of transport operations stem mainly from the burning of fuels. There are also emissions embedded in the manufacturing process of the vehicles and the disposal of the vehicles at the end of their life, but the focus during operations will be on fuel consumption. Fuel consumption is relatively easy to measure across transport operations, and is a major cost factor. Fuel savings therefore usually mean cost savings for operators, making the reduction of consumption an attractive focus for greening transport operations.

Alternative fuels

With the rising oil price and political willingness to reduce the dependency on oil, several alternative fuels were brought to the fuel market. Their environmental balances vary tremendously and since most of them are relatively new in their application to the wider transport industry it is worthwhile keeping a holistic and critical perspective.

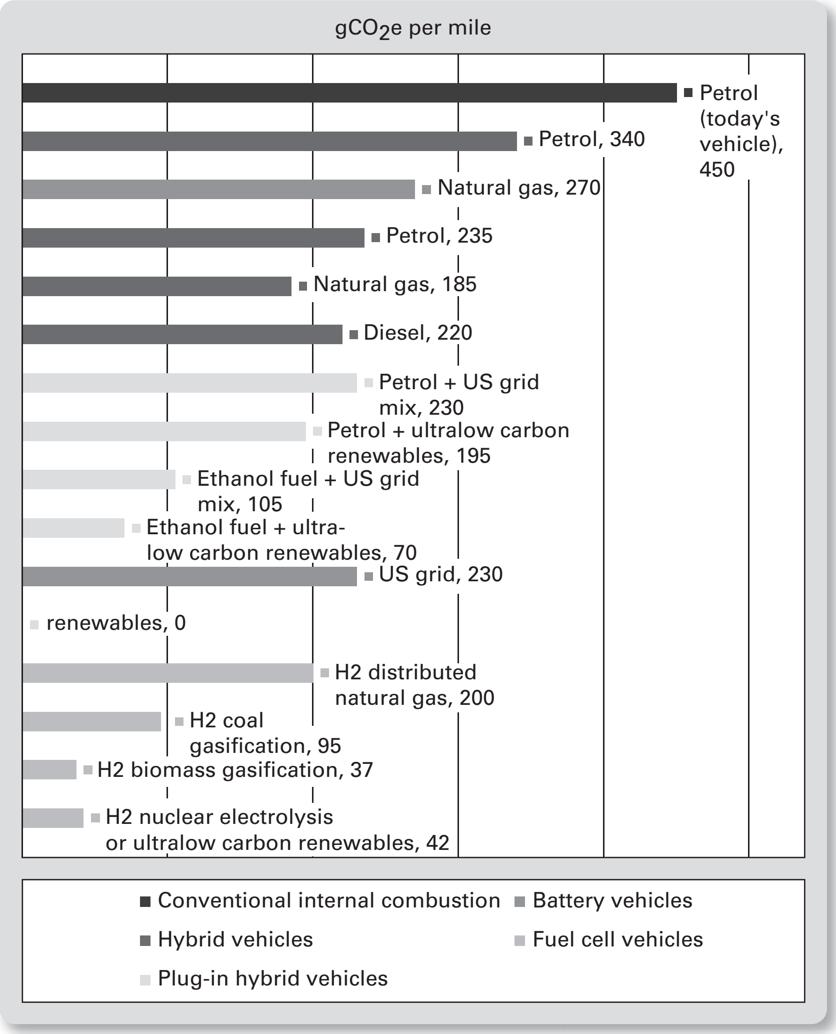
A prime example for hidden issues is the political promotion of biofuels. Political leaders in Europe and elsewhere promoted the use of biofuel as a way of reducing greenhouse gas emissions while at the same time providing a new income stream for rural communities. The European Union even demands that petrol contains 10 per cent biofuel. As discussed in Chapters 1 and 2, the implications of the promotion of biofuel are increased land use and a threat to biodiversity, and also increasing food prices leading to civil unrest in countries where citizens spend a large proportion of their income on food (as during the 'tortilla crisis' in Mexico in 2008). Furthermore the harvest of crops to make biofuel relies on weather conditions. After a serious drought in the United States, the world's major producer of corn, the United Nations asked it to change its biofuel laws, which demand 40 per cent of the corn production be used to make ethanol biofuel, amid fears of rising food prices worldwide (BBC, 2012). The use of agricultural products and allocation of farming land for biofuel which would otherwise be used for food therefore leads to a serious ethical dilemma.

Similarly the promotion of bioenergy in generating electricity needs to be viewed critically. Although electric vehicles are considered environmentally friendly and particularly suitable for short-distance urban travel, their 'fuel' may be produced from different sources. Electricity from wind power and solar power is sustainable, but they are also very unreliable and volatile, so other sources of energy are needed to ensure sufficient provision of electricity. These sources must come from fossil fuels, nuclear energy or biomass. While fossil fuels show high levels of emissions and nuclear power is often unpopular, the use of biomass can only be considered as sustainable if it comes from waste products and by-products that are occurring anyway. If biomass is especially grown for the purpose of energy production it cannot be considered as a sustainable source of energy due to ethical implications, the use of energy in the biomass supply chain itself, and the extremely low conversion from biomass into electricity (Leopoldina, 2012). Whenever electric power is used to run vehicles it is necessary to investigate how the electricity is generated, as this will be the main determinant of whether it is a 'sustainable' mode or not.

Liquefied natural gas (LNG) is a fossil fuel too, but it burns with lower emissions than most oil-based products. So far it hasn't gained a huge market share as a fuel for cars as the distribution infrastructure does not exist. However, it is expected to be increasingly used in international shipping. The International Maritime Organization (IMO) has limited the nitrogen content in fuel for ships operating in the North Sea and the Baltic Sea to 0.1 per cent from 2015 onwards. This low level of nitrogen cannot be achieved with the commonly used bunker fuel. Using higher quality oil-based fuels or cleaning the exhaust fumes would be more costly for operators than the use of LNG. Fuelling infrastructure for LNG already exists to some extent around the North and Baltic Sea but currently only a few vessels are operating on LNG and there is doubt whether the conversion of vessels to LNG is viable. More likely, new ships will be built to run on LNG so the market share of this fuel will increase gradually over the next decades (Germanischer Lloyd 2012; Tankstellenmarkt, 2012). It is expected that by the end of 2015 approximately 70 ships will be operating on LNG in north-west Europe (*Handelsblatt*, 2012). Compared to the fuel market for road vehicles, the ship fuel market has the advantage that only a relatively small number of refuelling stations need to be built, with some infrastructure already in place for local ferries particularly along the Norwegian coast and in ports. Although the number of potential consumers is rather small, the quantities needed make it worthwhile to erect a sufficient infrastructure. A final consideration is the regulatory pressure on operators to switch to a lower emission fuel (Germanischer Lloyd, 2012).

Figure 3.2 shows a comparison of greenhouse gas emissions for different fuel applications for cars and light duty vehicles in the United States. The emissions differ significantly and as discussed above all fuels have their particular production issues.

FIGURE 3.2 Well-to-wheels greenhouse gases emissions for future mid-size car



Notes: Ultralow carbon renewable electricity includes wind, solar, etc. Does not include the lifecycle effects of vehicle manufacturing and infrastructure construction/decommissioning.

Source: US Department of Energy (2010) 'well-to-wheels greenhouse gas emissions and petroleum use for mid-size light-duty vehicles', Offices of Vehicle Technologies & Fuel Cell Technologies

Infrastructure for hydrogen fuel

Hydrogen can be used as an alternative in most applications where fossil fuels are consumed today. It can be applied in two ways: as a fuel in a 'traditional' tank in a vehicle or within fuel cells where it is converted into electric power. These hydrogen-powered vehicles are less noisy than conventional engines and the only emission from the consumption of hydrogen is water. Hydrogen can be sourced conventionally as a chemical by-product, from coal or from natural gas (in which case hydrogen fuel's environmental balance is not as good as the one from renewable sources, but still lower in CO_2 emissions than fossil fuels). It can also be produced from biological processes or from solid and liquid biomass, or biogas. Either way the production of hydrogen by electrolysis consumes significant amounts of energy. The environmental balance of hydrogen fuel therefore depends not only on whether it stems from a conventional or a renewable source, but also on the source of energy for its production. If electricity from renewable sources can be used (for example from wind power or solar power at times when demand is much lower than production) hydrogen becomes a renewable fuel itself.

Already hydrogen power is used in cars, buses, forklifts and even submarines, but the use of hydrogen is still at an early stage. The major obstacles for a wider application of hydrogen fuel is the availability of sufficient energy from renewable sources, which is expected to change at a global level over the next decades; and a distribution network for hydrogen fuel to the wider population. As with other alternative fuels, customers will only switch to hydrogen if they can fuel their vehicle conveniently at a 'petrol station' nearby. The distribution network also needs sufficient geographic coverage so that drivers do not have to worry about refilling their vehicle during a longer journey. Due to the lack of refuelling infrastructure, applications naturally started with vehicles that return to a base after an operation cycle. This is certainly the case for the submarines, but also for buses that come back to the depot at the end of a route and forklifts that are fuelled at the operating site.

Local transit agencies in California are using fuel-cell operated buses. From their initial pilot in 2008 to their second generation project, the price for specially amended buses halved and the number of participating agencies increased. The acceptance of hydrogen fuel vehicles depends on the higher purchase price for the vehicle and the availability of fuel – and fuelling stations will only offer hydrogen fuel if there is a viable number of vehicles consuming hydrogen.

The next step for public acceptance of hydrogen fuel is the development of a distribution infrastructure. In an initiative called 'H2 mobility' car manufacturers, energy companies, petrol station operators and hydrogen producers are collaborating to put in place a hydrogen fuelling infrastructure with the overall aim to reach a level good enough for the commercialization of hydrogen vehicles in Germany. Supplying fuelling stations would be by conventional trailers transporting liquefied hydrogen under pressure, but there are also thoughts of a decentralized production network.

Source: Linde Group Gases Division, www.linde.com/hydrogen

Along with the choice of transport mode and of fuel, freight transport's emissions can also be reduced through operational optimization, improvements in the network design and further technology improvements.

Operational options to reduce emissions

One way of operating transport vehicles and vessels on less fuel is to run them at their engines' optimal level. In international shipping this concept is called 'slow steaming' and came up during the economic downturn in 2007. Usually the world's fleet engines are designed to run at full load, but that is not the most fuel-efficient way to run these engines. With overcapacities during the economic turmoil, shipping lines started to run their ships at slower speeds to save fuel (MAN, 2012). A ship like the *Emma Maersk* would save about 4,000 tonnes of bunker fuel on a trip from Europe to Singapore. When a ship runs at lower speed it needs longer to accomplish a journey; for instance a ship running from Hong Kong to Rotterdam scheduled to take 21 days takes 23 days using slow steaming. Using extra days means a ship makes fewer journeys in a given amount of time, but due to the overcapacities in the global shipping market this issue became less important. A side benefit of slow steaming is the increased reliability of shipping schedules, as the slow steaming provides a natural buffer for delays (AP Moeller Maersk, 2012).

An economically attractive operational improvement is the reduction of empty running in transport fleets. As shown in the discussion of transport modes, environmental performance depends strongly on loading factors and the utilization of operating vehicles. Transport companies naturally have an interest in finding a load for the way back, and the question is therefore more about why empty running occurs and how transport companies can be supported in finding backloading opportunities. An increase in utilization and a reduction in empty journeys will reduce the total number of journeys and therefore reduce emissions. The discussion on backhauling has two aspects: the issue of empty running and the underutilization of vehicles. Both can be caused by the same reasons.

Logistics strategies like just-in-time can be a factor when the arrival within the correct time window is more important than the availability of suitable backhauling opportunities. Many goods also have special transport characteristics, which mean they cannot be transported in the same vehicle as other goods, for example livestock and pharmaceuticals. Also, tankers transporting chemicals can only backload the same product or need to be cleaned before loading other chemicals. Vehicles may also be running underutilized because they follow a particular schedule, for example aircraft and ships usually need to follow a schedule regardless of their load on a particular journey.

Also, transport equipment may not be suitable for other goods and there may be directional imbalances. For example timber logs are usually transported on special trailers, designed for timber logs and not suitable for most other goods. Also, there may well be a lack of goods that need to be transported back to the place where timber is harvested. Imbalances in schedules can also cause underutilization. Delivery patterns vary and there is less demand for freight transport during the weekend. Many countries will limit freight transport during times when the road network is particularly busy, for example during public holidays.

Transport operators may also not be aware of backloading opportunities. Electronic platforms give transport companies easier access to potential backhauling. Opportunities to improve vehicle utilization can also exist in with customers and suppliers, and also with competitors. Despite being competitors, Nestlé and United Biscuits in the UK collaborate in their freight transport on one route where both own sites at either end. By combining their freight transport they save around 95,000 litres of diesel, 250 tonnes of CO_2 and around £300,000 per year. Although such collaborations need to cross many barriers and results in additional management effort, these are outweighed by the savings (IGD, 2012).

Underutilization can also be caused by product characteristics. If goods cannot be stacked on top of each other the operator cannot use the full volume of the vehicle. Similarly if a product is very heavy – for example steel – the vehicle will be quite empty, but it is already at the maximum weight capacity. The same problem applies to very light products, which may fill an entire trailer, but nowhere near reach the weight capacity of the trailer.

Vehicles are regulated in their dimensions and weight capacity and a load can only rarely perfectly match these determinants. Initiatives to introduce larger and heavier lorries have evolved. Currently 'gigaliners' are being tested in pilot projects in Germany. These vehicles have a length of 25.25 metres and a capacity of 44 tonnes (the maximum length for lorries at the moment is 18.75 metres). The gigaliners are expected to save up to 20 per cent of CO_2 compared to usual HGVs, but critics fear damage to the infrastructure, additional congestion and an increased risk of accidents when overtaking the gigaliners (Tagesschau, 2012).

Also, changes to vehicle design within the regulated dimensions can contribute to the reduction of emissions. Modern vehicles emit much less greenhouse gasses, but there is a limit to the fuel efficiency that vehicles can achieve using traditional diesel engines. The aim of fuel efficiency is also in a trade-off with the emissions of other exhaust fumes. Regulation usually gives priority to the reduction of health-damaging gases over the reduction of CO_2, leaving an estimated residue of 7–10 per cent increase of fuel efficiency.

Other aspects of vehicle design include aerodynamic profiling. The vehicle shape is designed in a way that the air flows as smoothly as possible around the vehicle to minimize air resistance. Such design can be seen in 'teardrop' trailers, which show a slight arc when viewed from the side. But additional spoilers and shields on the trailer add weight to the vehicle, offsetting some of the fuel savings. This is also in contrast to the aim of minimizing the weight of the vehicle. The lighter a vehicle the less energy is needed to move it when it's empty and it also allows loading more weight onto it. In Europe the maximum loaded weight is restricted to 40 tonnes, meaning that the weight saved on the vehicle can be used to load extra freight.

Information technology

Developments in IT and mobile communication offer huge potential for operational optimization in freight transport. On the one hand software can optimize the routing, scheduling and loading of vehicles and online platforms make it easier to find backloading opportunities; on the other, this information can be communicated to the operating vehicle through telematic systems. In road freight transport, telematic systems connect the vehicle with the dispatching office, which means operations can be optimized dynamically while they are running. Real-time routing can also provide warnings of motorway congestions and traffic accidents. By taking advantage of these opportunities telematic systems can save miles, increase backhauling and reduce fuel consumption, reducing emissions at the same time (Wenner and Trautrims, 2012).

Telematic systems can also be used for monitoring vehicles and driver behaviour. Monitoring the vehicle allows for dynamic optimization and also provides information to the company and its customers on the location of a particular consignment. The information can also be used to comply with regulations, for example maximum driving hours, or to check on non-moving vehicles. Through monitoring driver behaviour telematic systems allow comparison of performance between drivers. Behaviour such as avoiding harsh breaking, using the right gear and turning off the engine at idle times saves fuel, and monitoring drivers' performance can be used to encourage environmentally friendly driving performance. However, telematic systems are a significant investment for hauliers. Their use is most common in larger fleets operating in markets that require frequent route optimization and communication between vehicle and office. Smaller haulage companies – the majority of the road freight transport providers – are much less likely to use telematic systems. Nevertheless, telematic systems only cover the monitoring side of driver behaviour; positive environmental effects can only be achieved if drivers are trained about fuel saving.

Other measures to reduce fuel consumption are properly inflated tyres or automatic tyre inflation and automatic idle engine turn-off. However, measuring the potential fuel saving of all operational improvement actions is difficult as fuel savings can stem from numerous sources and is subject to many factors, for example the proportion of the journey time on motorways or the incline of roads. Comparing fuel efficiency between different fleets or countries is therefore difficult due to the specific situations and their influencing factors.

Virgin Atlantic – alternative jet fuel

The greenhouse gas emissions from aviation are an omnipresent topic in the debate on transport's impact on global warming. With increased globalization air transport became a regular feature of travel and supply chain routine, and the emissions generated by it increased. Not only do aeroplanes burn a lot of fuel per tonne-kilometre, they also emit greenhouse gases at a very high altitude, which increases the effect on global warming.

Together with other airlines, airports and aerospace manufacturers, Virgin Atlantic joined the Sustainable Aviation initiative in the UK and the Sustainable Aviation Fuel Users Group, both pledging to reduce the environmental impact of aviation. The Sustainable Aviation group in the United Kingdom aims to halve the CO_2 emissions of the UK aviation industry by 2050 compared to 2005 levels. Besides greenhouse gas emissions, the initiative also addresses issues of noise and air quality.

While air quality and noise can be considered important hurdles for the expansion of the aviation industry in the United Kingdom, greenhouse gas emissions (and in particular CO_2) are a global issue for the industry. The European Union now includes aviation in its carbon trading scheme, increasing the cost for air transport, but through this also creating an incentive to reduce greenhouse gas emissions.

The reduction of CO_2 is planned to come from several areas: a reduction of fuel consumption at the ground through using mains electricity from renewable sources instead of aircraft engines; a reduction of queuing loops when waiting for landing; and improved take-off and landing procedures. The main attention is on the development and use of alternative fuels, however. A project initiated by the Carbon War Room – founded by Virgin Atlantic owner Sir Richard Branson – aims to promote the development of renewable jet fuels and their application in aviation. The aim of the initiative, and of Virgin Atlantic, is to achieve a 50 per cent share of renewable fuels in overall fuel consumption in aviation by 2020.

So far flights using fuels from renewable sources have mainly used a blend of traditional jet fuel with biofuel. However, the Sustainable Aviation Fuel Users Group makes clear that the production of alternative fuel shall not compete with the growth of food crops. At the same time the biofuel needs to have a high enough energy density, as aircraft often carry the fuel (and therefore weight) over long distances. These considerations mean that the choice of currently available biofuels is significantly limited.

Virgin Atlantic and New Zealand-based biofuel company LanzaTech announced plans to introduce a biofuel produced from captured waste gases of steel mills. These are fermented and chemically converted into biofuel. An estimated 65 per cent of the world's steel mills would be eligible for the newly developed technology, which could potentially also be used for waste gases of chemical factories and oil refineries, reducing both the factories' and the airline's emission of CO_2 by transferring one's waste into another's input.

The airline is planning to use the new fuel within the next three years on its routes between Delhi, Shanghai and London and bring the new fuel into commercial use from 2015 onwards. After successful testing the airline is planning to extend the infrastructure for the new fuel and roll out the use of the new fuel to more of its aviation operations. A main advantage for its application in the aviation industry is that there are only about 1,700 'fuelling stations' for commercial aircrafts worldwide and widespread coverage is therefore achievable much quicker than in road transport.

Sources: Carbon War Room; Sustainable Aviation; Virgin Atlantic

Infrastructure

The growth in transport puts increasing demand on existing infrastructure. As freight transport infrastructure like ports, roads and railway tracks are significant financial investments that often come with extensive planning and consultation periods, the infrastructure is often not adjusted quickly enough in response to increased traffic demand and shifts in transportation. Insufficient capacity in the infrastructure automatically leads to congestion.

Congestion means that transport vehicles are not utilized well, as they spend much time queuing – and burning fuel – in traffic jams or waiting for a port terminal or a landing slot to become available. Land vehicles caught up in congestion do not operate at optimal speed, meaning their engines are burning more fuel than necessary. Continuous accelerating and braking in traffic jams or in front of railway signals leads to high fuel consumption while the vehicle is not moving far.

The problem of congestion can be addressed in two ways: reducing traffic demands or increasing capacity. Extending transport infrastructure can face political obstacles. On the one hand congestion in road transport leads to avoidable emissions, but on the other hand an extension of the road network might make the mode even more attractive for users. Furthermore, citizens will be affected by an extension of infrastructure. It may therefore be politically undesirable, as it can be seen in the discussion about a third runway for Heathrow Airport.

In cities an extension of the road infrastructure is often hard to achieve. Particularly in densely populated city areas and historic city centres, new road developments may be in conflict with the protection of historic sites and the quality of life of residents. Solutions can therefore only optimize the existing road network and its utilization, shift transport to other modes, reduce overall traffic or mitigate the impact on citizens.

While freight transport is hard to shift to other transport modes in urban areas, government can encourage the reduction of freight transport and the use of low-emission vehicles. Across Europe cities see access restrictions for 'environmental zones' for vehicles that do not comply with specified levels of emission exhaustions. London introduced a congestion charge for road traffic in 2003 and since 2011 the charge has been related to the emission levels of a vehicle. Through this measure traffic through London is reduced and the use of cleaner vehicles is encouraged.

Shifting freight transport to off-peak times can be a way of reducing congestion. Nevertheless, night-time deliveries are unpopular with residents, because of an increase in noise at unsocial hours. A variety of delivery hours across the same city also adds more complexity to the delivery schedule of logistics companies and may lead to non-compliance or more journeys. One way of reducing the number of delivery journeys in urban areas is the use of consolidation centres for city centre locations (see box below). This concept can also be found at congested sites like airports and shopping centres.

Clipper Logistics: Regent Street consolidation centre

Regent Street in London is one of the busiest commercial streets in the United Kingdom. The street is probably best known for its wide range of retailers and hospitality businesses, but it also hosts many office-based businesses above the shops.

The usual amount of traffic in inner-city London led the Mayor of London to introduce a congestion charge for entering the centre of the city by car or lorry, with the charge relating to the size and emissions of the vehicle. Nevertheless, in a mid-week survey in 2009 Transport for London counted 2,314 delivery, servicing and waste collection vehicles stopping at Regent Street within the 48-hour survey period. Almost 70 per cent of these vehicles were deliveries, three-quarters being made by light goods vehicles. The peak delivery period was at the beginning of the business day, between 7am and 10am, with very few deliveries occurring after 4pm. The delivery peak coincided with many pedestrians trying to go to work, leading to busy and congested pavements exposing pedestrians to an increased risk of traffic, exhaust fumes and reversing vehicles.

Most of the consignments were described as small or medium sized and the most common commodities delivered were milk and newspapers. The majority of the delivery vehicles came from outside London, with some deliveries even originating their journey at distribution centres in Continental Europe. Most of the delivery journeys occurred on a daily basis and were evenly spread along Regent Street.

To reduce the amount of delivery traffic on Regent Street, the establishment of a consolidation centre was explored, with the expectation that Regent Street could bear the potential of reducing delivery vehicle numbers by 50 per cent and therefore cutting 82,400 delivery journeys annually with a reduction potential of 18,200 vehicles related to retail tenants.

A consolidation centre was set up focusing on retail tenants as many of them were interested in the benefits of using a consolidation centre. Stores receive a consolidated delivery every day. The drivers are usually the same and can process the delivery quicker as they develop relationships with the store employees and get familiar with the delivery procedures. Deliveries are not determined by the carrier but follow the schedule that is convenient for the stores. Particularly useful for fashion retailers are 'pre-tailing' services in which the logistics service provider prepares some of the in-store tasks at the consolidation centre, for example putting items on hangers, saving processing time at the store. The use of a consolidation centre also means that stores free up storage space for sales activities and maybe even pavement widening to make the street more attractive for shoppers.

The initial consolidation centre serving Regent Street and the surrounding area was established outside the congestion zone and attracted retailers like Liberty, Ferrari, Banana Republic, Anthropologie and Gap. It proved so successful that the project was extended for a further two years. Clipper Logistics, the operator of the consolidation centre, also started using electric delivery vehicles on this project, reducing emissions further and improving the positive environmental impact for the city even more.

Sources: Transport for London; Clipper Logistics

Wider aspects of sustainability in freight transport

At the early stages of sustainability in freight transport, the discussion was mainly limited to the reduction of greenhouse gases and often narrowed down to CO_2 only. This perspective was replaced over the years with a more holistic view including more aspects of sustainability. Consequently the discussion became more complex through the consideration of other environmental issues like biodiversity, but also through the addition of social and economic issues.

We have already discussed the production of biofuels where an early-stage enthusiasm changed into a more critical debate over its effects on the environment and where ethical questions of food versus fuel are raised. Public interest in the sustainability of global sourcing and freight transport was stimulated in the 'food miles' debate. It also came with a trend for consuming more locally produced food products and generally an awareness of eating more healthily.

Environmentally aware consumers started considering 'food miles' – the distance a food product has travelled from the place where it's harvested to the place of consumption – in their shopping decisions. The perception was that the longer the journey of a food product, the more harmful it was for the environment. This perception turned into more complex lifecycle assessments. Food miles came up as a form of criticism towards a lifestyle where consumers in Northern countries expect fresh fruits and vegetables to be available all year round, ignoring seasons and locally available alternatives. However, a sole focus on food miles did not consider different modes of transport or greenhouse gas emissions from the transport. Food miles also completely ignore the emissions coming from the food's production and the fact that many fruits and vegetables cannot be grown in Northern countries and that the income of many farmers in developing countries depended on the export of their produce to Europe (Rama and Lawrence, 2008).

In a lifecycle assessment of dairy, lamb, apples and onions produced in New Zealand and sold in the United Kingdom compared with the same items produced in the UK and sold there, a more complex picture emerged. Despite the additional transport, lamb and dairy products from New Zealand showed much lower greenhouse gas emissions than those from the UK. The lower emissions for the imported products were explained by the lower consumption of energy and fertilizers in the production of fodder in New Zealand, as agricultural and pasture space is more easily available. They also showed much fewer emissions from buildings as the climate in New Zealand allowed farmers to keep animals outdoors (Saunders *et al,* 2006).

Summary

Freight transport activities contribute to global greenhouse gas emissions. Although their share is much smaller than manufacturing, there is significant pressure to reduce transport emissions. With a still increasing trend for globalization, more and more complex supply chains, specialized actors along the supply chain and higher customer expectations in developing markets, the growth of transportation is going to increase emissions further. Although mainly focusing on greenhouse gas emissions, transport also has sustainability impacts as it emits noise and causes accidents. On the positive side it makes goods available to people, enables us to travel and explore other cultures, and allows participation in society, or more generally: transport makes our modern lifestyles possible.

The available transport modes vary significantly in their emissions, with the slower transport modes being generally less CO_2e emitting than the faster ones. A reduction of emissions from transport can be achieved by avoiding transportation altogether, for example through local sourcing, a reduction of the emissions from transport by using cleaner engines and fuels, or applying concepts like slow steaming, and through operational improvements achieved through technological support and collaboration.

Much of the shift for greener transportation will come from public pressure and government initiatives to increase the costs for greenhouse gas emissions. The provision of infrastructure and support for the development and application of green technology are governmental incentives that help to reduce the impact of transport.

The applications and solutions can be highly individual. With many green technologies being at an early stage, some options may not be applicable to all shippers, lack an infrastructure of sufficient coverage or may need reconsideration after some time. In the area of alternative fuels for example, the perception of biofuels as a more sustainable solution has changed.

Sustainable warehousing

04

Despite initiatives like 'just-in-time' and other inventory reductions in modern supply chains, warehouses can usually still be found at almost all stages along the supply chain. Not only do they buffer imbalances in the supply chain, they fulfil various functional activities and roles alongside the mere storing of goods. This chapter starts by looking at the environmental impact of warehousing and how warehouses can be categorized. We will then portray the different functions of warehouses and their design before we investigate opportunities to reduce the impact of warehouses on the environment and to improve their wider sustainability.

The environmental impact of warehouses

The World Economic Forum (2009) estimates that about 13 per cent of all supply chain emissions stem from logistics buildings, and the UK Warehousing Association (UKWA, 2010) quantifies the emissions coming from warehouses at about 3 per cent of the United Kingdom's total greenhouse gas emissions. Understandably, environmental issues of warehouses receive considerably less attention than transport operations, which account for the remaining 87 per cent of logistics emissions. Nevertheless, next to environmental improvements there is also a large potential for cost savings by running warehouses more efficiently (UKWA, 2010). Regulatory pressure on the construction industry to reduce its carbon footprint (RICS, 2010) and the cost of land usage in densely populated areas together with a reluctance of residents to have a warehouse close to their neighbourhood make it worthwhile to consider environmental issues in the design and operation of warehouses.

The impact of warehouses goes beyond their greenhouse gas emissions. Warehouses add to the traffic of heavy and lighter goods vehicles. They cause noise and cover large areas of land, interfering with wildlife and rain water trickling into the ground. But they are also a workplace that offers employment and they are essential in making products available to consumers and to keep factories and other businesses running.

The roles and functions of warehouses

Warehouses are an important operational part of supporting a company's supply chain strategy. They are the nodes in a supply chain network and they hugely influence service and costs of the network. Failures in holding and effectively dispatching the right stock at the right time in the right quantities and quality will result in unhappy customers. But warehouses and the inventory that is inside them also give rise to costs. These consist of fixed costs for the erection of the building and equipment, and the operational costs, which depend on the initial design of the warehouse. Similarly, the environmental 'costs' stem from the construction phase and from the operations.

The design of the warehouse – and the design of its operational processes – are supposed to support the overall business and supply chain strategy. Considerations at that stage are what market the warehouse serves: is it growing, stable or declining? Where is the demand for the products and where does the supply come from? Take for example a fast fashion online retailer. The opportunity to provide a 24-hour delivery service may be an essential feature of the business model. Or look at aircraft spare parts: warehouses are usually located right next to an airport with a dense flight network so that parts can be distributed quickly to operators around the globe. How much flexibility do operations require? Is cost more important than agility? And what is the expected duration of the investment and who owns and runs the warehouse? In well-developed logistics markets there will be a range of service providers operating a warehouse. They will offer a range of options and the selection depends on the underlying business imperatives of the client (Baker, 2010).

Warehouses have a range of roles in the supply chain. The most prominent differentiator is whether they actually store stock. 'Cross-docking' is goods being received, processed and dispatched without being stored and is often used for goods that need to be moved rapidly, for example perishables, and in warehouses further away from centralized stockholding points.

Besides the increased speed, cross-docking is also popular for centralizing inventory and saving inventory costs. Cross-docking is gaining further importance in future supply chains (BNP, 2010). With a reduction of warehouses holding the same inventory the required safety stock can be reduced through the 'square root law'. This is based on the rule of thumb that when centralizing inventory the ratio of inventory held in a decentralized system to the inventory held in a centralized system equals the square root of the number of initial locations. As an example, by reducing 10 inventory holding warehouses to one centralized site, overall safety stock inventory can be reduced by 68 per cent (Maister, 1975). The number of inventory holding warehouses is therefore a trade-off between transport costs (for longer journeys) and the costs for holding inventory. However, the choice is usually more complex with many more considerations.

Fulfilment centres are another role of warehouses, where many operational activities occur in the warehouse. Orders are picked either by workers or by automated systems, items are put together in orders, packed and sent out to the customer. Online retailers who use these fulfilment centres experience some very high return rates, which led to improved and specialized facilities for processing returned items in fulfilment centres.

Warehouses can also cover value-added activities in the final processing and customization of products. This can be part of assembly and packaging operations. In retail trade distribution centres we can also see the preparation of goods for shops (for example putting items on hangers or adding price tags). But warehouses may also have a much stronger inbound focus. Consolidation centres bundle smaller deliveries into larger shipments. This can often be found in export-oriented places to ensure shipping containers are filled up with loads from multiple suppliers. Similarly, in warehouses in port-centric logistics, goods are received and consolidated in the warehouse at the port of arrival.

In just-in-time supply chains, warehouses at the customer end of the supply chain are avoided. Stock is stored at the suppliers (or ideally only produced as needed) and transported to the assembly line as and when it is needed. This concept is particularly widespread in car manufacturing. Due to high levels of customization, just-in-time developed into just-in-sequence, where the delivered products are arranged to suit the production schedule. These concepts are very complex and vulnerable and require a high level of logistics competence and sophisticated operations in all parts of the supply chain, including the warehouse nodes. Warehouses in these supply chains are mainly buffering supplier and customer production schedules and prepare goods for delivery direct to the assembly line.

Despite all these trends and changes in warehouse design, most warehouses still fulfil the classic warehouse function of receiving goods, storing them and dispatching them at a later point. Most warehouses also combine several roles and operational aspects and would for example have a cross-docking area in addition to holding some stock of other products.

Many logistics activities are outsourced to external providers. In Europe just over a quarter of the warehousing market is outsourced, and a slightly larger proportion of the contract logistics market, where the entire distribution function to a third party, usually including warehousing, fulfilment and delivery operations is outsourced under contract (Fraunhofer SCS, 2010). The outsourcing of warehouse and fulfilment operations can have many facets, usually categorized by who owns the assets and manages the operations. Important for sustainability issues is whether the owner of the warehouse has a long-term perspective for a site, which impacts the decision to invest in sustainability measures that have a longer payback period (Rushton and Walker, 2007). Using external service providers also makes it easier to collaborate with other customers or to use shared facilities, which can result in better utilization and economies of scale. Logistics property developers may construct sites speculatively without knowing the eventual specifications, making it more difficult to estimate whether future clients are willing to pay for sustainability features.

Warehouse location

The number and locations of warehouses in a logistics network determine to a large extent the amount of transportation that is required within the network. Ideally a warehouse is located at the so called 'centre of gravity' of the transport journeys in the area that it serves. The number of warehouses in the overall network and the areas they serve are ideally the optimal trade-off between the costs of transport and the costs of the warehouses (and the inventory, etc).

A reduction in inventory holding points leads to a reduction of safety stock and consequently a cost reduction in inventory. In this trade-off between inventory holding and transport journeys, there has been a general trend towards more centralization of inventory in recent decades. This can mean that a central distribution site may be run more efficiently, but it may also mean more journeys and transport kilometres (Kohn and Brodin, 2005). The centralization of inventory is encouraged by low transportation costs. Additionally the elimination of border controls (and the resulting reduction of waiting times at border crossings) in Europe encouraged companies to centralize their distribution in fewer sites and often in a single European site (Ferrari *et al,* 2006). Furthermore, logistics approaches like just-in-time in manufacturing and efficient consumer response (ECR) in retailing led to more frequent deliveries of smaller batches.

The decision on warehouse location is more complex than a pure optimization of the transport network at the centre of gravity. Planning permission for a greenfield development may be difficult to obtain and land use can be restricted by legislation. If an existing site is to be used, it may be that available sites are not in the preferred location and a suitable warehouse at a less favourable location is the next best option.

Another criterion can be access to particular transport modes. BNP (2010) reports that the majority of logistics real estate customers consider multi-modal transport as being increasingly important. The access to rail and water transport may be an essential feature for particular products and sustainability strategies. With increasing cross-border trade, port-centric logistics is also becoming more popular. Locations like ports can also be chosen if the warehouse needs to be in a free-trade zone or access to service providers specializing in sea transport is required.

The proximity to customers or to supply sources is a strategic decision that can be an essential feature in supporting a business's market strategy and may even be a requirement in the contract with a large single customer. Access to labour is another aspect: fulfilment centres provide opportunities for employment. In the case of online retailers for example, demand during the Christmas period peaks and the fulfilment centre needs large numbers of temporary staff. The availability of sufficiently skilled staff is even more important when more value-added services are performed at the site and when there are more complex logistics processes and handling equipment.

Handling equipment

The operational processes in a warehouse are supported by the use of handling equipment which is also a major consumer of operational energy. The selection of handling equipment is usually determined by the purpose and design of the warehouse and the goods that are processed at a site. The level of automation varies considerably between warehouses. Unmanned automated warehouse equipment, often referred to AS/RS (Automated Storage/Retrieval System), usually leads to higher throughputs but also decreases flexibility. Using people also makes it easier to cover peaks more easily. Retail fulfilment centres in particular rely on human labour, as the packing of boxes is difficult with automated equipment and returned goods rely on human judgement of whether they are in a re-sellable condition. Automation might be a preferable option in harsh environments, for example in refrigerated warehouses or in low-oxygen environments. Conveyor belts, cranes and dredgers are used to handle bulk cargo. Other typical handling equipment is forklift trucks, commonly found in palletized goods environments. Forklift trucks come in many varieties and engines, using batteries, diesel or even hydrogen.

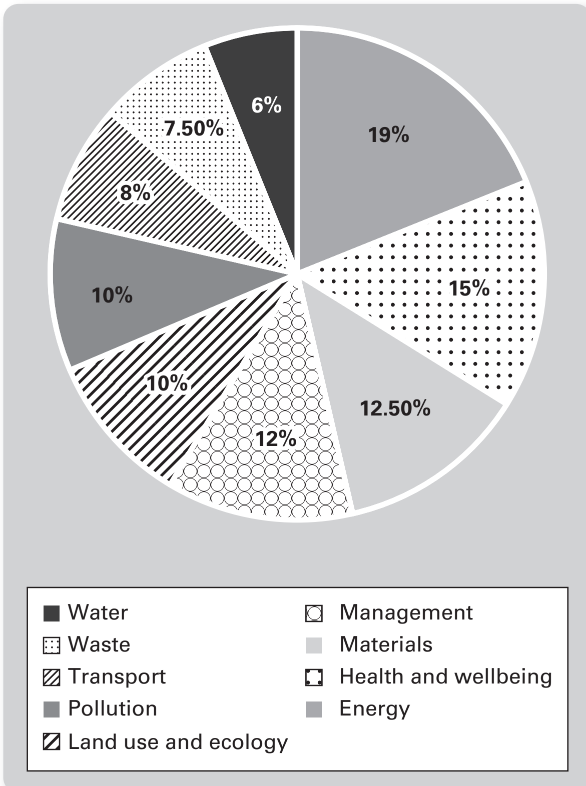
All these types of handling equipment have different characteristics. After strategic considerations of longevity of investment and flexibility and operational aspects of throughput capacity, item characteristics and warehouse site need to be looked at. If a warehouse is expected to have a high throughput, goods need to be stored more densely, otherwise the journeys between receiving, storage, order picking and dispatching become too long. Also the site and cost aspects may restrict the land use of the warehouse. Automated warehouse equipment can cope with a higher throughput, and it also achieves a higher storage density as it can reach higher levels in the warehouse and needs less aisle space for manoeuvring than forklifts.

Assessing the impact

The environmental balance of a warehouse consists of two levels: the emissions from the construction and the operational emissions. Before we look into how the impacts from those can be reduced, we need to learn about the current standards to assess the environmental performance of warehouses.

The most widely used standards for assessing the sustainability of warehouse design are LEED, the Leadership in Energy and Environmental Design framework from the US Green Building Council; and BREEAM, the Building Research Establishment Environmental Assessment Method from the Building Research Establishment (BRE) based in the UK. Both schemes measure the sustainability of warehouses by awarding point scores in several weighted categories. Depending on the overall score the warehouse is accredited a certain sustainability class: BREEAM statuses range from 'Pass' to 'Outstanding'; LEED categorizes warehouse sustainability from 'Certified' to 'Platinum'. Both schemes add a weighting

FIGURE 4.1 BREEAM weighting factors

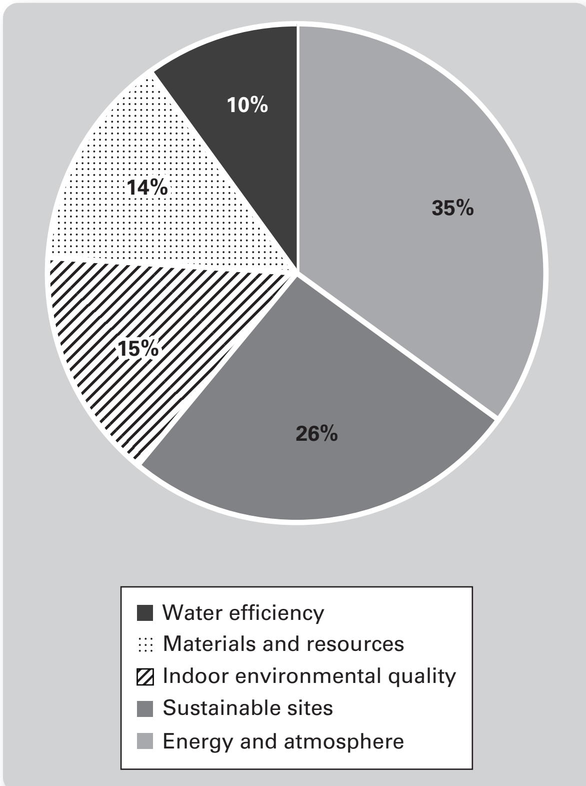


factor of 10 per cent for innovation. The two schemes can be compared in Figures 4.1 and 4.2.

Within each category points are awarded according to a warehouse's performance against the scheme's benchmark standards. These points are then multiplied with the category's weighting. Under the BREEAM scheme for example, a score of 85 per cent must be obtained to be classified as 'Outstanding' and 70 per cent for 'Excellent'. Also minimum scores in some sub-categories must be obtained, for example 10 out of the 15 available credits for reducing CO_2 emissions to achieve 'Outstanding' compared to 6 credits for being rated as 'Excellent' (BRE, 2012).

The first warehouse to achieve 'Outstanding' status under the BREEAM scheme is the G Park Blue Planet distribution centre in Chatterley Valley, in the English county of Staffordshire. The developer Gazeley projected the savings in operational costs due to the environmental features in its design

FIGURE 4.2 LEED weighting factors



to be £300,000 per annum (BRE, 2012). It features non-stick self-cleaning roof lights, solar photovoltaic laminates and kinetic plates to recover energy from arriving vehicles (Baker, 2012).

Despite the proposed operational savings resulting from high environmental ratings this does not necessarily lead to equivalently higher yields in terms of rent or value. A recent study found that energy savings expressed in better EPC (energy performance certificates) ratings did not result in an equivalent increased rent and there is only limited evidence that better EPC ratings had an impact on yields (Fuerst and McAllister, 2011). Although tenant surveys express willingness to pay a premium for operational savings, tenants also identify a tendency to shorter-term leaseholds, which reduces the attractiveness of longer-term investments in sustainability measures (BNP, 2010; ProLogis and Capgemini, 2006).

The gap between environmental performance and rents may be explained by the different interests of the many stakeholders involved in a building over its lifetime. Real estate developers are mainly interested in the return on investments, short-term risks and only indirectly in the functional quality of the warehouse. Financial investors have their main interest in the return on investment, the expected development of the property value and the anticipated risks. If the warehouse is going to be owned by the user, future rents are not part of the consideration, but more focus is on functionality, risks and lifecycle costs. Tenants in contrast are mainly focused on the rent and functional quality, while the public and public authorities are mainly interested in the external costs and total costs of the warehouse and the risks anticipated with the construction (Gregori and Wimmer, 2011).

The accreditation schemes initially focused very much on the design stage of warehouses. However, lately they have developed guidelines for assessing sustainability improvements at existing sites. Embodied energy in existing buildings is often overlooked and an assessment of the whole lifecycle of a building, considering the embedded energy, carbon and other emissions, is therefore a more complete approach. This also applies to considerations of end-of-life issues, such as the disposal of materials and the energy consumed in the deconstruction. Overall, the lifecycle analysis should consider inputs and outputs from raw material extraction, manufacturing, construction, use and disposal (Menzies, 2011). One must also note that the accreditation schemes use a set framework without considering variations between countries in the importance of various sustainability aspects. In water-scarce countries water usage may have a much higher priority than land use.

The overall environmental balance depends on the sum of emissions from all stages of the warehouse lifecycle. It may therefore be less environmentally damaging to use an existing site despite poor operational performance, since the embedded energy and emissions have already occurred (Menzies, 2011).

The relative proportions of operational impact and embodied impact differ significantly between warehouses and also strongly depend on their lifespan. In a comparison of various roof light ratios and insulation options, Rai *et al* (2011) identified that the combined impact of embodied and operational CO_2 emissions of a warehouse over a 25-year lifespan did not show huge differences in the total CO_2 impact. The study compared scenarios of decisions on roof lights and insulation at the design stage of a conventional distribution centre of 8,000m^2 and the impact they have on heating during the operational phase of the warehouse. Due to the higher carbon embedded in the insulation material and the roof lights, an increased level of insulation had only a very marginal positive effect on the environmental balance of the warehouse over its whole life. However, the proportion of operational impact and embedded impact is crucial in the lifecycle assessment. Gregori and Wimmer (2011) assume that 80 per cent of costs are caused during the operational phase of a logistics building, which gives sustainability considerations in the design stage more emphasis. They also point out that over the 25-year lifespan of a warehouse, one needs to assume rising costs for energy.

An assessment is even harder to make when looking at the often high turnover of tenants. A warehouse may often not be fully utilized, leading to inefficiencies. It can also mean that additional emissions from construction activities occur at a later point when altering the warehouse to a new tenant's needs.

Reduction of the environmental impact

Following the lifecycle concept, for buildings we can generally differentiate between operational carbon (or carbon equivalent) emissions and the embedded emissions. Investments in the operational improvement of the sustainability of a warehouse may often occur at the construction stage and it is therefore important to understand the purpose and the anticipated lifecycle of the building. RICS (2010) considers the share of embodied carbon equivalent emissions to be 60 per cent of a warehouse's overall CO_2 equivalency emissions. However, if assuming a lifecycle of only 10 years, the share of embodied CO_2e rockets to 95 per cent, shifting the focus of emission savings from the operational phase to the construction itself. In comparison, a supermarket over its lifetime would usually have a ratio of 10 per cent embodied energy to 90 per cent operational energy, as a supermarket typically uses a lot more energy than a warehouse.

The differentiation becomes crucial when discussing what emission reduction levels are supposed to be achieved (RICS, 2010). For the erection of a short-term warehouse, operational emissions can almost be ignored, and more emphasis needs to be placed on avoiding CO_2e in the construction operations and material; while for long-term use of a warehouse, operational savings become more worthwhile even if they cause more emissions (for example for additional insulation) in the construction phase.

In the construction phase, emissions are caused by the construction materials and the construction processes. The emissions embodied in the construction materials vary, and so does their lifespan. An aluminium curtain wall contains around 1,000 MJ/m^2 of embodied energy but has a life expectancy of less than 40 years. The lifespan of a timber frame with aluminium cladding is of similar length, but the embodied energy is only 400 MJ/m^2.

When comparing the aluminium curtain wall with a concrete panel the importance of lifespans becomes apparent. The concrete wall contains a little over 800 MJ/m^2 energy – not quite 20 per cent less than the aluminium curtain wall – but its life expectancy is almost double that of the aluminium curtain wall. If a structure were really used for more than 40 years, the energy savings become really significant, as the aluminium curtain wall needs to be fully renewed (RICS, 2010). When looking at timber, the importance of local sourcing becomes obvious: while imported timber typically embodies 7,540 kWh/m^3 (significantly more than the 800 kWh/m^3 for concrete), the local timber alternative contains only 110 kWh/m^3 (Harris, 1999).

For warehouses, it may be unlikely that they will really be usable for the full 40 years lifetime. Storage and logistics requirements change over time and particularly the layout of multi-client sites needs to be changeable to adjust the number of doors, allow more height, floor strength for heavy goods or special storage arrangements like clean rooms or refrigerators (ProLogis and Capgemini, 2006).

Many logistics sites cluster in areas that are close to the transportation centres of gravity for the markets they are serving or they cluster around ports and airports. Availability of the right warehouse space in the right areas therefore becomes an issue. The most popular locations are most often found in relatively densely populated areas, where space is scarce and expensive. Additionally, traffic congestion and local restrictions on traffic and operating hours limit warehouse operations. The high cost and limited availability of space may lead to the construction of higher buildings and the installation of handling equipment that uses up less space, and real estate developers will naturally look into brown-field developments. Although this incurs demolition costs, it may benefit sustainability as upgrading existing structures avoids the addition of embodied carbon from construction material used in building a new warehouse (ProLogis and Capgemini, 2006).

The use of land itself is an emission and newly built warehouses interfere with the environment. This can be rainwater no longer trickling into the ground, interference with local wildlife and destruction of green areas, and visual impact on the landscape. The area also becomes unable to absorb any carbon, which in the case of the site that was once agricultural or vacant, has a permanent effect. The amount of land used for warehousing in the United Kingdom has been increasing significantly over the last decade and is now greater than the land covered by offices or retail stores.

Construction processes rely on heavy machinery and engines to move building materials, earth and rubble. Lane (2012) assesses the carbon created in the construction process of a 10-storey office building in inner London to

13 per cent and estimates the demolition process to clear the building site at 2 per cent of the lifetime carbon footprint. Although warehouses are usually of a lighter structure than office buildings, it shows that the construction processes add significantly to the carbon footprint of any building, including warehouses. However, supply chains in the construction industry are influenced by many stakeholders who have different interests. Involving all stakeholders of a building's lifetime is complex and must look beyond the client-contractor-supplier relationship. The shift towards sustainability in construction must come through the purchasing power of influential buyers and their demand for specified performance criteria (Ofori, 2000). During the construction phase much of the building material is delivered directly from manufacturers to the site and very little communication exists across the network of manufacturers, contractors and hauliers. Transport efficiency is also negatively affected by the geographical location, accessibility and a lack of infrastructure at greenfield sites (Sternberg *et al,* 2012).

Besides the embedded emissions in the building stemming from the construction materials and construction processes, the operational emissions need to be considered. Although the discussion is mainly focused on reducing the energy consumption of a site the warehouse's operational sustainability also consists of other aspects like using all resources more efficiently and reducing the waste generated by a site.

Benchmarking and comparison of the energy performance of warehouses is difficult as they are built in different environments and contexts and for different lifespans, products and purposes. Also, environmental auditing schemes vary and may work in favour of particular solutions. For example the PAS 2050 carbon auditing guidelines exclude employees' commuting journeys from the audit – giving an advantage to a warehouse that's operated with more human labour and less technology and also ignoring the additional emissions from commuting journeys if a warehouse is poorly connected to public transport and far away from the employees' residences.

Temperature control is estimated to contribute up to 20 per cent to a frozen goods warehouse's operating cost (Marchant, 2010). Refrigeration units use electricity; the way that electricity is produced therefore determines much of the carbon footprint. Heating systems are usually based on burning fossil fuels or materials from renewable sources. The loss of heat depends on the temperature difference between the inside and outside of the warehouse, insulation and building fabric, and controlled and uncontrolled air ventilation (Carbon Trust, 2012a). Warehouses may require a wide control of humidity or even the oxygen content. For example fresh fruits are usually stored in a CO_2-filled environment to decelerate the ripening process.

However, temperature control also needs to consider the comfort of warehouse employees. Although the storage area may be refrigerated, the staff room right next to it will be heated at the same time. Health and safety regulations limiting employees' time in the low temperature environment and safety clothing limit the operations in such warehouses. The heat from handling equipment, lighting and machines adds to the required refrigeration effort. Temperature-controlled warehouses therefore not only depend on the ability to achieve the required temperatures, but also to hold those temperatures.

Regardless whether the warehouse requires heating or cooling, thermal insulation and heat/cold loss barriers reduce the consumed operational energy (although they may increase the embedded emissions, as discussed earlier). Some ventilation is needed to exchange air and maintain an environment that is safe for people to operate in; however, controlled and uncontrolled air ventilation need to be considered separately. The exchange of air means constant temperature adjustment. A warehouse with high rates of uncontrolled ventilation (also called air infiltration) wastes energy for heating/cooling. Air leakage causes about 25 per cent of heat loss in a typical industrial building (Carbon Trust, 2012a). Unnecessary losses of temperature-controlled air from air exchange can be prevented through separating temperature zones effectively; installing fast-acting gates, closely fitting doors, using thermostats and opening doors and gates only when necessary (Marchant, 2010). Warehouses are usually built with very high ceilings. Hot air rises, which can lead to temperature differences between ground level and close to the ceiling of up to 10 degrees Celsius. Ceiling circulation fans redistribute the heat back to the ground floor where the operators are working. Usually the savings from the value of heat exceeds the energy consumed by the fans (Carbon Trust, 2012b).

The thickness of insulation reduces the temperature loss and therefore also reduces the required energy for constant temperature adjustment. However, the thicker the insulation the larger the embodied energy in the insulation material; there is consequently a maximum at which insulation makes sense (Harris, 1999). Warehouses can also be separated in zones, with barriers between them to limit the air exchange to smaller units and to adjust temperatures more precisely. The lower the temperatures required the greater the refrigeration effort and the electricity consumed. Therefore separating products into groups of the same temperature storage requirement levels avoids the storage of products at temperatures lower than necessary.

An ambient warehouse of an average size uses about two-thirds of its electricity consumption for lighting (UKWA, 2010). Installing more efficient lighting technology, roof lights, and switching off unneeded lights can reduce the electricity used for lighting. New energy efficient lights, like LEDs or fluorescent lights, convert a higher proportion of the input energy into light and less into heat than conventional lights. They are also lower in maintenance and have a short payback period of only a few years (Long, 2010). The overall number of installed lights can also be reduced by about 30 per cent through the installation of reflectors above the light source (Gregori and Wimmer, 2011). Generally, however, the lighting requirements are determined by the tasks performed in a particular part of the warehouse, for example lighting at the storage area depends on aisle width and height. Solutions therefore need to be adapted to individual warehouse designs and purposes (Marchant, 2010).

Allowing sunlight to shine into the building, for example through the installation of roof lights, can be a way of reducing the need for artificial light (Marchant, 2010). Natural sunlight is also perceived as more comfortable than electric light (Gregori and Wimmer, 2011). However, roof lights need to be considered in their overall effect, as they may have a negative impact on insulation (Baker, 2012). Both roof lights and electric lights need cleaning periodically, as the dust of two years of operations can reduce the light levels by up to 50 per cent, increasing energy consumption by 15 per cent (Marchant, 2010).

Arranging for light only in the areas where it is needed, turning off lights manually or through the installation of movement sensors or time controlled light switches saves significant amounts of electricity (Gregori and Wimmer, 2011). Changes in warehouse lighting usually show rather short payback periods, making it an attractive sustainability improvement for rented warehouse sites and shorter lease times (UKWA, 2010).

Another area of energy consumption in the warehouse is the use of handling equipment. This includes automated storage systems, which consume electricity for moving goods around and computer systems controlling the movements and storage. Forklifts can come in many varieties to suit the characteristics of the goods and the site. They run on various types of fuels or electricity (see the section on alternative fuels in Chapter 3). Similar to lighting installations, material handling equipment emits heat in addition to energy consumption, increasing the energy used in temperature-controlled warehouses. Fumes from fuel-based handling equipment also increase the need for ventilation, reducing the thermal efficiency of the building.

A shift to lower emission fuels and electric forklifts reduces the CO_2 emissions from warehouse operations. No clear general statement of what energy type for forklifts causes the least emissions can be made from prior studies. Evaluations differ between 'well-to-pump', 'well-to-wheel', 'outlet-to-battery', 'battery-to-wheel' and 'wheel-to-exhaust', making the alternatives hard to compare. A full lifecycle assessment including maintenance, lifespan, disposal and energy consumption would have to be considered to really compare the options. The complexity of such an assessment and the difficulty of comparing the alternatives tend to lead to a cost-of-ownership approach rather than a total emissions assessment (Marchant, 2010).

Improvements in battery technology and battery energy efficiency may increase the sustainability and attractiveness of electric forklifts. As they are charged from the electric mains, the source for the electricity can be determined by the warehouse user. Modern electric forklifts can also regain energy when the forks are lowered with a load or when the machine brakes (Marchant, 2010). The regaining of energy together with improved battery endurance, faster charging modes and better energy efficiency results in longer operating times, reducing the overall number of batteries or forklifts required. Through advances in technology, electric forklifts became the main mode for the indoor use of forklifts (Long, 2010).

Similar to the optimization of any other transport network, journeys within the warehouse made by forklifts or other mechanical handling systems can be optimized by using IT and warehouse management systems (WMS). Forklifts enabled to communicate with the WMS can reduce the number of journeys, for example by avoiding detours to input data into a computer station (Long, 2010). Other electricity-consuming technology applications in the warehouse are picking systems, such as pick-to-voice or pick-to-light (Marchant, 2010).

A warehouse's overall emissions can also be reduced by consideration of the wider operational issues. Operating hours and delivery can be scheduled to avoid peak traffic times. Avoiding congested areas for the warehouse site also means fewer lorries are sitting in traffic (Thuermer, 2009).

Warehouses also consume water. Water is consumed for workers' needs, but also in the cleaning of the warehouse lorries (Gregori and Wimmer, 2011) and in the processing of goods (if value-added activities are happening at the warehouse site). Also, refrigeration units may consume water. Due to the usually large roof surface many warehouses are ideal for harvesting rainwater and reusing it in grey water areas in the warehouse.

Depending on the level of value-adding activities and packaging processes, warehouses create waste like any other industrial site. Incoming deliveries may need to be split up, unpacked or re-packed before they are stored. Outgoing products need wrapping, may be put on disposable pallets or packaged in other ways. Reducing and avoiding packaging, recycling packaging materials and packaging in a way that makes it easier to recycle, all reduce the environmental impact of the warehouse's waste.

Green energy

Since much of the operational emissions is related to energy consumption, the harnessing of green energy at warehouse sites can be used to improve the overall operational sustainability of the warehouse. Warehouses are often situated away from residential areas in industrial estates, close to ports, motorways and other transport infrastructure. Opposition from local residents groups to green energy harnessing installations in their neighbourhoods can therefore often be avoided, making warehouse sites most suitable for the generation of green energy. Solutions to the sustainability of new non-domestic buildings are categorized into 'on-site rich' (63 per cent of regulated reductions to comply with targets coming from on-site improvements), 'off-site rich' (44 per cent of reductions from on-site), and 'balanced' (54 per cent of reductions from on-site). On-site reductions mainly come from higher building energy efficiency and the use of low and zero carbon energy generation. The ability to generate low-carbon energy on-site and therefore the reduction of emissions on-site will depend hugely on a site's context and environment; the installation of wind turbines for example may be politically much easier at a rural site close to a motorway than in an urban location (UK GBC, 2010).

Green energy produced on-site can either be consumed directly, fed into the electric grid or a combination of both, whereby on-site produced green energy is consumed by the site but a connection to the electric grid is used for balancing out the site's power supply and demand. At the same time, electricity bought in from energy suppliers can also be sourced from 'green' form of electricity generation.

Energy at a warehouse site can be generated from biomass or low-carbon fuels (which are not totally carbon-neutral, but may have a lower emissions impact than a previously used fuel), wind turbines, solar panels, recovered waste energy, kinetic energy and thermal-exchange units (Marchant, 2010). The way energy is generated and sourced for a warehouse site is individual to the site's requirements, settings and context. The decision on the types of electricity and energy to be used depends on operational, regulatory, environmental and market factors. The general issues are operational patterns of energy consumption against the generation of energy at the site; the costs of the energy generation technology and the scale at which the energy can be produced at a reasonable cost (and whether there is enough demand to build a power-generating facility of the necessary scale); the availability and maturity of technology; and regulations and market conditions (Marchant, 2010).

The generation of energy on-site increases the complexity of energy management. Balancing energy demand with supply, the fluctuation of energy market prices, the fluctuation of production depending on local geographical circumstances and weather, the proximity of other energy consumers nearby and infrastructural access to the national grid all make energy management and the investment decision more complex. Despite energy generation on-site warehouses need to be connected to the electricity grid to transfer electricity into the wider network and to source from it. Around 44 per cent of the on-site generated electricity will be fed into the national grid. Governments worldwide are currently implementing different ways of encouraging or even enforcing an increase in low and zero carbon energy generation. Feed-in tariffs (a regulated price for renewable energy that is fed into the national grid) financially encourage the installation of renewable energy-generating infrastructure. Other regulations impose minimum energy efficiency levels for sites, the purchase and trade of renewable obligation certificates or emission allowances, the sourcing of a certain percentage of the consumed energy from renewable energy sources, or the inclusion of on-site energy generation in planning permissions for new buildings (UK GBC, 2010).

The costs for sourcing and generating 'green' energy vary across the available options. Comparing the costs for on-site and off-site generated energy from renewables, the on-site solutions appear more costly in many cases. The annual cost per kilogramme CO_2 avoided for small-scale wind is more than tenfold the cost of large-scale wind. The cost for solar photovoltaic installations is even higher, whereas the usually off-site installation of a biomass CHP (combined heat and power) plant is not much more expensive than the large-scale wind option (UK GBC, 2010). Large-scale wind and biomass CHP are more likely to be off-site, as they often require more than one user. Off-site solutions in most cases use an external supplier avoiding the warehouse operator being tied to a long-term commitment. Solar panels for example only make sense if the warehouse user owns the facility or if the owner considers the solar panels a worthwhile investment; the payback period in the United States, for example, is around 15 years (Long, 2010). Sourcing 'green' energy from an external supplier might therefore in most cases be cheaper and carry less investment risk than small-scale on-site generation.

It may often be governmental regulation and incentives that make on-site energy generation a considerable option. Looking at the large investments and long payback periods for 'green' energy generation on-site, it is probably unsurprising that managers prefer to invest in energy saving and waste avoidance solutions like improved lighting, recycling and air circulation fans than solar panels or wind technology (Material Handling Industry of America, 2011).

Sustainable distribution centre – Alnatura

Alnatura was founded in 1984 and is now Germany's largest supermarket chain specializing entirely in organic and sustainable products. The chain runs 70 stores of usually around 550m^2 in size in 39 cities across the country, each store listing around 6,000 organic SKUs (Stock Keeping Units), including around 1,000 lines of its own-label branded products. The company also sells organic products through a network of other retailers. In 2011 it was given the German Sustainability Award by the Agricultural Ministry in recognition of its overall sustainability drive. The company is owned and run by its original founder. Besides its achievements in environmental sustainability and organic agriculture, the company uses a multi bottom line approach, adding for example spiritual-cultural to the usual dimensions of social, economic and environmental of the triple bottom line approach.

In 2009 the company built a new distribution site in Lorsch in central Germany to serve its stores and retail customers. The site comprises warehouse space of 20,800m^2 with 17,000 pallet places and office space of 1,400m^2. The building blends in with the surrounding area and much green space is left around the building to provide a pleasant environment for employees and passers-by. The space around the buildings is also used to transfer rainwater from the roofs into the ground and thereby maintain groundwater levels. The building achieved the highest outcome – gold – in the ranking of the German Council for Sustainable Building.

The new site also saves emissions in the transport network. Previously the distribution network was run in a decentralized fashion and suppliers delivered into multiple locations. Perishable produce is delivered by local suppliers directly to the stores and nationwide supplies are distributed centrally, saving transport kilometres.

The outer shell of the buildings consists of larch wood, which is sourced locally from a nearby forest. Similarly most other construction materials were sourced locally to save emissions embedded in the materials. Even the spades used in the traditional German ceremony starting construction works were manufactured locally.

The building's rooftop is covered by a photovoltaic installation of 7,821m^2, producing 1.100 kW at peak – enough to provide energy for approximately 260 households and saving 918 tonnes of CO_2 annually. Heating and cooling of the warehouse area is achieved through the use of an air-warmth pump; energy for the office building is generated through the use of a geothermal station. Energy bought in from outside to cover times when the on-site energy supply is low is generated from water power.

Going beyond the sustainability of the distribution warehouse, the organic products stored in the warehouse are all produced under a sustainability approach, for example using natural fertilizers to avoid the emissions that come from chemical fertilizers usually used in growing non-organic food.

Sources: Alnatura, Deutsche Gesellschaft für Nachhaltiges Bauen

Social dimension of sustainability in warehousing

The social dimension of sustainability also needs consideration in warehousing. With value-added activities and processes being increasingly shifted to logistics service providers, warehouses and distribution centres employ more people with a wider set of skills. Technology and the increasing complexity of supply chains mean warehouse operators require new skills sets and knowledge.

Issues of health and safety need to be considered in the warehouse and workplace design. With the demographic change to older populations in many developed countries, ergonomic workplace design and wellbeing gain more importance. The use of handling equipment and supportive technological applications needs to be considered differently in the light of an ageing workforce. Additionally, the overall number of workers is shrinking, making it more important to keep staff and to provide an attractive workplace.

bauMax 'Human Programme'

The discussion of sustainability in warehousing is often limited to the environmental sustainability of structures and operations, usually in combination with an economic evaluation of environmental measures. But as places of employment, warehouses and logistics sites also impact on the social dimension in their sustainability under the triple bottom line concept.

The Austrian do-it-yourself (DIY) retail chain bauMax runs a company-wide programme to integrate employees with disabilities into the organization, mainly in logistics and maintenance processes but also in customer service and in headquarter functions. Moreover, integrating employees with disabilities and collaborating with disability charities form an essential part of the company's overall corporate strategy.

bauMax is Austria's largest DIY retailer with large box retail stores across the country. It has expanded into Central and Eastern Europe and employs around 10,000 people overall. The proportion of handicapped employees is 2 per cent in the entire group and 4 per cent in the Austrian home market. The company is family owned. Since its foundation in 1976 Christian social principals are embedded in the company's corporate identity and actions. The focus on integrating employees with disabilities was not due to biographical experiences or a charitable motivation, but stems from the Christian beliefs of the family owners to provide a socially sustainable and human-friendly workplace for their employees.

The company collaborates with local disability organizations by contracting them with parts of the maintenance and service operations, and products made in factories and workshops for the disabled are sold through the stores. In Austria every bauMax store partners with a local disability organization. The actions and level of collaboration are left to the local store management and over time many different approaches have evolved. Store management is additionally encouraged to employ disabled employees by not considering their output in internal store performance reviews. Many disabled employees are naturally not able to work to the same productivity levels. Also, indirectly tangible benefits from integrating disabled employees, for example increased workplace satisfaction of staff, would be hard to quantify in these performance reviews.

The handicapped workers directly employed by bauMax are preselected by the disability organizations, which helps the company find suitable candidates for employment and reduces the risk of failing to integrate the disabled employee. Disabled employees are paid under the same collective bargaining agreement as all other employees and have access to the same benefits. Savings on monetary penalties that are imposed if a company employs less than a particular quota of disabled people is not a significant motivator for the company; only in Hungary are penalties so severe that the employment of disabled people has a direct monetary advantage.

The integration of disabled employees is by no means a pure cost factor. The work environment improves and employee satisfaction is also high among non-disabled employees. The customer feedback from interaction with disabled employees is positive throughout and customers appreciate the initiative as a differentiator to competitors.

Integrating disabled employees also helps bauMax to prepare for a future that will see ageing societies in the markets where it operates. More and more older consumers will move their buying power to places where they can shop conveniently without barriers. Through the integration of disabled co-workers bauMax employees are prepared to interact with customers who may need additional assistance and service.

Source: bauMax

Risks and vulnerability in warehousing

In the economic dimension of sustainability, risks and supply chain disruptions have gained importance. Globalization, extremely lean supply chains with low inventory levels and a trend for centralization of inventory have increased the vulnerability of supply chains and the impact if a warehouse fails to operate properly (Christopher, 2011). Warehouses are often essential nodes in supply chains and the damage or loss of a warehouse can cause significant disruption to a business and threaten its economic wellbeing. Preparing for supply chain disruptions does not always come with higher inventory levels, but depends more on risk profiling, visibility and the right supply chain design (Eltantawy and Giunipero, 2012).

Natural and man-made disasters can disrupt companies' supply chains. Warehouses form a sort of buffer for such cases and can be set up to mitigate supply chain risks; however, they are also vulnerable themselves even if they are located in otherwise safe locations.

The outbreak of a fire in a distribution centre or warehouse will most likely have an immediate and significant impact on business operations. The Buncefield oil depot fire in the United Kingdom is a good example: the depot burst into flames shortly before Christmas 2005 and had a serious impact on oil distribution in England. Furthermore, distribution centres on a commercial estate nearby could not be accessed for several days due to heavy smoke and the damage to the building's structure caused by the explosion of the oil depot. Most of the stock was damaged not only by the explosion but also by the water from sprinklers. It took fire brigades several days to put out the fire. During that time ASOS, one of the fastest growing online fashion retailers, could not use its central warehouse and distribution site and couldn't send goods out. The company had only moved into its single global distribution site months before. The potential effect on the business in the run-up to Christmas was so significant that its shares were initially suspended from trading (Daley, 2006; Sturcke, 2005). Although ASOS recovered from the disruption, it shows the significance of warehousing on the economic dimension of a business' sustainability.

Data centres

With the rapid development of computer and internet technology a new form of warehousing emerged: the storage of electronic data. Physical documents and files used to be stored in archive buildings (which are essentially warehouses) but the introduction of electronic documents did not eliminate the need for storage. Storage facilities for electronic data are usually called 'data centres'. Within a data centre a large number of servers perform computing operations to store and process data. Although only little physical traffic goes in and out of the site after the construction phase is finished, a lot of data traffic emerges and is 'transported' in and out by communication technology.

The amounts of data that need processing and storing are continuously increasing. The US Department of Energy (2006) forecast that despite the industry improving energy efficiency, the energy use for US servers and data centres was just under 110 billion kWh in 2011. The electricity used by Google alone is equivalent to the power consumed by 200,000 homes (Glanz, 2011).

Data centres are a worthwhile target for energy savings. The typical annual energy costs per square metre are 15 times that of a typical office building (Greenberg *et al*, 2006). In extreme cases data centres consume up to 100 times more energy than a standard office building (US Department of Energy, 2006). Data centres also operate continuously with peaks following office working hours and therefore have to source much of their electricity when it is the most expensive in time-dependent tariffs (Greenberg *et al*, 2006).

Opportunities for energy efficiency improvements in data centres exist at four major points: cooling, server load and computing equipment, power conversion and distribution, and alternative power generation. The electricity consumption in a data centre can be differentiated into supply (support systems like cooling, lighting, etc) and demand (computing equipment such as server power supply, processors and communication equipment). More energy-efficient server components therefore have a leverage effect on the overall data centre's energy consumption as not only the energy in the 'production' is saved but also the energy required by the support systems is reduced (Emerson, 2008).

Energy required for cooling can be reduced through improved air management. Optimized distribution of cool air and the collection of waste heat for energy production can be addressed in design and operations at the data centre. On average cooling accounts for around 38 per cent of a data centre's energy consumption (Emerson, 2008). Cooling is one reason why Facebook built its own 30,000m^2 data centre in northern Sweden, where temperatures are low most of the year and even in summer do not rise above 20 degrees Celsius. During 10 months of the year outside air can be used for cooling. Furthermore, Facebook can source its energy for the site primarily from a nearby hydropower plant, reducing its carbon emissions even further (BBC, 2011).

A major performance figure for benchmarking data centres is the power usage effectiveness (PUE), which is the total power used by the data centre divided by the energy used for IT systems: the lower the consumption of auxiliary systems the lower the PUE score. A state of the art data centre like Facebook's in northern Sweden achieves a PUE score of 1.07 and Google claims to reach a PUE of 1.13 across all its data centres (BBC, 2011; Google, 2012). Apple on the other hand builds up its own green energy supply by building a large solar array park in North Carolina, producing 60 per cent of the overall energy consumption of its nearby data centre (Apple, 2012).

Summary

Warehouses are the nodes in logistics networks. Within the network design their number and locations influence the need for transportation. But they also have a footprint from their building and the activities in and around the warehouse. The environmental impact is usually classed into two main parts: construction and operations.

The emissions in the construction phase are often in a trade-off with the operational emissions. More insulation in the construction means more energy is embedded in the building but less is consumed during its everyday operations and as a consequence the anticipated lifetime of a warehouse building is a crucial component in this trade-off. Whereas much of the energy consumption is determined at the design stage of the warehouse, the warehouse's energy consumption and its environmental impact can also be reduced to some extent later through the installation of energy- and water-saving technology, for example in updating temperature control or lighting systems.

Warehouses are not necessarily built or run by a single company that owns the stored products inside them. Logistics service providers or real estate investors may own the building and use it for more than one client. Different interests and priorities between these stakeholders may lead to less than optimal solutions.

Warehouses also fall into the social dimension of the triple bottom line as they are places of employment. The wellbeing of the workforce therefore must also be part of sustainability considerations.

Product design, cleaner production and packaging

05

Background

Traditionally the main objectives of product design, production and packaging are to reduce cost and at the same time meet product pricing strategies, specifications and customer needs while maintaining compliance with health, safety and environmental legislation. In the past there had been very little awareness about the amount of natural resources and chemicals used, the adverse health effects on workers, or the amount of pollution being discharged during the production and usage of a product. There is now growing evidence indicating that the ways supply chains manage product design, production and packaging are major contributors to various environmental sustainability, health, safety and social responsibility problems.

Let's take the production of a pair of jeans as an example. According to World Wildlife Fund (WWF) research, it takes an average of 8,500 litres of water to grow the one kilogram of cotton lint required to make one pair of jeans (WWF, 2012). In comparison, a person only needs to consume about two to three litres of water a day. Water is also required to produce food, industrial crops, livestock, and fish, as well as to generate electricity. Furthermore, the printing and dyeing of jeans involves hazardous substances such as cadmium, chromium, lead and mercury, which are found to be illegally discharged into rivers and have affected the health of many workers in China and other developing countries (Greenpeace, 2010; IPE, 2009).

In these countries the enforcement of regulation of the discharge of industrial waste or effluent is rather difficult. As a result, hazardous substances are released to the water systems in large volumes. Not only does such pollution kill aquatic creatures and other food sources it also destroys the water systems that provide the main sources of water used for the production of food and agricultural products in many countries. Globally 70 per cent of the freshwater withdrawals from rivers and groundwater are used for growing agricultural products (FAO, 2011) and many of these water systems are in danger of being heavily polluted. In addition, the production of goods and packaging materials emits greenhouse gases (GHGs) and contributes to global warming and climate change.

Based on the natural resource-based view, Hart (1995; 1997) laid down a framework towards sustainability. This framework can be used to guide the transformation in the ways we manage product design, production and packaging processes. Accordingly, the first step is to achieve pollution prevention by shifting away from pollution control. While the control of pollution in factories in developing countries is still a problem, the time it would take for these countries to truly enforce regulations up to the developed world's standards is too long. Pressures from non-governmental organizations (NGOs), regulators and buyers from the developed countries could make some differences but are still inadequate. Instead of focusing on the end-of-pipe solutions to control pollution, some companies have begun to look into the design of cleaner production processes that minimize pollution. The question here is who is paying for the pollution prevention solutions.

In the next stage the focus is product stewardship. In addition to minimizing pollution from manufacturing processes in the factories, more efforts associated with the full lifecycle of a product are required to minimize environmental impacts. This stage extends the efforts in pollution prevention to include the reduction of the use of natural resources and energy all the way from the extraction of raw materials to the end-of-life management of the product. That means there is a need to go back to the drawing board – greener product design. During the product design stage companies can review the choice of materials so that environmentally friendlier raw materials and packaging materials that can be recycled or recovered are used. The design of the assemblies and sub-assemblies of the products can also be modified to make disassembly and segregation easier and facilitate reverse flows. This also means companies need to extend their environmental management efforts to collaborate with suppliers, customers, governments and NGOs. In this stage companies can take the opportunity to set new environmental standards in the industry and make it a sustainable advantage.

In the third stage companies are encouraged to invest in planning and development of clean technologies that make the entire supply chain sustainable. This is because the ways we produce food and goods today are still environmentally damaging. For example we rely heavily on non-renewable sources of energy and materials. We use a lot of water and chemicals on farms and in factories. New technologies such as biotechnology, cleaner chemical engineering, agricultural technologies and renewable energy are required. For example, a lot of research has been conducted to develop clothing and washing machines that do not require water for cleaning. According to the natural resource-based view, companies that excel in the above stages can finally develop a shared corporate vision that directs efforts towards the solution of social and environmental problems for achieving sustainable development.

Product design for environment and sustainable logistics

Traditionally, industrial designers have concerned themselves with improving products by reducing cost, enhancing ease-of-use, and by making products beautiful and distinctive in the marketplace (Walker and Dorsa, 2001). Nowadays, design for environment (DfE) or eco-design is becoming the main concern among industrial designers and original equipment manufacturers (OEMs). This is guided by the principle of sustainable development and the aim is to simultaneously reconcile environmental sustainability, economic security and social wellbeing. Guided by this principle, industrial designers have started to modify their practices to address the ecological damage caused by materials and resource acquisition, manufacturing processes and product disposal.

DfE can be achieved by looking into the selection of materials, design for sustainable logistics, design for cleaner production, and design for sustainable consumption. The following are some of the main principles of eco-design:

- Selection of materials:
  - use non-hazardous materials;
  - use environmentally friendlier materials;
  - use alternative materials to those that harm the environment and society;
  - use recyclable materials.

- Design for sustainable (reverse) logistics:
  - design components such that can be easily identified and disassembled for recycling, and reduce time for disassembly;
  - minimize space and weight to reduce the need for fuel and transportation cost;
  - reduce the need for materials;
  - reduce the need for packaging;
  - design close-loop reverse logistics process into the products.
- Design for cleaner production:
  - use materials and production techniques that consume less energy and water;
  - use cleaner technology to replace the use of hazardous substance in production;
  - design cleaner production techniques for new products.
- Design for sustainable consumption:
  - produce durable products to avoid wastage;
  - design products that consume less energy and water during use.

The selection of materials for product design is a challenging task. Most of the essential raw materials we use are finite resources. Materials such as anthracite, bauxite, beryllium, cautchoc chrome, coal, cobalt, diamonds, gold, indium, iron, manganese, nickel, platinum, silicon, silver, titanium, vanadium, water, crude oil, and natural gas are crucial for human life. Some of them are still abundant but others are not. They will all one day become rare, if they cannot be reused and recycled. Furthermore, the supply of other raw materials from agriculture activities can become unpredictable due to the effects of climate change, over-finishing, pollution and natural disasters.

The design of products that favours cleaner, reusable and recyclable materials requires knowledge about a lot of materials and regulations. For example, there are 58 families of plastics and over 1,000 grades of plastics which are used for different applications. Due to advances in science and technology, the list of raw materials is growing. Some of the more recent raw materials include metal matrix, advanced composites, nano-materials, specialty polymers, flexible ceramics and memory metal. For example in the textile industry it is desirable to use materials for making fabrics that are free of carcinogens, mutagens, persistent toxins, heavy metals, endocrine disrupters and bioaccumulatives. Such fabrics are compostable and can be safely returned to the earth at the end of their useful life. However, there is a need to consider the cost and feasibility of obtaining a constant supply of such fabrics.

It can be difficult for non-technical logisticians and supply chain professionals to comprehend such scientific knowledge. Thus some guidance is desirable. In terms of the selection of material for designing sustainable products, there are several useful guidelines for logistics and supply chain professionals. One may refer to including databanks for hazardous substances, for example:

- Hazardous Substances Data bank, United States National Library of Medicine (http://toxnet.nlm.nih.gov/);
- Priority list of hazardous substances, Agency for toxic substances and disease registry, ATSDR (http://www.atsdr.cdc.gov/);
- List of materials from Lenneth (http://www.lenntech.com/periodic/elements/f.htm);
- List of material subjected to several regulations in the United States, Environmental Protection Agency (http://www.epa.gov/);
- Other material selection criteria and tool such as Okala Ecodesign, Cambridge Materials Selector Software, etc.

In various industrial applications some useful substances are also hazardous; they include:

explosives	flammable substances
oxidizing agents and peroxide	toxic substances
substance causing diseases	radioactive substances
mutant causing substances	corrosive substances
irritating substances	other substances, either chemicals or otherwise, that may cause injury to people, animals, plants, property, or environments.

Table 5.1 provides a list of selected hazardous substances, most of which are identified by the essential directives and regulations on hazardous substances. Some of them are highly hazardous materials and should be avoided. Some of them are banned in some countries but not in others.

Driven by regulations and/or environmental ambitions, most companies have now established a list of banned and restricted materials, and another list of preferred materials. These lists have to be integrated into the

TABLE 5.1 List of common hazardous materials

Materials	Common usage	Environmental and social impacts
Acid and alkalis	They are used for various cleaning processes and the production of chemicals.	Highly corrosive liquids used in industry that can corrode metals and destroy tissues of living organisms.
Arsenic	It is used as an alloy in lead shot and electrical circuits, as a pesticide, and as a preservative for wood. It is used in the microchip and copper production industries.	It is highly toxic and carcinogenic. People who work with pesticides and wood preservatives can be exposed to arsenic. It may cause infertility, miscarriages, skin problems and brain damage.
Asbestos	It was once widely employed in construction primarily for insulation. It is still used to make gaskets, roofing and other materials.	When inhaled it can cause lung cancer and mesothelioma.
Cadmium	It is used in batteries, pigments, metal coatings and plastics. It is also used in nuclear power plants. It is produced from the smelting of zinc.	Exposure risks are from metal refinery factories, cigarette smoke and contaminated foods. Breathing cadmium can damage lungs and kidneys, and cause infertility and cancer. It can pollute surface water and poison earthworms and soil organisms.
Chromium	It is used as a rust-resistant coating on other metals, a pigment in paint, and in wood preservatives and liquids for tanning hides. It is also used for leather and textile production.	People who smoke or work in steel or textile industries can be exposed to chromium compounds. They may experience skin and respiratory problems, kidney and liver damage and lung cancer. Chromium can be toxic to organisms.

Clinical wastes	Hospitals must dispose of large quantities of syringes, medication baffles and other materials.	Can be infectious and spread pathogens and harmful micro-organisms.
Cyanide	Compressed hydrogen cyanide gas is used to exterminate rodents and insects on ships and to kill insects on trees.	In large doses can cause paralysis, convulsions and respiratory arrest. Chronic exposure to low doses can cause fatigue and weakness.
Dyimethylfumarate (DMFu)	Used as biocide in furniture and shoes to prevent the growth of mould during transport.	Skin allergies.
Lead	Used in the production of batteries, ammunition, paints, metal products such as solder and pipes, and devices to shield X-rays.	If ingested or inhaled can harm the nervous system, kidneys and reproductive system.
Mercury	Used to produce chlorine gas, caustic soda, thermometers, dental fillings and batteries.	Exposure occurs through contaminated air, water and food, and dental and medical treatments. High levels may damage the brain, kidneys, and developing foetuses.
PCBs	Compounds used as heat exchange fluids, in electric transformers and capacitors, and as additives in paint, carbonless copy paper, sealants and plastics.	Pose risks to nervous systems, reproductive systems, immune systems, and the liver.

(*Continued*)

TABLE 5.1 *(Continued)*

POPs	Persistent organic pollutants include aldrin, chlordane, chloredecone, dieldrin, dichlorodiphenyltrichloroethane (DDT), endrin, heptachlor, hexachlorobenzene, hexachlorocyclohexane, lindane, mirex and toxaphene and are commonly used in agriculture to control pests.	POPs are a class of chemicals and pesticides that persist for many years in the environment, are transported great distances from their point of release, bioaccumulate (thus threatening humans and animals at the top of the food chain), and cause a range of health effects.
PBB and PBDE	Polybrominated biphenyls (PBB) were used to make products such as computer monitors, televisions, textile, plastic foams, etc to make them difficult to burn. Polybrominated biphenyls ether (PBDE) is used for the same function.	Cause nausea, abdominal pain, loss of appetite, joint pain, fatigue, and weakness, also possibly skin problems.

Towards an integrated product design for environment

Motorola, Inc. was an US telecommunications company. The company designed and sold network infrastructure equipment, mobile phones, and many other telecommunication components and products. In January 2011, the company was divided into two independent public companies – Motorola Mobility (later purchased by Google) and Motorola Solutions.

Even though the company has been divided and partly sold, the ways in which it integrates environment into its business deserve some attention. In 2011, Motorola was ranked sixth in Greenpeace's Guide to Greener Electronics (www.greenpeace.com). Motorola attempts to develop an integrated environmental management system within its factories and subsidiaries as well as its supply chains. The Environmental Preferred Products (EPPs) is a programme to achieve the following set of environmental product goals:

- designing products to increase recyclability;
- reducing the use of hazardous materials;
- reducing energy use in production and consumption of a product;
- increasing the use of recycled material in products;
- minimizing the ratio of packaging material to product volume;
- labelling all plastic parts weighing more than 4 grams to increase future recycling.

Motorola maintains specific internal protocols and reporting requirements for its factories worldwide. Each factory is required to report on a standard set of environmental metrics consistent with its corporate environmental goals. Some of the main environmental metrics are:

- volatile organic materials emissions (metric tons per billion dollars of sales);
- hazardous air emissions (metric tons per billion dollars of sales);
- hazardous wastes (thousands of metric tons per billion dollars of sales), water use (million cubic meters per billion dollars of sales);
- electricity use (billions of kilowatt hours per billion dollars of sales);
- annual Environment, Health and Safety (EHS) compliance record (number of noncompliance notices and fines and penalties). (Motorola, 2002: 32)

This case study focuses on the way Motorola integrates product design for the environment. Motorola divides its product design process into three tiers. Tier 1 involves concept development and product systems design; Tier 2 covers detailed product design and manufacture of a prototype; and Tier 3 covers actual mass production (Hoffman, 1997). During each design stage some protocols and tools are developed to integrate environmental considerations. A list of banned substances (called W18 Specifications) details the allowed concentration levels of specific substances (measured in parts per million). Motorola also develops and uses specific software tools to assist its environmental improvement programmes. An environmental assessment tool called Product Environmental Template (PET) supports the identification, limitation or elimination of hazardous substances during the pre-design stage or concept development stage (referring to the W18 Specifications). PET also helps the design team to identify energy efficiency of the products, as well meeting the various regulations.

The Motorola Toxicity Index identifies and weighs chemicals used in a product in terms of their toxicity. This allows product designers to sum up the aggregate measure of the toxicity of a product. A Green Design Adviser (GDA) is used in the detailed product design stage to improve the recyclability of products while designing out toxicity (Feldmann *et al*, 1999). GDA is also involved at the prototyping and production stage. During the prototyping stage the environmental impacts of a new product are further assessed by the Environmental Product Assessment at REAL (Rapid Environmental Assessment Lab).

During the mass production stage a Parts Information Management System (PIMS) is used to track supply and production of parts. The Environmental Data Management Team is responsible for updating and recording the environmental data of the parts and products. Chemicals and substances embedded in each part are tracked and recorded, together with supplier details. Compliance Connect is used to ensure compliance of the environmental policies in the factories and supply chains. It is a tool that electronically identifies each part in each Motorola product by a part number, by preferred global supplier with contact information, by technical specifications (including the W18 Specifications), and by toxic substance and toxicity.

procedures and protocols of environmental management within the companies and supply chains. There is also a need for an effective and integrated information system that facilitates the application of and compliance with the list so that the companies can design out the hazardous and environmentally damaging substances as well as reduce the consumption of energy and other natural resources. The Motorola case study illustrates how all these can be achieved.

Regulatory frameworks

Logistics and supply chain professionals also need to understand the legislation frameworks related to product design, production and packaging. At a global level, the Basel Convention, Rotterdam Convention and Stockholm Convention are highly instrumental in setting up legislative frameworks for the application, trans-boundary movements and environmentally sound management of hazardous and other waste. Some of the earlier legislation established during the 1980s focuses mainly on the controlled use of those highly hazardous substances and the control of pollution. The following are some of the essential regulations.

Restriction of the use of certain Hazardous Substances (RoHS)

Computers, laptops, monitors, mobile phones, tablets and other electronics contain a certain amount of lead, cadmium, chromium, PBB and PBDE. Owing to the increasing speed of new product development, there are more obsolete products being discarded, ending up in landfills and in countries like China, Pakistan, and third world countries for recycling. People (both adults and children) collecting and recycling such e-waste are being poisoned by the heavy metals. These problems become the main drivers for the introduction of RoHS and WEEE Directive.

RoHS (Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011) is an EU Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment. RoHS was adopted in February 2003 by the EU and took effect on 1 July 2006, and became law in each Member State. This Directive restricts the use of six hazardous materials (lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls, and polybrominated biphenyl ether) in the manufacture of various types of electronic and electrical equipment. The maximum permitted concentrations are 0.01 per cent for hexavalent chromium and 0.1 per cent or 1,000 ppm by weight of homogeneous material for the other five materials. Products affected by RoHS include paints, pigments, PVC (vinyl) cables, solders, printed circuit board, leads, glass in television, CRT and camera lenses, metal parts, lamps and bulbs. Batteries are not included within the scope of RoHS.

RoHS goes hand in hand with the Waste Electrical and Electronic Equipment Directive (WEEE) 2002/96/EC which sets collection, recycling and recovery targets for electrical goods. These two pieces of legislation attempt to solve the problem of toxic e-waste. There are standards or legislation similar or equivalent to RoHS, such as the Final Measures for the Administration of the Control and Electronic Information Products, also known as RoHS China (or China Order No. 39), and Electronic Waste Recycling Act of 2003 (EWRA) in California. A revision of RoHS (RoHS2) is expected to cover other equipment such as medical devices, control and monitoring instrument, and industrial control and monitoring instrument, in phases.

RoHS has been criticized for its high cost of compliance. Some complained RoHS is not fair for some electronics that use less of the restricted materials; others complained about the adverse effects of limiting the concentration of these substances on the reliability of the products. Some companies managed to innovate such that they could comply with RoHS without much additional cost and at the same time maintaining the reliability and quality of their products.

Registration, Evaluation, Authorization and Restriction of Chemicals (REACH)

REACH is the EC regulation on chemicals and their safe use. REACH aims to improve the protection of human health and the environment through better and earlier identification of the intrinsic properties of chemical substances. REACH also aims to enhance innovation and competitiveness of the EU chemicals industry. Under this regulation the industry is given greater responsibility for managing the risks from chemicals and providing safety information on the substances.

Manufacturers and importers of chemicals in volumes of more than 1 tonne are required to gather information on the quantities and properties of their chemical substances and register the information with the European Chemicals Agency (ECHA) in Helsinki. The Agency acts as the central registrar, manages the chemical registration databases and coordinates the evaluation of suspicious chemicals. Its aim is to build up a public database in which consumers and professionals can find hazard information and therefore help to ensure the safe handling of the chemicals in Europe.

Under the regulation the manufacturers and importers will also have to pass on safety information to downstream users. They have to ensure that the use of the chemicals in their production processes does not create risks for their workers, the end consumers or the environment. Chemicals that cause cancer require authorization. Similar to RoHS, there is a list of restricted substances – there are about 59 categories involving 1,000 such substances. For example the amounts of benzene in toys and PBB in textiles are restricted. REACH also calls for the progressive substitution of the most dangerous chemicals with suitable alternatives.

REACH became one of the drivers making manufacturers and importers ask their suppliers to disclose the use of chemicals in their production and products. As with any new legislation, there are complaints about the high cost involved in collecting and maintaining the information required by the manufacturers and importers. The European Union argues that at a macro level there are more benefits to society and commercial firms in the long term.

REACH in Europe has also some influence in other countries. In 2010, the Ministry of Environmental Protection (MEP) of China released a revised version (the Order No. 7) of the Provisions on Environmental Administration of New Chemical Substances. This means the importation of chemicals into China also requires registration. Since this regulation is similar to the European REACH it is known as the 'China REACH'.

Regulations on packaging and packaging waste

The 94/62/EC Directive on packaging and packaging waste is a Single Market measure, with environmental goals. The Directive applies to all packaging placed on the market within the EU, and all packaging waste, whether disposed of at industrial or commercial sites, or from private homes. 'Packaging' means all products made of any materials of any nature to be used for the containment, protection, handling, delivery and presentation of goods, from raw materials to processed goods, from the producer to the user or the consumer. 'Non-returnable' items used for the same purposes also constitute packaging. In principle the Directive aims for:

- packaging to be minimized;
- packaging to be designed for recovery and reuse;
- recovery targets to be met for waste packaging;
- heavy metals in packaging to be restricted.

There are three essential requirements of the Directive:

1. Packaging volume and weight must be the minimum amount to maintain the necessary levels of safety, hygiene and acceptance for the packed product and for the consumer.
2. Packaging must be manufactured so as to permit reuse or recovery in accordance with specific requirements.
3. Noxious or hazardous substances in packaging must be minimized in emissions, ash or leachate from incineration or landfill.

In addition, there are aggregated heavy metal limits applicable to cadmium, mercury, lead and hexavalent chromium in packaging or packaging components. While the Directive promotes the prevention of packaging waste and sets recovery and recycling targets for EU Member States, it is the individual countries' responsibility to take appropriate measures, including national programmes and the introduction of producer responsibilities. The United Kingdom for example has established the Producer Responsibility Obligations (Packaging Waste) Regulations 2007. This legislation basically specifies 'collective producer responsibility' and requires producers of packaging to take responsibility for their environmental impact by paying a proportion of the cost of the recovery and recycling of their packaging. Under this legislation the 'packaging supply chain' is divided into four activities, each with a different level of responsibility:

6 per cent	manufacturers of raw materials for packaging;
9 per cent	converters such as manufacturers of cans, bottles, etc;
37 per cent	packers/fillers or those who put a product into packaging or apply packaging to a product;
48 per cent	sellers or those who supply the packaging to the end user of that packaging, eg the supermarkets or wholesalers.

Importers may have to pay all of the costs. Producers or importers pay the obligations by buying a Packaging Waste Recovery Note (PRN) issued by reprocessors who are licensed to issue them. For the export of packaging waste the export version (PERN) is used. This legislation applies to those with a turnover of more than £2 million and handling more than 50 tonnes of packaging in the previous calendar year.

Cleaner production

The terms 'cleaner production' and 'pollution prevention' often mean the same thing. Pollution prevention is generally used in North America, while cleaner production is preferred in other parts of the world. One of the most commonly used definitions of cleaner production is that of the United Nations Environment Program (UNEP): 'Cleaner production is the continuous application of an integrated preventive environmental strategy applied to processes, products, and services to increase eco-efficiency and reduce risks to humans and the environment.'

Cleaner production attempts to improve the efficient use of energy and raw materials and prevent undesirable pollution during production processes and the delivery of products and services to customers. Cleaner production also seeks to optimize the reuse and recycling of hazardous and non-hazardous materials. Cleaner production is a strategy that protects the environment, the consumer and the worker while improving the industrial efficiency, profitability and competitiveness of enterprises. The fundamental principles of cleaner production are supported by the natural resource-based view theory of Hart (1995), which argues that the sustainable production of products and services for human consumption is the basis for sustainable competitive businesses.

Cleaner production requires a shift in the mindsets of industries. Industries have to move away from ignoring pollution, or diluting or dispersing pollution, or focusing on end-of-pipe or pollution control solutions simply to comply with regulations. There is a need to recognize that the end-of-pipe technology simply shifts waste or pollutants from one environmental medium to another. Governmental environment agencies have to realize the disadvantages of command and control methods, which may increase the cost of compliance and not allow companies to explore other, cheaper solutions. The following new concepts can be used to drive cleaner production efforts:

- *Eco-efficiency*: coined by the World Business Council for Sustainable Development in 1992, the term 'eco-efficiency' is defined as 'the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the lifecycle, to a level at least in line with the Earth's estimated carrying capacity'. Eco-efficiency means producing more goods and services with less energy and fewer natural resources. Eco-efficient businesses get greater value out of their raw materials as well as producing less waste and less pollution.
- *Waste minimization*: introduced by the US EPA in 1988, waste minimization is a waste prevention approach focusing on the on-site reduction of waste at source by changes in the input raw materials, technology, operating practices and product design, and off-site recycling by direct reuse after reclamation.
- *Pollution prevention*: according to the EPA, pollution prevention is about source reduction. It is about preventing or reducing waste

where it originates, at source. This includes conservation of natural resources through increased efficiency in the use of raw materials, energy, water and land. Pollution prevention is part of the national environmental policy of the United States (Pollution Prevention Act 1990).

- *Green productivity*: similar to cleaner production, green productivity is a strategy for enhancing productivity and environmental performance to improve overall socio-economic development. Green productivity is used by the Asian Productivity Organization (APO) to address the challenge of achieving sustainable production.

Cleaner production emphasizes the application of 'integrated' and 'preventive' systems instead of the typical end-of-pipe solutions. Based on the concepts of cleaner productions, the following general principles can be applied to the entire production cycle:

- Reduce the consumption of raw materials and energy used in the production of each unit of product.
- Increase productivity by ensuring a more efficient use of raw materials, energy and water.
- Promote better environmental performance through reduction at source of waste and emissions.
- Reduce the environmental impact of products throughout their lifecycle by the design of environmentally friendly but cost-effective products.
- Reduce at source the quantity and toxicity of all emissions and wastes generated and released.
- Eliminate as far as possible the use of toxic and dangerous materials.

In practice, companies can establish principles of cleaner production themselves. For example, the following are typical principles for cleaner agricultural production:

- minimize the harmful impact of crop protection practices;
- minimize the harmful impact of crop growth stimulating practices;
- efficient use of water and care for the long-term availability of water;
- care about the health of the soil;
- conserve natural habitats;
- care for and preserve the quality and health effects of the produce;

- reuse and recycle packaging materials;
- promote decent work and fair labour practices.

When looking to make the principles work, companies need to develop opportunities for implementing cleaner production. Many of such opportunities are related to lean production efforts. For example the use of 5Ss or good housekeeping routines can make sure materials for production are clearly labelled and located at the right place and therefore allow for a more efficient use. The application of better process control using statistical control techniques helps to reduce process variations and subsequently fewer rejects and less rework. Using by-products for production helps to reduce consumption of raw materials while saving costs. Other by-products can be collected for on-site recycling and some can even be sold as another source of revenue. Workers are reminded to switch off lightings and air-conditioning when they are not required. All these opportunities require minimum financial investment. Other opportunities that may require some initial outlay include material substitution and product modification. This requires a change in the product design process. In addition, the production experts may look into equipment modification and technology change.

Cleaner production can be achieved via technological innovation. The following are some examples of innovation solutions for cleaner production for textile dyeing processes:

- To improve the techniques of purifying wastewater discharged by textile dyeing process, a Swedish researcher Maria Jonstrup experimented with both fungal enzymes and bacteria from the drains at textile and municipal wastewater-treatment plants. She combines both biological and chemical purification techniques and collaborates with a Swedish clothing company Indiska Magasinet and its suppliers in large-scale testing of the new techniques.
- In 2012, a Dutch company called DyeCoo commercialized a machine to use carbon dioxide instead of water on an industrial scale to dye polyester. The fabrics dyed in this process, called Drydye fabrics, have the same quality as the conventionally dyed fabrics but use no water. The process consumes half the energy and chemicals. Global brands such as Nike and Adidas have forged a partnership with the company. A Taiwanese contract manufacturer for Nike started using DyeCoo technology in 2013.
- In 2012, a company called ColorZen developed a treatment that changes cotton's molecular composition, making it more receptive to

> dye without creating toxic discharge. It tested this formula on about 400 pounds of cotton fibre, successfully dyeing it with 95 per cent fewer chemicals, 90 per cent less water, 75 per cent less energy, and 50 per cent less dye in under a third of the standard eight hours.

To make cleaner production an integrated part of environmental management efforts it is encouraged to make it part of an environmental management system (EMS). An EMS is a 'formal system and database which integrates procedures and processes for the training of personnel, monitoring, summarizing, and reporting of specialized environmental performance information to internal and external stakeholders of the firm' (Melynk *et al,* 2003: 332). An EMS generally provides formal structures of rules and resources for managers to establish organizational routines that help achieve corporate environmental goals, and to innovate. It is also the main mechanism for creating awareness and providing training to workers. A number of well-known international manufacturers (eg Sharp, 3M and Xerox) have decided to manufacture their products according to (or beyond) the highest environmental standards (Thierry *et al*, 1995), and they are achieved through the establishment of an integrated EMS.

ISO 14001 is the international standard for EMS and among the most widely used EMS in the world. The Eco-management and Audit Scheme (EMAS) is the second most popular EMS standard in Europe. These two standards have very similar structures but there are some fundamental differences. EMAS firms must be compliant with relevant environmental rules and regulations to guarantee their certification. However, ISO 14001 emphasizes only the commitment to compliance but such compliance is not essential to keep certification. In addition, the evaluation of the EMAS standard is guaranteed by obligatory audits every three years where all requirements are checked and a statement is made public. ISO 14001 audits check for environmental system performance against internal benchmarks; somehow there are no penalties for the lack of improvement and the frequency is left to the discretion of the individual firm.

In the literature some novel concepts such as Factor 4, Factor 10 and zero emission have been established. These concepts can be used to guide companies when they set cost and environmental improvement targets. Factor 4 (http://www.wupperinst.org/) means being twice as productive with half the resources (von Weizseker *et al*, 1998). It also means the same functions of a product can be achieved by using only a quarter of the resources. To achieve Factor 4, a seven-step approach to resource productivity has been proposed (von Weizseker *et al*, 1998) based on the idea of using material input per service (MIPS). This method is very similar to the concept of value engineering, whereby fewer materials are used to create the same value for the customers (functions or perceived benefits). Factor 10 means 10 times more product with the same input, which is a more ambitious target. The main motif is to drive environmental ambition. These concepts have been applied by governments as well as commercial firms. Similarly, zero emission is not practically possible but it is a goal that could drive serious efforts. Zero emission is becoming a benchmark and some companies are competing to become the first to achieve zero emission.

Towards a cleaner production of textiles

The textile industry is one of the major contributors to many developing economies in terms of jobs and economic growth. The textile industry is also known as one of the dirtiest as it requires many chemicals and a lot of water during wet processing. Thousands of different chemicals including heavy metals (mercury, cadmium, lead, chromium), bleaches, detergents, and brighteners are used, some when making yarn from natural fibres such as cotton but a lot are used to dye and wash fabric. Textile workers, especially those involved in wet processing, are exposed to hazardous chemicals that may cause acute toxicity, respiratory problems, asthma and even cancer (Zhang, 2009). A lot of wastewater containing chemicals is discharged, which damages the natural environment. Some chemicals harmful to the environment are even found in finished textile products.

These problems are among the reasons for the establishment of a restricted substance list (RSL) by textile and clothing retail and trading companies. An RSL is a list of chemical substances a company wishes to eliminate or to keep below a specified concentration in its products. The effectiveness of the list depends on how suppliers are selected, monitored and managed. However, this effort has not been able to stop factories using hazardous substances and discharging them into the natural environment. This is a reactive approach such that suppliers would only provide information when they are strictly required by a customer.

To control the selection and use of chemicals some companies adopt ecolabelling or standards such as EU Flower or Oeko-Tex Standard 100. Oeko-Tex requires suppliers to declare raw material use in the production process and detailed information about each chemical used in every production stage, verified by third-party tests and certification. The challenge is that not all chemicals are sourced from established chemical manufacturers (Dyestar, BASF, Clariant, etc) which often already have products certified by the Oeko-Tex system. Many factories source chemicals from trading agents or local chemical producers and therefore information regarding the contents and certification can be rather inaccurate. As discovered in Zhang's (2009) study of Chinese textile factories, problems include the lack of the proper records of chemical usage and the passive attitudes of the suppliers toward customer demands for compliance with documentation requirements. Another problem is that new textile factories are built in countries that require less transparency in terms of wastewater discharge. For examples, the West Java region of Indonesia has been described as 'Pollution Paradise' by Greenpeace after they discovered some irresponsible factories that supply clothing to many global brands. Until the day that Environmental Product Declarations (EPDs) become common the textile supply chain will still be using a reactive environmental information system.

Following the release of two Dirty Laundry Reports by Greenpeace in 2011, top clothing brands including Nike, Puma, Adidas and H&M have agreed to eliminate discharges of all hazardous chemicals across their entire supply chain and product lifecycle by 2020. For example, H&M has defined seven ambitious commitments on sustainability:

1. Provide fashion for environmentally conscious customers.
2. Choose and reward responsible partners.
3. Be ethical.
4. Be climate smart.
5. Reduce, reuse, recycle.
6. Use natural resources responsibly.
7. Strengthen communities.

H&M is committed to conserving water, soil, air and species. In terms of raw materials it aims to use only cotton from sustainable sources by 2020 by switching to certified organic cotton and other raw materials made from recycled materials including fabric. The use of organic cotton grown without chemical pesticides or fertilizers is good for the health of the farmers as well as the environment. H&M has been actively involved in the Better Cotton Initiative (BCI). H&M also continues to increase the use of recycled polyester, polyamide and wool that are certified independently by third-party certification following the Global Recycling Standard (GRS). In terms of water and chemicals, H&M needs to work with the factories to improve the way water is used and treated from cotton to customer and to ensure chemical safely and eliminate discharges to water, soil and air.

The company does not own factories and therefore develops environmental requirements for suppliers according to the above commitments. Suppliers are audited by an external auditor according to the Textile Exchange Standards or Organic Content Standards (OCS) and transactional certificate (TC). The OCS verifies the presence and amount of a given raw material in a final product. It is a voluntary standard that tracks the flow of a raw material from the source to the final product and is certified by an accredited third party. The certification of the raw materials itself is verified independently by another production process certification.

For those who own factories that use a lot of water and chemicals, cleaner production becomes the main strategic objective. Esquel Group is a producer of premium cotton shirts. It has production facilities in China, Malaysia, Vietnam, Mauritius and Sri Lanka, and a network of branches servicing key markets worldwide. Esquel manufactures for the world's best known and highly respected brands, including Ralph Lauren, Tommy Hilfiger, Nike, Brooks Brothers, Hugo Boss, Lacoste, Bestseller and Muji. Esquel chose to vertically integrate its supply chain operations to remain in control of its product quality in every step of the production process. Cotton is grown in its own facilities in Xinjiang province in north-western China. The company takes care of the remaining value chain activities including spinning, weaving, dyeing, manufacturing, packaging and retailing.

Esquel uses the pollution database developed by the Institute of Public and Environmental Affairs in China to identify environmental problems of suppliers and its own factories. External auditors are sent to the factories whenever a problem is reported. Strict demands are made of suppliers to make corrections and explanations whenever an environmental problem or offence is discovered. In some cases suppliers do not have the financial capability to install water treatment facilities, and customer orders are not large enough to support the investment of such facilities. In such instances, the company helps suppliers to identify chemicals that are less polluting and use less water. As a result suppliers save energy and water, and some of them even receive ISO 14000 certification and rewards from the Chinese government. The company also uses the Oeko-Tex Standard 100 to require suppliers to declare raw material use in the production process and detailed information about each chemical used in every production stage. These are verified by third-party tests and certification. The drivers for adopting cleaner production appear to come from Esquel's E-culture, which comprises Ethics, Environment, Exploration, Excellence and Education. Since ethics and environment are the main corporate culture, environmental responsibility is at the heart of the whole organization.

Packaging for the environment

Globally the packaging industry has a turnover of around US $5000 billion (World Packaging Organization, 2012). Packaging is required for practically any goods such as food, beverages, healthcare, cosmetics, electronics, clothing, etc. For some beverage products, packaging is actually the most expensive part. The packaging is typically made of glass, plastic, paper, cardboard, metal and/or wood. Glass is used for beverages and liquids; paper for light goods; corrugated cardboard for heavier goods; wood for crates and pallets; metal cases and tanks for containing and transporting bulk products. Packaging is very important for supporting production, logistics, supply chain and marketing activities because it protects goods, it allows goods to be held and transported in a standard unit of loading (eg, cartons, pallets, and containers), and it also allows marketers to provide essential information about the goods to customers.

Paper and cardboard are among the most popular packaging materials, although there is an increasing trend to use plastic. Since plastic is light it reduces both the weight of transporting goods and the amount of packaged goods that go to waste, both of which reduce CO_2 emissions. Without plastic packaging, it is estimated that the tonnage of alternative packaging materials would increase by a factor of 4, greenhouse gas emissions by a factor of 2, costs by a factor of 1.9, energy use by a factor of 1.5 and waste by a factor of 1.9 in volume (PlasticEurope, 2009). That means that ceasing to use plastics in packaging would result in significant increases in the weight of waste, energy consumption in making the alternatives, and costs. From the supermarket perspective whether to give customers paper or plastic bags is an ongoing debate. For example, shoppers in the United States use 100 billion plastic bags a year, made from about 12 million barrels of oil, but using 10 billion paper bags each year means cutting down 14 million trees (*Science World,* 2008). According to *Science World* (2008), the production of every tonne of paper bags consumes four times more energy than the production of plastics bags, produces more air and waterborne pollution and, furthermore, the recycling of paper consumes 85 times more energy than the recycling of plastics bags.

Using innovative technology and appropriate materials, packaging also helps to conserve resources, reduce carbon emissions and make a supply chain more cost-efficient. For example, it protects food as it travels from farm to supermarket and into our kitchens so there is less waste along the supply chain. The same principle is applied to extend the lives of prepared sandwiches and meals. At the supermarket, loose fruit and vegetables create more waste than pre-packed produce. Plastic film extends the shelf-life of vegetables from a few days to about two weeks. Multilayer films in a MAP (modified atmospheric packaging) used to pack meat extends shelf-life from a few days to over a week. From a lifecycle perspective, the amount of CO_2 used to produce a single portion of meat is almost 100 times greater than that used to produce the multilayer film.

Technically, all packaging materials can be reused, recycled or recovered. However, packaging is also one of the main waste streams that can harm the environment, if not properly managed. This is because not all packaging materials (eg plastic) are biodegradable and there are scientific studies that prove that such materials could affect biodiversity. According to PlasticEurope (2009), 265 million tonnes of plastic are produced globally each year; 38 per cent is for packaging. Since plastic waste is relatively more difficult to collect and recycle, millions of tonnes of packaging materials made of plastic are being landfilled globally. Since there is a lack of efficient recycling systems and participation in many countries, the packaging industry is pressured to develop more biodegradable packaging materials or materials that can be used for energy recovery without side effects on human health and the environment. Some packaging manufacturers have developed food-grade recyclable packaging materials eg, r-HDPE for milk containers, which can be recycled into plastic pellets for producing milk containers again.

The following principles for environmentally friendly packaging design, production and commercialization are particularly for manufacturers, and form part of the EU Directive for packaging and packaging waste (94/62/EC):

- Use minimum packaging volume and weight as long as it meets minimum requirements to maintain the necessary levels of safety, hygiene and acceptable for the packaged product and for the consumer.
- Packaging shall be designed, produced and commercialized for reuse, recovery, recycling and to minimize its impacts on the environment when being disposed of.
- Packaging shall be produced so that the presence of noxious and other hazardous substances as constitutes of the packaging material be minimized when they are being incinerated or landfilled.
- Packaging designed for energy recovery shall have a minimum inferior calorific value to allow optimization of energy recovery.
- Packaging designed for composting shall be biodegradable so that it should not hinder the separation, collection and composting processes.
- Biodegradable packaging shall be capable of undergoing physical, chemical, thermal or biological decomposition so that the finished compost ultimately decomposes into carbon dioxide, biomass and water.

To make packaging materials lighter and yet strong enough to contain goods (being functional), research and technology developments are used to strengthen existing packaging materials. Lighter corrugated cardboard is an example; others look into issues related to over-packaging for online businesses. Another very important development is the use of recycled packaging materials and labelling to facilitate recycling.

Towards sustainable packaging for grocery supply chains

Grocery retailers in the United Kingdom are facing increasing pressures from regulations and NGOs. In September 2010, several companies were prosecuted for using excessive packaging. Sainsbury's was prosecuted for using 'excess' wrapping on its 'Taste the Difference Slow Matured Ultimate Beef Roasting Joint' (*Daily Mail*, 2010). The joints were packed in plastic shrink-wrap, placed inside a plastic tray, topped with a transparent plastic lid and surrounded with a cardboard sleeve. The law on excess packaging, introduced in 1999 in the UK, says packaging should be limited to 'the minimum adequate amount' to ensure safety and hygiene. The fines for excessive packaging according to the law were relatively low and some activists are trying to lobby the government to increase them. The company later redesigned the packaging and reduced the total amount of packaging by 53 per cent.

Sainsbury's was founded in 1869 and in 2012 operated over 1,000 stores in the UK. It employs over 150,000 employees. It is a major grocery retailer in the UK. Its main businesses are supermarkets, convenience stores and internet-based home delivery shopping services. Its vision is to be the most trusted retailer where people love to work and shop. One of its main purposes is to provide great (healthy, safe, fresh and tasty) food to its customers. The ways the retailer operates its business are largely guided by five values: best for food and health, sourcing with integrity, respect for environment, making a positive difference to the community, and being a great place to work.

Sainsbury's was one of the first supermarkets in the UK to adopt sustainable initiatives to reduce its environmental impact. Sainsbury's joined a voluntary agreement with WRAP, called Courtauld Commitment, to improve resource efficiency and reduce the carbon and wider environmental impact of grocery retail. The supermarket has been continuing actively participation in Courtauld II and III. In November 2012, Sainsbury published a document called 20x20 commitments to declare its 20 commitments to help people to live well for less. Sainsbury's is committed to making sure that its own packaging has been reduced by half compared to 2005. The following examples demonstrate how redesign of packaging materials can help to reduce environmental impacts and fuel consumption:

- Glass used in peanut butter jars is replaced with plastic, cutting packaging by 83 per cent or 882,000 kilograms.
- The size of the outer shelves for ready-meals packaging is being reduced by 45 per cent, leading to a saving of 5,500,000 kilograms of cardboard each year.
- Heat-seal lids on soft fruit lines are introduced to reduce 440 tonnes of packaging each year.
- Reducing Easter egg packaging by 57 per cent since 2008.
- Removing the cartons from canned tuna fillets to reduce packaging by 20 per cent.
- Reducing the cardboard on pizza base mix to save 87 per cent of packaging.
- Reduce the diameter of the inner cardboard tube of toilet rolls by 24 per cent, cutting down 500 delivery lorries, saving 140 tonnes of CO_2, as well as 335 tonnes of packaging a year.
- Promote the use of refill instead of the original bottles and boxes to reduce the use of heavier packaging materials.

The use of biodegradable packaging materials is another great opportunity. Sainsbury's has looked into the use of home compostable packaging. Sainsbury's replaced plastic with packaging made of maize, sugar-cane or starch. Such packaging materials can naturally break down in a garden compost heap, and eliminate the need to landfill or recycle. Sainsbury's first tested the use of such home compostable packaging in 2001 on a small range of food and plans to use its scale to make 'home compostable packaging' mainstream. In 2007, Sainsbury's made an announcement that it would replace 150 million plastic trays and bags on ready meals and organic food with home compostable packaging every year. The use of compostable packaging also means saving fossil fuels required to make plastic for packaging and reducing the amount of plastic waste reaching landfill sites. The launch of the home compostable packaging received a lot of publicity in the media.

Summary

There has been growing recognition that the way we design a product and its production and deliver processes have to change. In addition to ensuring that the product is making money there is a need to reduce the natural resources and chemicals used, while making sure that there are no adverse health effects to workers and minimizing environmental damage. It is not just about a carbon footprint: one has to consider one's water footprint and energy consumption. The design of cleaner products and the use of cleaner production technologies and packaging are essential for preventing pollution, conserving natural resources and for recycling. Many innovative methods have been developed such that design of a product should consider reducing energy and material consumptions during production and use. One important starting point is the selection and discovery of environmentally friendlier materials. In this respect, many regulations have already been developed to control the use of the most hazardous substances and to track the production and use of chemicals.

In addition, it is possible to design cleaner production and logistics processes. It is not just about pollution prevention. A more comprehensive cleaner production programme should take into account waste minimization, greener packaging, green productivity, energy and eco-efficiency. Those who invest in developing new and cleaner technology for production can lead the industry and even make this a new business opportunity. Others who develop new packaging materials or work with suppliers to reduce packaging weight are becoming environmental leaders of their industries, gaining more business and improving their reputation. It is also evident that success in implementing eco-design, cleaner production and packaging requires an integrated EMS, and the ability to extend environmental improvement efforts to supply chains. Companies in the forefront are taking up challenges such as Factor 4, Factor 10 and zero emissions.

Even though companies are investing in many efforts they rely on the consumers to drive the need for environmentally friendly products. Eventually it is the end consumers who pay for the products. Companies should consider working more with consumers and making them realize the environmental implications of the products they purchase so that they share the responsibilities with everyone else in the supply chain.

Sustainable purchasing and procurement

06

The idea that it is not products competing with each other but supply chains directs the view on sustainability away from an intra-organization perspective to the inclusion of suppliers, sub-suppliers, customers and service providers. Businesses do not exist in isolation and their environmental performance is judged on the final overall impact of their supply chain. Consumers hold companies accountable for their wider supply chain, regardless of how peripheral a supplier might be to a brand. Much of the environmental impact often stems from earlier stages and the suppliers' and customers' operations add to the sum of the environmental balance. In an organization aiming for sustainability the procurement activities are given a crucial role in reducing environmental footprint as they mainly control emissions stemming from the upstream supply chain by selecting suppliers, making wider sourcing decisions and determining collaboration and interaction with suppliers.

This chapter starts with a look at the development of the procurement function, what green procurement is, why it is crucial to a company's sustainability efforts and what the main drivers and barriers for green procurement are. We then go deeper into how green procurement actually works and how it supports sustainability improvements in the supply chain.

The role of procurement in the supply chain

The role of the procurement function changed significantly with the genesis of the idea of competing supply chains. Simple sourcing and buying procurement developed into the boundary-spanning function that links the company to the downstream suppliers. Due to an increase in specialization, global competition and a focus on core competencies, supply chains started to involve larger numbers of international suppliers, resulting in an increase in complexity and the need to coordinate and manage suppliers in a structured way. Today's supply chains usually show a high proportion of third-party spending (the services and products that are bought in from outside) (Booth, 2010). With the increase in outsourced activities, the selection and management of suppliers became much more important for a successful supply chain.

When mapping supply chains, suppliers are structured into tiers. The first tier of suppliers is those closest to the focal organization. Their suppliers are then referred to as second-tier suppliers, and so on. Picking the 'right' supplier for a particular product or service has a strategic dimension. Supply chain maturity, stages of the product lifecycle, sourcing risk, importance of the sourced good and plenty more considerations need to be made in strategy frameworks (Booth, 2010).

How green is your pint? Muntons Maltings

Malt is one of the key ingredients in beer brewing. Malt is made from roasting barley. Like other grains it is a food product grown on farmland. Farming itself is a major contributor to greenhouse gas emissions and the growing of cereals stands for 5 per cent of land use globally. With a rapidly growing world population the land occupied for farming will increase tremendously. At the same time rising temperatures caused by global warming make crops more vulnerable to damaging organisms, meaning more pesticides need to be used or the agriculturally used land is expanded even further.

Although in the UK farming contributes only 1 per cent of the overall CO_2 emissions, it causes 7 per cent of NOx (nitrous oxide) and CH_4 (methane) which have a much stronger effect on global warming. The atmospheric warming effect of a tonne of CH_4 equals the effect from 25 tonnes of CO_2 and one tonne of NOx emitted even has the same effect as 295 tonnes of CO_2.

Another major emission from food production is the consumption of fresh water. The wastewater stemming from malting could be treated to the standards for human consumption so that 70 per cent of the process water could be saved. But the water treatment creates a trade-off with CO_2 emissions, as 1.23 kg of CO_2e is required for the treatment of one tonne of water.

Muntons analysed its malt supply chain from the farm to the sold malt and discovered that almost two-thirds of the overall carbon footprint stems from the initial barley growing; nitrogen fertilizers are contributing almost half of the footprint and N_2O from soil nitrogen losses. The largest contributor within the malting operations is the consumption of energy (gas and electricity) mainly in a process called kilning, in which the malt is dried in an oven-type facility. The specifications from customers usually request a final moisture level of around 3 per cent; achieving this uses 45 per cent more carbon emissions than a level of 6 per cent, and even moisture level of 4 per cent needs 25 per cent more emissions than the 6 per cent level. Although higher moisture content would require more haulage overall to deliver the same amount of dry weight, the emissions increase from haulage is neglible in comparison to the huge potential carbon savings in the kilning.

Upstream, an essential part of becoming greener was to talk to the farmers in the supply chain to substitute previously used fertilizers with biofertilizers. Downstream, Muntons' customers needed to be consulted on higher levels of moisture in the malt. Customers did not really require such low moisture levels for their operations and were willing to accept higher levels (also, the energy saved meant that prices could be lowered). A higher moisture level than 3 per cent was simply something nobody ever looked into before and customers used the standard 3 per cent level that they were accustomed to. The footprint analysis and collaboration with supply chain partners on either end enabled Muntons to reduce the carbon footprint of its malt significantly in its mission to be the greenest maltster in the world.

Source: www.muntons.co.uk

With a rising number of tiers and suppliers the complexity increases and monitoring the supply chain – including all sub-suppliers – is a difficult task. Nevertheless, customer and consumers tend to hold companies responsible for what is happening further down their supply chain. Despite a large share of activities in the supply chain being outside an organization's core boundaries, improving its sustainability must include all its suppliers and supply chain activities whether they are within direct control or not.

What is 'green procurement'?

The aim of 'green procurement' or sustainable procurement practices is the inclusion of sustainability issues in the procurement strategy and in procurement decisions, for example in sourcing decisions or supplier selection.

Similar to the development from a debate focused only on 'green' to a wider supply chain perspective, this chapter does not want to limit the discussion to the dimension of the natural environment but addresses all parts of the triple bottom line. Sustainable procurement was and is very often initiated from an ethical perspective. Social injustice (for example the situation of coffee farmers in less developed countries) and the violation of basic human rights (for example in child labour) triggered consumer reactions in two ways: avoidance of particular brands and retailers or the support of 'good' products like Fairtrade coffee. Other issues of a sustainable and socially responsible procurement are the rejection of bribery and corruption, and the ethical behaviour of purchasing personnel (Hoejmose and Adrien-Kirby, 2012).

Although the terms 'procurement' and 'purchasing' are often used interchangeably in the literature, they are distinctively different. Procurement has a more strategic positioning and covers all activities of acquiring goods or services (including the purchasing function), while purchasing is described more narrowly as the functions and activities of the buying process (Vitasek, 2010). Consequently we have to differentiate between the more strategic picture of procurement and the more operational perspective of purchasing activities.

The focus on procurement as a key function for greening supply chains is based on stakeholder theory and the idea that in many cases the customer or buyer has the more powerful position in the supply chain and can therefore lead a supply chain towards more sustainability. However, the idea that the buyer is always in a stronger power position in the supply chain relationship may be a misperception. In supply-side dominated markets with little and fragmented buying power on the demand side, this theory will not hold. Additionally, in-sourcing operations, if no suitable external supplier is available, may often be more of a theoretical option, particularly for small companies with limited investment capital.

Nevertheless, on many occasions the push for a more sustainable supply chain needs to come from the customer or even consumer side. The pressure on the upstream supply chain to support sustainability initiatives often needs leadership from the larger and more powerful actors. Public procurement can play a crucial role in the leadership for green and sustainable procurement. Within the European Union around a seventh of overall GDP is spent on public procurement by municipalities, state governments or the European Commission. However, much public spending occurs in the construction and maintenance of buildings and physical infrastructure and the importance and impact of sustainability considerations in public procurement would be mainly in this area (Erdmenger, 2003). Even in areas where public bodies are not the main buyers, the insistence on sustainable practices from public authorities can stimulate the creation of a market for more sustainable products and services. Public spending can provide the base demand to enable the development of new products that can also be acquired by commercial buyers (Crespin-Mazet and Dontenwill, 2012).

The Mayor of London – Green procurement code

Due to its spending power the public sector – central governments, state-run healthcare services, schools, municipalities, etc – can take a lead in sustainable procurement and act as a driver for sustainable supply chains (in the United Kingdom the public sector has an annual procurement spend of around £175 billion) but sustainability is not always factored into the procurement decision yet.

Including sustainability considerations in the procurement practices of a large public organization needs direction from the top. The Greater London Authority set itself a framework to deliver responsible procurement, covering three dimensions: people, businesses and city. The annual spend of £3 billion, of which only 19 per cent was with small and medium-sized enterprises (SMEs) in 2007/8, covers a wide range: police uniforms, construction of new railway lines or fireworks for New Year's Eve.

Making it easier for SMEs to access public sector contracts is part of supporting the local economy, so barriers and paperwork requirements like contract pre-qualification questionnaires were to be simplified and less documentation required for small contracts. Also, payment cycles were shortened to help SMEs with cash flow. Suppliers were encouraged to promote diversity in their own workforce and within their suppliers further up the supply chain.

The framework for responsible procurement does not only look at the supplier side of emissions but also aims to reduce operational emissions. The reduction of emissions from internal operations is interlinked with procurement practices and is achieved through an increase in buildings' energy efficiency, purchase of environmentally friendly vehicles, or the freight operator recognition scheme, which sets a quality standard to improve efficiency, safety and environmental performance of freight operators in the city.

The London Fire Brigade (LFB), in spite of being a relatively small part of public procurement in London, is the world's third largest fire fighting organization and has significant buying power in some niche areas. With 6,000 operational and 1,000 non-operational staff it provides fire safety and regulation, emergency response services and emergency planning to the community. The LFB's procurement strategy includes targets for performance improvement and contributes to the Greater London Authority's framework by covering supplier diversity, fair terms of employment, skills development, and improving environmental sustainability.

The LFB's vehicle fleet achieved the set environmental targets, improved the energy efficiency of buildings and sourced green electricity. It also changed the way it distributes goods to the fire stations across London, with a single distribution site now the nucleus for deliveries and returns to the 112 fire stations. Deliveries changed from direct to station to cross-docking, and suppliers now deliver goods packed ready for distribution into the distribution centre. From its delivery routine the vans also collect items for return and recycling. The new distribution network achieved savings of road miles on the supply side and a reduction of inventory levels across the organization. It is now looking into using electrically powered vans to reduce emissions further. Besides the savings in emissions and costs, the service level improved as suppliers used to be unable to deliver to individual fire stations when the staff were called out to emergencies.

Also, end-of-life issues were considered and the LFB introduced recycling schemes for water hoses and mobile phones. These recycling schemes are linked to donations to the Fire Fighters Charity, encouraging participation by the workforce.

Source: www.greenprocurementcode.co.uk

Drivers and barriers for sustainable procurement

Generally, the drivers and barriers for sustainable procurement can be divided into two groups: external and internal. As well as pressure from customers, external drivers are also pressure from the general public, governmental regulation and legislation, and the desire for a competitive advantage by gaining a positive and sustainable image. The main internal drivers are the personal commitment of managers and investors, and the wish to cut costs by a reduction in waste and pollution. The drivers are somehow interlinked; for example an internalization of costs for emissions through governmental regulation backs the internal driver to save costs through sustainable practices.

Although sustainable procurement is considered a strategic decision needing top management support, environmental purchasing is actually more connected with the personal and ethical values of a company founder filtering into the wider organization and related to middle management support. The motivation for middle management to support environmental purchasing can stem from an intrinsic reward source or from the wish to strengthen their position in the organization (Walker *et al,* 2008).

Cost reductions through environmental projects are usually achieved by a reduction in pollution and waste; often motivated by a desire for quality improvement at the same time (Pil and Rothenberg, 2003); cost performance improves with the quality performance. At the same time quality performance improves with the environmental performance and with the adoption of social sustainability practices (Pullman *et al*, 2009). Waste reduction within green purchasing strategies can occur in two ways: reducing waste at the source; and eliminating waste after it occurred through waste treatment (Walker *et al*, 1997).

In a relatively early perspective on green purchasing, Min and Galle (1997) limit the debate to an operational purchasing perspective between supplier and costumer. Reducing the amount of waste generated or changing the type of waste can be achieved through recycling, reuse and source changes. The overall amount of environmentally harmful products can be decreased, the purchase volume of recycled or reused content be increased and unnecessary packaging be avoided. Packaging should ideally be biodegradable or returnable. Recycling is widely used and in many countries is part of compliance with local legislation. Most commonly paper, cardboard, aluminium, pallets and plastics are recycled as part of source reduction; another way is the reuse of packaging like pallets or reusable containers. There may also be options to avoid hazardous materials in the first place and substitute materials with more sustainable alternatives.

Eliminating waste is meant to simplify the processing of waste products. Scrapping and sorting non-toxic and biodegradable packaging can be part of reducing landfill. Such strategies can link back to the product design stage. Forcing responsibility for car scrapping onto the automobile industry in Europe through the end-of-life vehicle directive led to considerations at the design stage of how scrapping and recycling of cars can be made easier at the disposal stage.

The internal adaptation of environmental practices in organizations can be categorized into four groups: resistant, reactive, receptive and constructive adaptation (Walton *et al*, 1998):

1. *Resistant adaptation* of environmental practices means that organizations only adapt environmental practices if it is unavoidable. The attitude here is that sustainability and environmental issues are

'anti-business'. There is no intrinsic motivation to improve sustainability in the organization and sustainability and environmental laws are followed only by the letter but they do not feed into the policies or strategy of the organization.

2. *Reactive adaptation* derives from the mere ambition to comply with environmental law and to avoid penalties. Solutions often focus on reducing the harm from emitted pollutants, for example by collecting and disposing of waste, and not on reducing emission levels in the first place. Environmental issues are appreciated but with no change of current processes, actions usually occur at the end of the supply chain with only incremental solutions.
3. *Receptive adaptation* starts considering possible competitive advantages from environmental improvements, but translation into operational processes and procedures is still small.
4. *Constructive adaptations* embrace the value of integrating product and process design into environmental planning. These companies also maximize the benefits from environmental initiatives and maximize the productivity of resources.

These four levels of internal adaptation of environmental practices do not go beyond the organization's boundaries. To achieve truly environmental practices the involvement of more supply chain members is crucial. Achieving sustainable procurement may often start at an operational level, but needs to develop into an integration of environmental considerations in the strategy (Walton *et al*, 1998). From its focus on the operational side of the supplier-customer relationship, green purchasing therefore began to include more and more supply chain stakeholders, developing the discussion further into the downstream and upstream supply chain and into making the entire supply chain management more sustainable.

While the wish for cost reduction is a major internal driver for sustainable procurement, cost concerns are also a main barrier. Customers may aim for the lowest possible price and are not willing to pay a premium for more sustainable products. Costs associated with the implementation of sustainable practices are even more significant for SMEs with fewer resources to hand for investment. A managerial attitude of seeing ecology in a trade-off with economy increases the cost barrier even further.

Not knowing how to make procurement more sustainable can be an internal barrier too. Incorporating sustainability issues at a concrete, practical level appears to be difficult for many managers, even if they accept the necessity for more sustainability in their procurement. Managers are used to addressing issues of efficiency or governance in their interaction with suppliers and are often simply 'illiterate' in how to address sustainability.

A lack of legitimacy is another barrier. Paying only lip-service to sustainability and working on sustainability purely from an 'image' perspective for 'greenwashing' purposes prevents individuals from buying into the agenda and committing to sustainability improvements.

Before we look further into the inclusion of suppliers in 'green' or sustainable procurement for supply chain sustainability improvements, we discuss what external drivers and barriers determine whether organizations embark on the implementation of environmental supply chain practices or not (Walker *et al*, 2008).

Regulation can be considered a major driver for organizations' environmental efforts. Although compliance is not a guarantee of improved environmental performance, it is related to the involvement in green practices in purchasing. An improvement in environmental performance is more likely to be seen at those companies that adapt and integrate sustainability into their supply chain rather than using a reactive adaptation strategy. Nevertheless, regulation is a motivator for new solutions to reducing environmental impact at a low cost. Regulation can be the initial trigger to start thinking about new ways of reducing waste, leading to improved production yields.

Customers are drivers for environmental considerations in supply chains and procurement in many ways. This pressure can stem from the final consumer, and is then filtered up the supply chain. Consumer-facing companies are particularly exposed to pressure groups and environmental campaigners. Large, high-profile corporations with much buying power are also often seen as being in the driving seat of demanding sustainability improvements in the upstream supply chain and therefore face most attention from campaigners and the media, with the potential threat of negative publicity. Increasing public environmental awareness and the influence of non-governmental campaigning groups are part of the societal drivers for sustainable supply chain practices. Pressure groups and environmental campaigners often have the potential to publicly embarrass companies and thereby influence customers and law makers.

In a business environment competitors act as drivers for green supply chain practices. Competitors may become technology leaders or guide the industry to norms and legal frameworks and thereby drive other companies down the same route. Solution and innovation leadership among competitors can mean a competitive advantage since the pioneers often set the industry standards for future developments. When competitors gain a competitive advantage because of their environmental supply chains, companies have to respond to this challenge by implementing sustainability improvements themselves.

Suppliers as a possible driver for sustainable supply chains have received little attention in academic research. Some argue that suppliers are generally not the driving force behind sustainable supply chain practices but can support implementation and provide valuable knowledge (Carter and Dresner, 2001). Also, supply chain integration and collaboration with customers is an essential contributor to sustainability improvements. New products and services developed with other customers can also make the supplier the more knowledgeable partner for sustainability improvements.

Many of the external drivers can also act as external barriers. Regulation can reduce innovation or lead to changes that aim to satisfy the law rather than achieve objective sustainability improvements. These can also be industry-specific. Regulatory priorities might prevent organizations from sourcing the most environmentally friendly option. For example, can competition law stop companies from collaborating with their competitors?

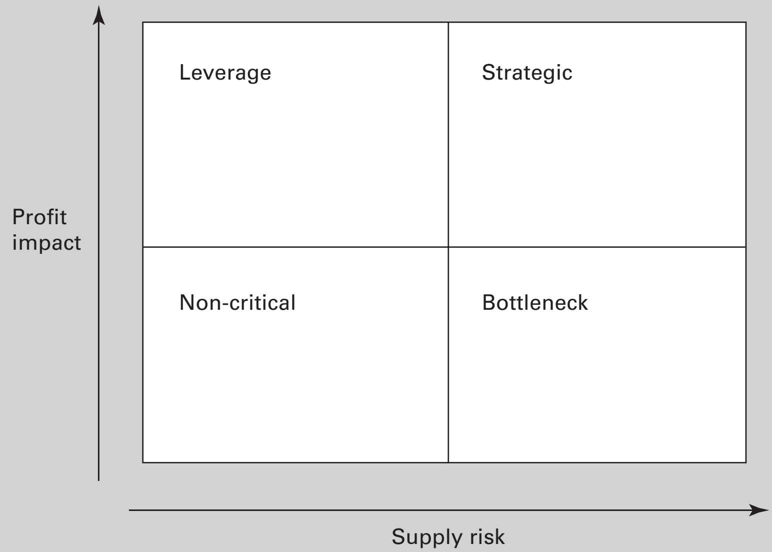
Suppliers may not be willing to share more information in the supplier-customer relationship and prevent further integration necessary to make the supply chain more sustainable. Depending on the power balance in the relationship, customers may not be able to convince their suppliers to implement changes and suppliers therefore become a barrier to environmental improvements.

Drivers, barriers and practices vary across different industries. Sectors are adapting to sustainable supply chain practices at different speeds, with market structures, ownership, governance, industry-specific regulation and the contextual situation leading to different results.

Procurement frameworks

Knowing about the internal and external drivers and barriers leads us back to how companies can achieve sustainable procurement. As mentioned earlier, purchasing and procurement functions developed into the concept of managing supply chains. Consequently, sustainable purchasing and procurement must develop into sustainable management of supply chains (or supply networks). The main idea for the development from purchasing to supply management was published by Kraljic in 1983. His matrix framework, shown in Figure 6.1, categorizes supplied items according to their profit impact and their supply risk into four sections: strategic (high profit impact – high supply risk), bottleneck (low profit impact – high risk), leverage (high

FIGURE 6.1 The Kraljic matrix



Source: Adapted from Kraljic (1983)

profit impact – low supply risk) and non-critical (low profit impact – low supply risk).

While suppliers of strategic items are managed in a partnership with a lot of collaboration and innovation between the supply chain partners, bottleneck items are mainly about volume insurance and control. The supply of leverage items is focused on making the most use of purchasing power and short-term and spot buying. The supply of non-critical items aims at efficient ordering processes and standardization. Consequently, the supply chain relationships between customer and supplier vary between the item classifications, therefore requiring different approaches for integrating sustainability in the procurement activity.

For strategic items sustainability as a performance criterion leads to new product development and innovation with the suppliers, benefiting from each other's knowledge to minimize the environmental and social impact of supply chains. Due to the close relationship, sustainability will also become a priority for the supplier and within the supplier's organization.

Bottleneck items are probably the most complicated ones for adding sustainability as the buying company does not have much power to force the supplier into sustainability improvements or changing suppliers. Buying organizations can try to push for industry-wide standards and regulation to improve the sustainability of bottleneck items but improving the sustainability of leverage items may be easier. Sharing best practices with suppliers enables sustainability improvements. Solutions consider a reduction of material intensity, using recyclables with a focus on lower costs.

For non-critical items sustainability needs to be included in the supplier selection criteria. To keep processes simple and efficient, certifications can be used for the achievement of sustainability criteria. Since the number of potential suppliers is sufficient, a non-compliant supplier can be easily replaced (Krause *et al*, 2009). However, the supply risk may increase as the number of potential suppliers is cut.

Although actions to achieve sustainability differ between the item categories, sustainability must be part of the agenda in all of them. Sustainability may become more and more a common performance criterion and therefore eventually develop into an order qualifier (Krause *et al*, 2009). Sustainability performance measures may also be raised as sustainability becomes common practice and buying organizations need to keep pace.

Understanding that sustainability must become a criterion in procurement decision making, we now need to understand how the sustainability of a product or service can actually be judged, which is essential when suppliers are compared in a selection process. Certification and ecolabelling help to identify suppliers that achieve sustainability standards.

Ecolabels

To simplify the selection of suppliers, certificates or ecolabels of external and independent organizations can be used. Certifications show that the supplier is following certain standards set by the awarding organization. The burden of monitoring and auditing the supplier is therefore shifted to an external auditor, usually paid for by the supplier, which is charged by the awarding organization for auditing and the use of the awarded label. Certifications are mainly used for suppliers of non-critical and leverage items, but they are also found in other supplier categories. Certifications and labels are also a way of avoiding pressure from campaigners as they provide evidence that the company fulfils the set standards. However, these standards are determined by the awarding organization and often only focus on a particular aspect rather than the overall sustainability of the product or service. Particularly common is the use of ecolabels in consumer products, and below we discuss some of the more well-known environmental certifications.

Fairtrade

The Fairtrade label is awarded through national bodies that form part of the international fairtrade organization. It focuses on ethical aspects and aims to help producers from developing countries out of poverty. Chocolate, coffee, cocoa, sugar, bananas and other agricultural commodities are the main products certified with the label. The retail value of fairtrade-certified products in the United Kingdom exceeded £1.3 billion in 2011. It certifies that farmers are supplying in long-term contracts and are paid a stable and 'fair' price. The long-term engagement enables the farmers to invest in the development of their farm and provides them with a more predictable stream of income than the global spot prices for commodities. Farmers are also paid a premium for their products which can only be used for the social and economic benefit of their workers and communities. It also favours small-scale farmers and cooperatives to support rural communities and their development (fairtrade, 2012).

Marine Stewardship Council

The label of the Marine Stewardship Council (MSC) was founded by the environment protection organization World Wildlife Fund (WWF) and the frozen fish producer Unilever (WWF, 2012). It focuses on setting standards for the sustainability of wild-captured fishing. It is not auditing any fishing businesses itself, but simply sets standards for fisheries and supply chain traceability. A product can have the MSC label applied if it can be traced back under MSC standards to an MSC-certified fishery. The MSC considers fishing stock levels, fishing operations and the managerial approach to sustainability (adapted from www.msc.org). Despite recognition of its achievement of environmental benefits, it has been criticized for setting its standards too lax (Smith, 2011).

Rainforest Alliance

The Rainforest Alliance ecolabel does not focus on a single product category but on the protection of the rainforest in the production of a product. It also has wider considerations towards the empowerment of forest communities and the establishment of sustainable business opportunities for SMEs in these communities. The Rainforest Alliance is a non-profit auditing organization for its own frog-themed ecolabels and the Forest Stewardship Council (FSC) ecolabel. The FSC, as the MSC, is only a standard-setting organization that is not engaging in the auditing process. Accreditation is aimed at the producers and at traceability through the supply chain to avoid mixing of certified wood with others (FSC, 2012; Rainforest Alliance, 2012).

Carbon Trust

The Carbon Trust is an independent non-dividend paying limited organization. It claims that in 2011/12 alone it worked with more than 6,000 companies, achieving cost savings of more than £500 million and CO_2 lifetime savings of 7.5 million metric tons ($MtCO_2$). Any profits made are reinvested in the Trust, whose aim is to 'accelerate the move to a global low carbon economy' through work for and with business and the public sector. The Trust is engaged in advising decision makers, supporting the development of new technology and the assessment of carbon footprints. It measures and certifies the carbon footprint of organizations, products and supply chains. For the carbon label certification, clients have a choice of the two most widely accepted carbon footprint standards: the Publicly Available Specification (PAS) 2050 from the British Standards Institution (BSI) and the Department for Environment, Food and Rural Affairs; and the Greenhouse Gas Protocol of the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI).

In contrast to other labels it does not only focus on one particular aspect or industry sector, but covers all areas of the supply chain (although it ignores the social and economic dimensions of the triple bottom line concept). It awards two labels. One merely shows that an organization is working with the Carbon Trust, the other requires active reduction of the measured carbon footprint, with such activities assessed every two years for recertification. Organizations applying the label to their products can decide whether they want to display the carbon footprint per unit within the label or not (Carbon Trust, 2012b; Greenhouse Gas Protocol, 2012).

LEED

LEED (Leadership in Energy and Environmental Design) is the certification of the US Green Building Council (see also Chapter 4 on warehousing). It sets standards on the sustainability of buildings. The standards vary in scope and requirements depending on the type and purpose of the building and differentiate between new constructions, existing buildings and refurbishments. Those applying for certification need to submit the details for their building and pay a charge for the review and certification of their building. Distinct from other environmental labels is the award of different achievement levels.

The best performing buildings gain platinum status, followed by gold, silver and certified (US GBC, 2012).

ISO 14001

Ecolabels are not only applied in consumer-facing environments: manufacturers and other business customers have a need to assess the environmental performance of their suppliers. In this setting the International Standards Organization developed standards for environmental management systems. These are part of the ISO 14000 series. Most notably ISO 14001 sets standards for the establishment and improvement of environmental management and aims to embark organizations on a continuous improvement process of their environmental management. The International Standards Organization however does not perform any audits or certifications itself, but simply develops standards at an international level, leaving the certification to independent auditors. Consequently, certifications in the 14000 series often go hand-in-hand with certifications in the ISO 9000 series on quality management and ISO 19000 series on auditing standards. In the United Kingdom the ecolabel image shows ISO 14001 certification by the British Standards Institution.

Beside the costs and time resources associated with ISO certification, the use of the ISO 14001 standards is subject to other criticisms (Murphy, 2012). Adopting the ISO 14001 standard does not specify the environmental targets. Achievements therefore depend solely on the organization's ambition, which makes comparison across sites, units and organizations difficult (Coglianese and Nash, 2001). The adoption can also lead to a focus on establishing formal structures, procedures and policies rather than on increasing efficiency and improving sustainability. The formal set up may also not always reflect the reality of activities in the organization (Meyer and Rowan, 1977). It is also felt that the comprehensiveness of the ISO 14001 standards varies widely from vague generalizations to detailed goals. Targets and their achievement can be seen as a rather mechanical process within a set regime of rules, limiting staff in choice and using their individual skills for improvements (Matthews, 2003). ISO 14001 also does not include the supply chain and supplier selection. Its scope is limited to the accredited unit and may in some cases ignore the main sources of a product's emissions (Krut and Gleckman, 1998).

Ecolabels in general are subject to limitations and criticism. The focus on particular aspects of sustainability makes a comparison and sourcing decision difficult. When comparing products and suppliers in a sourcing decision, the question becomes: what makes one product more sustainable than another? A widely applied and accepted way of evaluating the environmental balance of sourcing options is the use of lifecycle assessments. The manufacturing of one product may be causing more emissions than an alternative product but be more favourable in maintenance and disposal. Hence, the foundation of such a lifecycle assessment is to cover all emissions and impacts from cradle to grave (Schmidt and Frydendal, 2003).

Lifecycle assessment

A full lifecycle assessment is the most comprehensive and also most commonly accepted way of determining a product's or service's emission. Depending on the complexity of the assessed product and its supply chain, the assessment can become an extensive activity. To reduce the resource-intensity of a lifecycle assessment, average values are often used, for example for the carbon emissions per kilometre from a 40-ton diesel lorry or the use of a unit of main grid electricity. However, the more average values are used, the less exact and specific a lifecycle assessment becomes.

A lifecycle assessment consists of four steps. First, the scope of the assessment needs to be defined – what function, system or product is to be assessed; the definition of a functional unit; assumptions; and importantly the boundaries. The assessment is an iterative process and boundaries may be adjusted throughout the exercise. Nevertheless, standards like PAS 2050 now determine boundaries for the assessment. Examples for a functional unit can be the emissions 'per visit' for a service, per kilogram of a product, the usual lifetime of product (for example energy savings from the improved energy efficiency of an electrical item), or per driven kilometre. Within the boundaries all input is recorded and assessed in an inventory analysis, which forms the base for the assessment. Collecting data is often a more complicated task than initially anticipated and transferring input into functional units needs some consideration.

Following the analysis of the input side, all emissions are evaluated in an impact assessment. This is connected to the inventory data. All inventory data are put into impact categories and then processed within each category, so contributors to a particular impact can be grouped together. They can have different weightings, depending on their impact, for example within the group of greenhouse gases that contribute to global warming some have worse effects than others and therefore need to be factored differently. In the last step, the interpretation, the results from inventory analysis and impact assessment are connected to gain knowledge about the environmental impact of the assessed product and to make recommendations on improvements.

As thorough lifecycle assessments could require significant resources, different levels of detail and sophistication have evolved. The most accurate investigation can be found in a detailed lifecycle assessment, where all parts are evaluated individually. This requires expert knowledge about the processes and emissions occurring at the individual stages of the supply chain. It also differentiates between global impact and regional impact. The major disadvantage of the detailed lifecycle assessment is the effort needed to assess the supply chain so closely. Therefore more simplified methods, conceptual lifecycle assessment, and simplified or streamlined lifecycle assessment, evolved. The conceptual lifecycle assessment is positioned at the opposite extreme to the detailed assessment. It qualitatively examines what factors and areas in the lifecycle need to be focused on and then only assesses those. This can only be used as guidance for management, as the limited scope does not comply with the ISO standards for a lifecycle assessment.

The streamlined lifecycle assessment is in between these two approaches. It allows a comprehensive assessment, but uses generic data and does not measure each aspect individually. Therefore it contains all relevant aspects but does not require the effort of a detailed lifecycle assessment. Using generic data however means the assessment loses accuracy. Simplification can also be achieved through a screening stage in which insignificant emission contributors are identified and then do not need to be assessed in the analysis. Through this process the lifecycle assessment focuses on the key contributors, where the greatest environmental improvement potential lies.

The definition of the boundaries for a lifecycle assessment crucially influences the overall result and environmental performance of a product. The most comprehensive guidelines and definitions for boundaries of lifecycle assessments are in the area of greenhouse gases and carbon footprints. Standardized guidelines limit deviation in the assessment activity and simplify carbon footprint evaluations. PAS 2050 is currently the most commonly applied standard for carbon footprinting. For example it provides a threshold that inputs in the inventory analysis can only be deemed insignificant if they contribute less than 1 per cent of the lifecycle greenhouse gas emissions of a product.

When assessing greenhouse gas emissions the time dimension of the gases' impact influences the results. A range of greenhouse gases exists and their impact can be more short- or long-term after they are released. Depending on the chosen time horizon, the impact of greenhouse gases as CO_2 equivalents changes. The PAS 2050 standard sets 100 years as the time horizon for the impact of emitted greenhouse gases that needs to be included in the lifecycle assessment. It also specifies how carbon storage is allowed to be considered, and land use changes are included for the first 20 years (Sinden, 2009).

The significance of system boundaries is shown in a study of the carbon footprint of office paper. The study applies three approaches: ISO 14040/14044; PAS 2050; and the framework of the Confederation of European Paper Industries (CEPI). Unsurprisingly the industry's framework considers the least number of materials in its system boundary and the PAS 2050 standard includes significantly more materials than the ISO standards. In an assessment using the CEPI framework, only 90 per cent of greenhouse gas emissions were accounted for. Cut-off rules were comparatively narrow, for example in transportation in the CEPI framework only the journey to the distribution platform is taken into consideration. The ISO 14040/14044 standards considered 98 per cent of greenhouse gas emissions compared to the assessment using the PAS 2050 standard. However, they also required significantly less effort in data collection. The study allocated carbon footprints per tonne of office paper of 860 (CEPI), 930 (ISO 14040/14044) and 950 kgCO_2e (PAS 2050). However, when it comes to labelling products with a carbon footprint, the functional unit of a 'sheet of A4 paper' might be more accurate, as produced sheets can be of different weight categories depending on their thickness and density (Dias and Arroja, 2012).

Charcoal BBQ versus LPG grilling

Having a barbeque is a popular way of preparing food on a sunny day. Over the years several fuel options have been developed. The most commonly used ones are probably the charcoal and LPG (liquefied petroleum gas) from gas cylinders. Maybe consumers simply chose the option they perceive as more convenient or they are used to, but even in such a sourcing decision environmental performance can be compared.

Johnson (2009) compares the carbon footprint of these two barbeque methods in a lifecycle assessment. Considered in the system boundaries are the production of the fuel; use and disposal (for charcoal) of the fuel; and production, use and disposal of the grill and cylinder.

Charcoal is made of wood through heating under a deficit of oxygen. Sometimes it is argued that the wood used is waste wood; nevertheless it needs to be included in the inventory analysis as the wood could otherwise be used for energy generation or other forms of use. Charcoal in the United Kingdom is mainly imported from outside the European Union. LPG is liquefied and placed in cylinders in which it is transported to retailers and final customers.

The consumption of charcoal or LPG in a BBQ session was estimated through a test programme of grill sessions by experienced amateur grillers. Although the consumption of fuel varies a lot between users depending on the amount of meat, the design of the grill, cooking style and personal preferences, these variations are much greater for charcoal than for LPG. For LPG most grillers stayed within a range of 25–45 per cent of the food's weight, whereas charcoal consumption varied from 30 to 140 per cent. The consumption of firelighters was fairly consistent across charcoal BBQ sessions. Charcoal ashes are disposed via the municipal waste services. The calculations assumed 150 grill sessions over the BBQ's lifetime, with 1.5 kg of meat, 525 g of LPG or 733 g of charcoal and 115 g of firelighters per session.

The production of the LPG grill causes more CO_2e emissions than the charcoal alternative. Additionally, LPG is transported in cylinders, which need to be manufactured and can only be reused for a certain time and number of refills. On the other side, the firelighters used over the lifetime of a charcoal barbecue add up to 74 kgCO_2e.

The biggest difference is made by the fuel. The production and combustion of LPG emits so much less CO_2e than the charcoal that the emissions from the cylinder system are more than compensated for. Only if waste wood was used to produce charcoal do the two fuels almost draw even.

Assuming a lifetime of 150 grill sessions for both types, in total each LPG barbecue session causes 2.3 kgCO_2e, the equivalent of driving an average European car for 13 km. In comparison each charcoal barbecue session emits 6.7 kgCO_2e, almost half of it stemming from charcoal combustion. LPG grilling appears to be the more environmentally friendly solution, mainly due to greater efficiency in production and cooking.

Source: Johnson (2009)

For suppliers their customers' requirements will most likely matter the most when adopting a lifecycle assessment standard. In particular SMEs may not have the resources to run a detailed lifecycle assessment and need to fall back on standards that allow them some level of simplification. For suppliers it is essential to understand what frameworks their target markets apply and how environmental performance feeds into decision making.

Comparing purchasing options

One clearly needs to differentiate between the more strategic perspective of procurement, which includes market analysis, supplier portfolio management, etc and the more operational dimension of purchasing. We covered the strategic perspective earlier in this chapter. Making use of lifecycle assessments and supplier portfolios becomes part of the operational perspective. Quantifying the environmental advantage of one supplier over another is difficult and evaluating the value of environmental improvements even more so.

Environmental performance can be a knock-out criterion (for example only suppliers achieving a particular ecolabel are considered in the first place); it can be measured in monetary values and compared; or form part of the decision in a multi-criteria analysis (all criteria are scored and for example 20 per cent of the decision is allocated to the score in environmental performance). Quantifying the monetary value of environmentally 'better' products is a difficult task. As with the environmental lifecycle assessment, the lifecycle costs need to be measured and used in cost-benefit analysis or cost-effectiveness analysis.

The cost-benefit analysis looks at the positive and negative effects on the welfare of the environment. This approach considers environmental and other sustainability costs only if these external effects can be monetized (for example healthcare cost savings due to less respiratory illnesses if emissions from a factory are reduced). The cost-effectiveness analysis limits its focus to the project. The cost-effectiveness approach can be used to investigate and compare solutions on the way to a specific target. The target itself however is often not measured in money but in a unit of environmental impact. If several impact categories are considered, each category can be weighted (Pierrard and Faßbender, 2003).

Organizations need to evaluate their own sustainable supply chain performance to benchmark themselves against their competition. Often managers in supply chains are confused about what to measure and why for sustainable supply chains. The confusion arises from the traditional approach of focusing on cost in relation to output (for example service performance like the proportion of on-time in-full deliveries), while measures for environmental performance mostly look at inputs and emissions. Examples are the electricity consumed, fuel consumption, number of pallet movements and vehicle utilization. A monetary measure of environmental performance is often preferred by managers (Shaw *et al*, 2012). However, it is in most cases unsuitable or outright impossible to express a monetary value for environmental supply chain performance.

An example for integrating sustainability performance into supplier management is the US communication company AT&T. To provide guidance for its customers the company uses a rating system of one to five stars for own-label handsets, which contains five environmental attributes consisting of 15 sets of criteria. The eco-rating followed five principles: prioritization (focus on a targeted group of environmental impacts); alignment (with existing standards); simplicity (easy to understand information); credibility (performance criteria at multiple levels at suppliers); and transparency (providing details to support action is taken). Although initially created with the end customer in mind, the eco-rating provides guidance for the suppliers too as they want to improve their star rating. To make the rating meaningful suppliers were consulted in the design stage of the rating; suppliers are essential partners in this rating as the rating requires input data from them. The guideline, handset environmental performance and supplier improvements are published online, making progress easy to follow (Connolly, 2012).

Summary

Procurement provides a lever to improve the sustainability of the overall supply chain. It becomes even more crucial if the organization's own internal operations contribute only a little to the overall emissions footprint. Much pressure to improve sustainability performance usually comes from the customer end of the supply chain, which is why concentrations of buying power like public procurement and the procurement practices of industry leaders play an essential role in the development of more sustainable products.

The individual drivers and barriers vary between sectors, market segments, countries and companies. However, regulation clearly plays an essential role especially for those companies that have little intrinsic motivation to improve their sustainability, and the internalization of external costs makes it easier for companies to consider sustainability issues in their purchasing decisions. In a different way, ecolabels simplify sustainability in procurement as they set standards and take auditing and monitoring burdens off the buying side.

Implementing sustainability in procurement becomes particularly difficult when more sustainable products are more expensive and when sustainability achievements are hard to measure in monetary terms. Performance targets and sustainability specifications are needed to direct purchasing managers in the execution of their tasks.

Reverse logistics and recycling

07

Background

Reverse logistics and recycling play important roles in sustainable logistics and supply chain management. While typically a product ends at consumers, reverse logistics and recycling take care of the product's life after its 'death'. Waste or rubbish is generated when a product is no longer functional, needed, or fashionable, and which its owner wants to dispose or discard. Waste may also be generated during the extraction of raw materials, the processing of raw materials into intermediate and final products, and the consumption of final products. In the United States, 250 million tonnes of municipal solid waste were generated by US households in 2010 (EPA, 2011) and each year in the European Union 3 billion tonnes of waste are thrown away, some 90 million tonnes of it hazardous. These staggering figures do not include the air and waterborne pollutions produced by the industries that extract materials and make products for human consumption. The more we buy and use products the more waste we will have to discard and the more pollution we create. Many more environmental problems will be generated due to the rapidly expanding world population living in urban areas. By 2020, the OECD estimates, the European Union could be generating 45 per cent more waste than it did in 1995 (EC Environment, 2012).

Also, the Earth has finite natural resources. With an exponential increase in the consumption of natural resources to meet human demands there is a need for reverse logistics systems to reduce the use of natural materials and reuse the used products. Due to a lack of such systems in many countries we are increasingly confronted with the consequences of our throwaway society. Inadequate management of waste generated by human activities can lead to severe land degradation and exhaustion of natural resources. Dumping sites in developed and developing countries are getting congested. This problem not only damages the environment, but also our health. Large areas of land are no longer fit for habitation as a result of the enormous pollution of the ground by the waste produced by human activities. In many countries, water extracted from the rivers and groundwater has to be filtered before consumption, fish in large economically important rivers are not consumable, and smog in the urban areas caused by traffic and industry is creating severe health problems for elderly people and children. According to UN Water, more than 40 per cent of the world's population live without improved sanitation. In 2007 WHO data showed that 13 million deaths worldwide could be prevented every year by making the environment healthier.

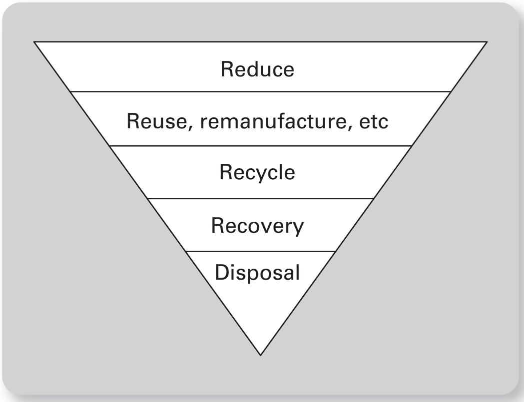
Increasingly both governments and commercial organizations have recognized the urgent need for effective reverse logistics systems to manage our waste or rubbish. Legislation at both global and national levels is enforced to control the use of natural resources and the logistics of waste. In some countries incentives are used to encourage the use of greener waste disposal methods. Many households nowadays have to pay for their waste disposal and some municipal authorities in the United States are implementing variable-rate pricing for waste disposal.

Some commercial organizations have started to reduce the waste they produce. This development is not only stimulated by the growing regulatory pressures from the government, but also driven by corporate citizenship or corporate social responsibility, as well as the need to save disposal, material and energy costs. In addition, more and more companies are set up to reap the valuable commercial opportunities in collecting, recycling, and reusing products and materials (Kroon and Vrijens, 1995). Other waste management and third-party logistic companies have taken this opportunity to enter profit-making businesses. In 2002, research revealed that over US $750 billion annually was being spent on reverse logistics processes in North America alone (RLA.org, 2013).

Reverse logistics and recycling

The systems required to take care of waste in a responsible, effective and sustainable way can be called 'reverse logistics systems'. Reverse logistics differs from forward logistics in that it is in the reverse direction of a typical supply chain. Reverse logistics is about the movement of goods from a consumer to

FIGURE 7.1 Hierarchy of waste management



a producer in a channel of distribution (Murphy and Poist, 1989). Reverse logistics is almost synonymous with material recycling and waste management in efforts to minimize cost, retrieve value from reverse flows, and to fulfil legislative and environmental requirements. Reverse logistics is a broader concept for overall supply chain optimization, which aims to support closed-loop supply chains by affecting activities like product design, supply chain design, product recovery. Reverse logistics plays the role of logistics in product returns, source reduction, reuse of materials, materials substitution, waste disposal, recycling, refurbishing, repair and remanufacturing (Stock, 1992, 1998); see Figure 7.1. From a process management point of view, reverse logistics is defined as the process of planning, implementing, and controlling the efficient flow of materials, in process inventory, finished goods, and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal (Grant, 2012: 220; Rogers and Tibben-Lembke, 2001: 130).

Reverse logistics is an important concept both for companies that organize recycling and for those that have to pay for disposal of rundown or waste products (Carter and Ellram, 1998). It is sometimes considered the backbone of 'sustainable development' in its economic and environmental impact on business practices (Stock, 1992, 1998). It is considered an instrument of sustainable development and a driving force in sustaining the economy and environment. Reverse logistics is a crucial element of a closed-loop supply chain. Closed-loop supply chains include the typical forward flows of materials from suppliers to end customers and the reverse flows of products (post-consumption) back to the manufacturing or distribution supply chains. Reverse logistics prevents the disposal of end-of-life products in less environmentally friendly channels such as landfill and incineration.

As illustrated in Figure 7.1, the level of environmental 'friendliness' can be determined from the following hierarchy of waste management – reduce, reuse, recycle, recovery, and disposal:

- *Reduce* is the most environmentally friendly option. This may involve the use of less (hazardous) material and energy. Cleaner production can help to reduce energy usage. Industrial production can be modified to reduce hazardous waste and other materials. This method is also called 'source reduction'; it involves changes in manufacturing technology, raw material inputs and product formulation. Consumer behaviour can also contribute to reductions. The fewer natural resources we consume the less waste is created.
- *Reuse* involves the use of some parts of a used product or even the entire used product if it is repaired or remanufactured. Reuse can be considered a direct recovery option. Reverse logistics systems such as waste exchange, car-boot or garage sales, and second-hand sales that facilitate reuse can help to reduce landfill.
- *Recycle* helps to separate waste into materials that may be incorporated into new products. Usually recycling consumes energy in changing the physical properties of the material; it is a recovery option that requires reprocessing. Activities such as composting and the reprocessing of used empty beverage containers or packaging materials are examples.
- *Recovery* normally means the process of creating energy in the form of electricity or heat from the incineration of waste such as organic materials. Alternately, it is called waste-to-energy or energy-from-waste.
- *Disposal or landfill* is the last option. The problem with this option is that some materials will not be easily degradable and some of them contain toxic substances.

The management of reverse logistics requires some specific knowledge and skills. First of all, there is a need to understand what (the product) and who (the actors) are involved, the recovery processes, and the reasons or drivers behind the involvement of the different actors (de Brito and Dekker, 2004). The following are the typical actors involved in the recovery processes:

- Retail companies primarily offer reverse logistics services to manage product returns, repairs and warranties. Such services are often associated with the product warranties offered by original equipment manufacturers (OEMs) and may include the resale and redistribution of unsold products and product warranties. Some retail companies provide consumer packaging collection facilities voluntarily or following governmental requests. A significant quantity of recycled materials can be collected by retail companies during the distribution process.

- Similar to retail companies, OEMs may offer services for product returns, repairs and warranties. Manufacturers generally do not have stores so they could own or outsource return centres to third-party logistics service providers, or provide channels (such as retail stores or postage services) for consumers to return used products.
- Governmental agencies or local authorities normally offer waste collection and disposal services to households and shops. In many countries, most household waste is collected by government agencies or local authorities. However, the extent to which the reverse logistics systems facilitates reuse, recycle, recover and disposal may vary greatly, depending on the collection and reprocessing systems provided.
- Private waste management and product return companies are third-party logistics service providers specializing in return management acting on behalf of retail companies, OEMs and government agencies. These companies normally also sort materials and sometimes reprocess used products. In some countries, there are also individuals (scavengers) who collect reusable materials or products from rubbish sites.
- Traders are companies that purchase and sell recovered products or recycled materials collected by government agencies, retail companies, waste management companies and scavengers. They play a significant role in aggregating and distributing recovered/recycled products to the reprocessors.
- Reprocessors are companies or individuals who disassemble, repair, remanufacture, refurbish, recycle and reprocess products and materials from the 'disposal' market and transform them into (re-) usable forms. Unless the products are reused without the need of reprocessing, most recovered products need to go to reprocessors. These businesses have to be commercially viable and therefore require a constant supply of recovered/recycled products and materials, as well as a constant and profitable demand from the markets.
- Customers are the last but the most important actors in the reverse logistics loop. They form the 'reuse' markets; they may be consumers,

commercial companies or non-profit organizations. Charities are also major customers of recovered products, and there are companies that distribute and sell used spare parts or remanufactured products. Without demand from these actors the reverse logistics systems will not be economically viable.

Even though many actors are involved in waste management and reverse logistic activities there is often a lack of efficiency and visibility. While providing reverse logistics services, many manufacturing and retail companies are more concerned about warranties and after-sales customer service than environmental sustainability. This is partly due to the lack of regulatory pressure and producer responsibility. However, in recent years, more commercial companies have established reverse logistics systems to recycle, but also reuse, refurbish and remanufacture. Product recovery activities can actually strengthen brand image (Guide and Van Wassenhove, 2002). Driven by increased environmental awareness, many electronics manufacturers for example have transformed their product safety and occupational health organization units from a focus on purely regulatory compliance to a comprehensive environmental policy. Nowadays most computer and mobile phone manufacturers offer attractive product recovery services simply because customers only purchase new products from those who are capable of taking back used products responsibly. The following case studies illustrate how multinational computer and mobile phone OEMs utilize and adapt existing international distribution networks as reverse logistics systems.

The reverse logistics systems for computer and mobile phone sector in Thailand

Thailand is a middle-income, developing country located in the heart of Southeast Asia. In 2008, demand for computers including desktops and laptops was approximately 2.56 – 2.82 million units (Technology Learning Center, 2010) and demand for mobile handsets in Thailand was approximately 8.8 million units (Samart Corporation, 2008). There were approximately 62 million registered mobile phone users in 2008, the 17th highest number of mobile phone subscribers in the world (CIA, 2014).

MobileCoD is a subsidiary company of a leading international corporation located in Hong Kong. Currently, the company operates in 54 countries and employs approximately 220,000 workers worldwide. Moreover, it has five core businesses – ports and related services, property and hotels, retail, energy, infrastructure, investments, and telecommunications. In 2003, the firm created a new segment in Thailand's telecom industry by launching new mobile services of the Code Division Multiple Access (CDMA) network, which was a second-generation (2G) multi-media mobile network. Handsets are delivered by air from vendors' factories abroad to the main distribution centre in Bangkok. When the handsets are delivered to the distribution centre, warehouse staff check whether a pallet of the handsets is correct via a barcode system and that their physical appearance is fine. The staff will also randomly check whether a mobile phone box includes the handset and accessories by using a scale, and again randomly, test the quality of the phone. The company keeps a safety stock for 30–60 days because the selling prices of mobile phones fluctuate considerably. The company classifies distribution channels into four types: company shops (30 in Bangkok and 6 in other provinces), big dealers, order by phone, and B2B (business to business) or B2G (business to government).

Handsets are returned for two main reasons: seven-day warranty returns and service returns (one-year warranty returns) and the company has set up a closed-loop network to cope with them. In terms of seven-day warranty returns, if a customer does not like a handset, or detects any defect, he or she can return it to a company shop. After that, the handset is collected by the third-party transportation service provider, and is sent to the company's head office, where it is checked and tested by a technician. First, if there is no defect, it is repacked and resold as a new mobile phone. Second, if there is any minor defect with a low repair cost, it will be repaired and resold as a new mobile phone via all the distribution channels. Third, if it is in working condition, but has a defect with a high repair cost, it will be resold as a second-hand mobile phone via dealers. Fourth, if it is in non-working condition and is beyond economical repair, it will be cannibalized and disposed of. The incidence of seven-day warranty returns is less than 0.5 per cent of total sales. In terms of service returns (one-year warranty returns), if a handset is in a non-working condition, it can be dropped off at a company shop. After that, the handset will be collected by the third-party transportation service provider, and will be sent to the company's head office to be repaired by a technician. After repairs are made, the firm will send it back to the company shop by the third-party service provider and the customer will collect it at the shop. The repair processes take about 7 days in the Bangkok service area and 14 days in the 'other provinces' service area. The percentage of service returns (one-year warranty returns) is approximately 0.8 per cent of total sales.

MobileCoF is a subsidiary of a multinational conglomerate established in 1938, with its headquarters in South Korea. The company classifies electronics products into four main types: digital media, semiconductors, telecommunications network, and LCD digital appliances. It became the number one seller in the Thai handset market with 33 per cent of market share value in 2009, and low-end, mid-range, and high-end handsets account for 53, 32 and 15 per cent, respectively, of total sales. Moreover, the company launches approximately 50 new handset models per year.

The mobile phone manufacturer has three factories based in Korea, and handsets are distributed through the main distribution centre located in Bangkok. The selected means of transportation from the factory to the main distribution centre is by sea. The company classifies the distribution channels into three major categories: dealers, organized retail groups, and modern trade, being, respectively, 50, 30 and 20 per cent of total sales. Dealers are categorized into two main classes: hub masters and retail partners. The hub masters distribute bulk quantities of handsets to sub-dealers; the retail partners sell handsets directly to individual customers. Half of the dealers are based in Bangkok and the middle part of Thailand. When an order is received, it is delivered to customers based in the Bangkok area within four hours, and to customers based in other provinces within 28 hours. All distribution activities including transportation and warehousing are operated by a third-party transportation service provider.

With regard to the reasons for returns, the firm classifies these into five main types: commercial returns, logistics returns, returns due to order processing errors, technical warranty returns, and service returns (one-year warranty returns). The company has employed a closed-loop structure to deal with commercial returns, logistics returns, returns due to order processing errors, and technical warranty returns and has set up an open-loop structure to deal with service returns: commercial returns, logistics returns, order processing error, technical warranty returns, and one-year warranty returns.

Source: Chanintrakul *et al* (2010)

Product recovery options

Based on a detailed understanding of their products, companies can learn to manage the recovery and distribution of end-of-life products, planning of production and inventory, and supply chain issues in reverse logistics (Rubio *et al*, 2008). Recovered products can be civil objects, consumer goods, industrial goods, minerals and chemical compounds, raw materials, distribution items and spare parts. Next is understanding suitable product recovery options for each type. Product recovery management (PRM) involves the management of all used and discarded products, components and materials that fall under the responsibility of a manufacturing company (Thierry *et al*, 1995). PRM aims to recover as much of the economic (and ecological) value as reasonably possible, thereby reducing the ultimate quantities of waste. Due to a belief that the cost of PRM should not outweigh its benefits, most manufacturers focus on the forward logistic flows from the factories to the end customers rather than the reverse flows of the used products. Therefore, the traditional approach of many manufacturers towards used products has been to ignore them or let other parties dispose of them.

In recent years manufacturers have been pressurized by both consumers and governments to reduce waste generated by their products. In general there are five major product recovery options (Thierry *et al*, 1995):

1 Repair
- the aim of repair is to return used products to working order;
- used products are normally not disassembled – they are fixed: some parts may be replaced while some can be reused;
- the quality of the repaired products is usually lower than the quality of new products;
- repair can be performed at the retail stores or repair centres;
- products such as computers, mobile phones and washing machines are suitable for repair.

2 Refurbishing
- the aim of refurbishing is to bring used products up to a specified quality;
- refurbishing needs similar processes to repair: it involves disassembly of used products into modules, inspection of the modules and fixing and/or replacing as required, then reassembly into refurbished products;
- the quality of refurbished products is often lower than those of new products;
- products such as houses and caravans can be refurbished.

3 Remanufacturing
- the aim of remanufacturing is to bring used products up to quality standards that are as good as those for new products;
- the processes involved are similar to those of refurbishing: used products are often completely disassembled into modules and parts; there is extensive inspection of modules; worn out parts or

modules are replaced; repairable parts are fixed and extensively tested; and approved parts and modules are reassembled into remanufactured products;
  - can be used for products such as copiers, engines, car parts and machine tools.
4. Cannibalization
  - the aim is to recover a limited set of reusable parts from used products or components;
  - only a small proportion of the parts are recovered for reuse, remanufacture, repair other products and components;
  - involves selective disassembly and inspection of potentially reusable parts;
  - the remaining parts are recycled or disposed of.
5. Recycling
  - the aim is to reuse materials from used products or components;
  - the recovered materials are separated into categories;
  - the materials can be used to produce original products and components, if their quality is high, or can be used to make other products;
  - examples include milk bottles and soft-drink bottles.

There are some main differences between these recovery options. In terms of disassembly, used products are disassembled at product level for repair, module level for refurbishment, part level for remanufacture and cannibalization, and material level for recycling. The quality of remanufactured products is the highest (as new), while the quality for repaired and refurbished will be lower. For repair some parts are fixed or replaced by spares. For refurbishing some modules are repaired or replaced and potentially there is a need for upgrade. For remanufacturing, used and new modules/parts are combined into new products with some potential upgrade. Cannibalization is quite different; it reuses some parts and the remaining product is recycled or disposed of. Recycling works at the material level; that means parts are reprocessed to raw material forms.

One of the very first steps to develop an effective PRM is to acquire adequate information: there is a need to understand the composition of products. The manufacturers should be able to identify each part and components of their products based on the bill of material and product/material technical specification. A manufacturer with a good environmental management system (EMS) will have a system to gather knowledge about the materials used to make each part or product and the legislation governing the end-of-life management of such materials and so can identify which parts/modules/products, depending on the quality of returned products, are suitable for reuse, repair, refurbish, remanufacture, recycle and recovery.

Different incentives can be provided to encourage customers to return used products. For example, used laser printer cartridges can be returned easily because customers are provided with cartridge boxes marked for free return shipment. Credits toward future purchases are given to encourage participation in product recovery. Sliding scales of prices to be paid by customers for products with different residual quality levels encourage customers to take better care of the products and subsequently help to increase the average quality of recovered products. Some companies offer free recycling services to customers who purchase a new product from them. Lexmark offers a 'pre-bate' discount to customers who agree to return their Lexmark printer cartridges to Lexmark for remanufacturing (Toffel, 2004). This scheme not only increased return rates, it has also positively improved Lexmark's brand image. Many companies have started to provide free take-back services, by working closely with their distributors and third-party logistics service providers. Even though setting up their own product recovery or reverse logistics network helps to ensure returned product quality, many manufacturers offer multiple return channels to increase recovery rates. Incentives for retail companies to collect end-of-life products can in some instances increase product recovery rates as well as sales of new products.

When choosing suitable product recovery options several factors need to be considered. First, not all used products are technically suitable for reuse, repair, remanufacture or recycling. For example, food packaging may not be suitable for reuse, but it may be recycled. Second, there is a need to investigate if there is a constant supply (from the 'disposal' market) of suitable used products and components. This depends on the efficiency of the product return logistics flow, the willingness of consumers to return used products, as well as the quality of the returned products. Sometimes participation in product return can be motivated by monetary incentives and regulation, as well as the ease of participation, the latter depending on the design of collection schemes (see Table 7.1). The design of collection schemes and the location of collection centres determine the magnitude of return flows. The quality of returned products depends greatly on the design of the products and components, as well as the incentives given to customers to maintain the products while they are in use.

Third, there is a need to ensure that there is a constant demand for reprocessed products, components and materials. A better option is to re-route the recovered products to the forward logistics flows for reuse.

TABLE 7.1 Collection schemes

Collection scheme and incentive	Definitions and operating principles
Deposit fee (advanced)	When customers make a purchase an advanced deposit fee on the product is charged. The deposit fee will be returned to the customers when the used products or packaging materials are returned to the collection centre in the right condition. This is an effective scheme to ensure return of used products or recovery of packaging materials. It is common to charge deposit fees for bottled beverages in some European countries.
Take-back	Retail companies or OEMs offer to take used products back for repair, remanufacture, refurbishment, etc. It could be free or there may be a fee involved. This scheme demonstrates the producers' responsibility to assure customers there is a reverse logistics system in place when they are making a purchase decision. The customers, OEMs or third-party service providers may be involved in physically returning the products. Take-back schemes are popular for copy machines, printers, batteries, automotive, etc. Products purchased under leasing agreements often include take-back schemes.
Trade in (rebates)	Used products may be returned to retail stores for trade in, meaning customers have to purchase another product in exchange. There is an agreed value for the used products so customers do not have to pay the full price for the new product. Trade-in schemes are commonly used for cars and mobile phones.
Pick-up system	Used products may be picked up from customer locations, often for a fee. This collection scheme is often operated by local authorities (municipals) and charities for households, and also commercial waste management companies for commercial organizations.
Public recycling centres	Offered by the local authorities (municipals), householders can take their used products to the public recycling centres. This scheme is normally free of charge but customers have to be prepared to return the used products themselves.

In some cases the (secondary) markets for reprocessed products could be thousands of miles away from the sources of used products. Since the cost of reprocessing plastic is expensive in Europe, a significant amount of recycled plastics collected there is shipped to China or other developing countries to be reprocessed, and the reprocessed plastics are then shipped to Europe for making new plastic products.

The final consideration is economic and environmental cost and benefits. The value of the products, parts and materials indicate if there is any economic value in setting up or investing in a PRM. Since most reverse logistics systems contain many actors with a fragmented structure and a lack of supply chain leadership, the efficiency of the systems are often constrained by the least profitable parts of the chain. It is therefore important to understand the costs and benefits of each actor in the entire reverse logistics system.

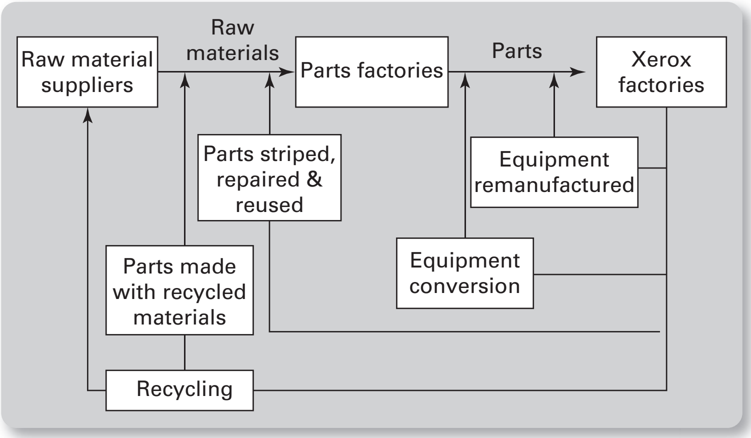
To understand the economic value of PRM, a new concept called 'value recovery' (VR) was introduced by Srivastava (2008). Collection, inspection/sorting, reprocessing, and logistics and distribution network design are four important functional aspects in value recovery. The dimensions used to characterize the value are returns volume, returns timing, returns quality (grade), product complexity, testing and evaluation complexity and remanufacturing complexity. VR strategies and programmes can result in increased revenues, lower costs, improved profitability and enhanced levels of customer service, leading to better corporate image (Carter and Ellram, 1998; Stock *et al*, 2006).

Choosing the right recovery options and developing efficient PRM are onerous tasks and not everyone can make them economically viable. Others aim to become the leader in product recovery and environment within their industry. Xerox, for example, attempts to achieve environmental leadership, and the case study below illustrates how the extended responsibility and environmental leadership provided by a producer can significantly improve a reverse logistics system.

Xerox Corp's environmental leadership

Xerox is a leader in document technology and services and is among the world's leading enterprises for business process and document management. Xerox offers global services such as claims reimbursement, automated toll transaction, customer care centres and HR benefits management. The mission of Xerox is: 'Through the world's leading technology and services in business process and document management, we're at the heart of enterprises

FIGURE 7.2 Xerox's closed-loop supply chain



small to large, giving our clients the freedom to focus on what matters most: their real business' (www.xerox.com).

Xerox's aim is 'waste-free products manufactured in waste-free factories to enable customers' waste-free workplaces'. Launched in 1991, Xerox's environmental programme achieved the 2-billion-pound milestone by waste avoidance in two areas: 1) reuse and recycling in imaging supplies, and 2) product take-back and recycling and parts reuse. Next, Xerox's Energy Challenge 2012 programme began with the goal of lowering greenhouse gas (GHG) emissions from its worldwide operations by 10 per cent from 2002 to 2012. Recognizing the obligation to do even more, in 2007 Xerox set a new and challenging goal to reduce its GHG emissions by 25 per cent by 2012, from a 2002 baseline. Figure 7.2 illustrates Xerox's closed-loop supply chain.

During product design, Xerox focuses on minimal use of hazardous substances and efficient use of materials. Reuse and recycling of parts and components are seriously considered. The product lifecycle costs are estimated and reduced by considering extended life of parts, easy disassembly, part reusability and material recyclability. The products are designed so that some major parts (eg frames) will last longer and could be used for remanufacturing to another product or repaired. To achieve this effectively, the product design team develop product lifecycle cost models, material guides and disposal coding. The product lifecycle cost, material usage and recovery options for each part and component are discussed in a mandatory review during the product design process. Training is provided to ensure all staff involved are capable of executing such robust product design processes.

The manufacturing processes are also designed to create waste-free factories. The focus is to achieve low emissions and efficient use of energy during the production processes; these are considered during the product design stage. Another unique feature of Xerox factories is that they are designed not only to build new products but also remanufacture used ones. The production lines are designed to be able to build new products by using some of the major parts recovered from the used products.

More importantly, Xerox recognizes the significance of energy usage during customer use. In addition to paper-saving features, a lot of research has been devoted to designing copy machines that consume the least energy while in use or in energy-saving mode. According to Xerox, ‘standby’ is a waste. When the copy machines are not in use, better energy saving options such as ‘low power’, ‘sleep’ and ‘auto-off’ can be used. Recognizing the need for some heat to fuse toners onto papers (making copies) a lot of research has been conducted to make the printing process work at lower temperature, to achieve the optimal use of energy during use and energy-saving modes. As a result, it is possible to use energy-saving modes 80 per cent of the time. Since 1993, Xerox has worked with the EPA and the industry to set criteria for energy-saving copy machines. Xerox Energy Star products are internationally recognized. To meet the stringent requirements, common procurement requirements were launched, and in 2010, 100 per cent of newly launched eligible products achieved the Energy Star standard.

Another focus is to improve the customer return process, via enhancements at Xerox the Green World Alliance recycling website (www.xerox.com/gwa). There are three different return methods: single item return programme, bulk returns on a pallet, and Eco Box.

1 *Single item return* is a programme for customers to return a single item, for example a cartridge. Customers can submit a cartridge return label request and receive a label for shipping the cartridge by post free of charge. Depending on the types of returned products and the locations of the customers, Xerox decides which recycling centre is to receive the returned products.

2 *Bulk returns* on a pallet is a return programme for those who have more than 30 items to be returned. The Xerox Pallet Returns process allows customers to download Xerox Bulk process, which contains the instructions on how to prepare items and schedule a pickup.

3 *Eco Box* is a programme where customers may order kits of three boxes each at no cost, bundle items together in the box, download a pre-paid label, and return them to a returns partner. In Europe, Close the Loop is a company, like Xerox, dedicated to Zero Waste to Landfill recycling. The company takes cartridges that Xerox cannot reuse, and through its patented recycling

process, separates cartridges into plastics, toner powder, metals and other materials, then cleans and processes them for return to the market as raw materials or new products.

Since copy machines contain chemicals (eg toners) the cleaning process has to be hazardous. Advanced technology for cleaning and predicting part reliability has been developed. Instead of traditional cleaning methods and materials, Xerox uses automated CO_2 blasting to clean up used parts. Advanced technologies are developed to determine range for noise, heat and vibration during use, so that reusable returned parts are selected for reprocessing. Platform design is adopted and parts commonality is emphasized. Xerox has further extended the concept of remanufacture to product conversion. The new build remanufacture processes are integrated with the conversion processes. For example, the reusable parts and machine frames of end-of-life machines are used to build new (or 'reman') machines; for instance Document Centre 220 becomes Document Centre 440.

Xerox also extends its recovery channels further upstream by involving parts suppliers and raw material suppliers, as shown in Figure 7.2. Machines for remanufacturing and conversion are sent back to Xerox factories. Parts that can be reused are sent to parts factories where they are stripped, repaired and reused; parts that cannot be reused but can be recycled are sent to parts factories as raw materials. Recycled materials are sent to raw material suppliers to be reused.

Other examples of reverse logistics solutions

Other companies have been constantly improving their reverse logistics systems to achieve environmental sustainability:

- IBM had to decide how to organize the collection of product returns, and which parties to involve depending on the processes required. In many countries IBM has set up a take-back programme allowing business customers to return used products on top of the take-back responsibility that IBM has for the consumer market. IBM has set up a business unit dedicated to the management of recovery with 25 facilities steering repair, remanufacturing and recycling (also with the involvement of third parties).
- BMW has been conducting recycling research in a pilot vehicle disassembly plant in Landshut, Germany since 1990. There are three main focused issues. The first is the recycling of materials from

existing cars. BMW aims to reuse 80 per cent of all plastics and has been able to incorporate recycled plastics into certain components, eg luggage compartment lining, recycled bumpers. The second focus is the reuse of high-value parts from existing cars. The aim is to remanufacture high-value components such as engines, starter motors, and alternators. Remanufactured parts are sold as 'exchange parts' for 50 to 70 per cent of new product prices. The third focus is the design and modification of future cars by avoiding composite materials and marking parts and components to ease sorting tasks. Further, design for disassembly is used to allow parts to be disassembled within 20 minutes. For example, the use of two-way fasteners instead of screws and glue is being considered.

- Mercedes-Benz accepts and disassembles end-of-life Mercedes vehicles to harvest and sell spare parts to both consumers and commercial customers at a significant discount compared to virgin spare parts (Toffel, 2004).
- Companies such as Fujifilm and Kodak, which sell single-use cameras, launched a take-back programme that recycles more than 90 per cent of such cameras and reversed the product's poor environmental image (Toffel, 2004). (More on the product return strategies of Fujifilm's Quicksnap camera can be found in Grant and Banomyong, 2010.)
- Dell seeks to increase recovery rates and end-of-life products and energy efficiency by endorsing a global Electronics Industrial Code of Conduct (EICC), providing low- to no-cost convenient recovery programmes and working with the Forest Products Stewardship (FPS) initiative.
- Other cases such as Hewlett-Packard (Guide *et al,* 2005), Infosys in India (Srivastava, 2008), jet engine components (Guide and Srivastava, 1998) and cellular telephones (Jayaraman *et al,* 1999) provide good examples of the development of reverse logistics and recycling systems in different industries.

As illustrated by the Xerox case, hazardous materials are one of the major problems that reverse logistics has to deal with. CRT (cathode ray tube) and LCD (liquid crystal display) are classified as hazardous because they contain lead glasses and mercury. PCs contain printed circuit boards with heavy metals and rechargeable lithium batteries. Another major waste from electronics goods is plastics, which can be toxic when they are burned and a problem for photocopiers is the emissions of waste volatile organic compounds (VOCs) and other hazardous substances (Tischner and Nickel, 2004). There is a need for the development and dissemination of an environmental handbook for product development, and education programmes and information for employees, customers and waste managers.

Recycling

Not all products can be reused, refurbished and remanufactured. However, their materials can be recycled and recovered (for energy). It is possible to design a product recovery system to extend the life of a product or material and here recycling plays a major role – recycling is big business. To illustrate how a recycling network works, let's first examine metal recycling. Metal recycling is a £5.6 billion industry in the United Kingdom, processing ferrous and non-ferrous metal scrap into vital secondary raw material for the smelting of new metals (www.recyclemetals.org). The UK is one of the five largest metal scrap exporting countries in the world and iron and steel make up the majority of the recycled metal in the UK. In the United States, of the 132 million tonnes of metal supply, recycling contributed 67 million tonnes (http://www.doitpoms.ac.uk/tlplib/recycling-metals/what.php). Virtually all metals can be recycled into high-quality new metal. Scrap metals can be primarily recycled from:

- Packaging materials – some 2 billion aluminium and steel cans are recycled every year.
- Vehicles – over 75 per cent of a car is metal. Around half of the material processed by metal recycling shredders comes from vehicles.
- Electrical and electronics products – the industry already recycles most discarded household appliances. Electronic and telecommunications goods are significant users of non-ferrous metals.
- Batteries – the metal recycling industry recycles most lead acid vehicle and industrial batteries.

Metal recycling is a 'pyramid' industry that includes many small, family-owned companies, as well as large, international businesses. SIMS Metal Management (uk.simsmm.com) is one of the largest metal recycling companies in the UK. It focuses on non-hazardous scrap metal recycling such as end-of-life cars and metal waste from manufacturing processes, WEEE and fridges. The company recycled over 14.3 million tonnes of metal in 2011, enough to off-set carbon emissions of almost 3.3 million people (based on the average global emissions of carbon per person being almost 4.5 tonnes).

Metal recycling companies carry out a range of functions, often including several of the following activities, with smaller operators supplying partially or fully processed metals to larger operators and traders:

- Collection, weighing, sorting and distribution of metals: dealing with a wide range of suppliers, including engineering industries; small traders, such as plumbers or vehicle dismantlers; local authority collection sites; and householders disposing of domestic appliances.
- Shearing, which is required to reduce the size of large pieces of metal by cutting.
- Baling/compacting to improve ease of handling and transportation.
- Shredding of recycled materials to reduce feedstock to fist-sized lumps; and separating metals from other materials using magnets and air classification methods. A large shredder can process a car in less than 10 seconds.
- Magnetic separation to further separate any remaining non-ferrous metals using liquid density and hand or mechanical sorting methods.
- Melting is the final process, which aims to return the recycled materials into their various metal components.

In theory all metals can be recycled. Lead, zinc, copper, aluminium and steel are the most commonly recycled metals. In addition to the cost of collection and separation, the economic viability of recycling metal relies on the energy saved by reprocessing a kilogram of recycled metal, compared to the energy used to produce the same amount of metal from ores. According to the British Metals Recycling Association, energy savings due to recycling of metals are high: 74 per cent for steel, 87 per cent for copper, 63 per cent for zinc and 60 per cent for lead.

Plastics are another important material for recycling. The use of plastics as opposed to papers and other materials has always been controversial. Should supermarkets ask customers to use plastic or paper bags? As far as packaging is concerned, the use of plastics is indeed more environmentally friendly than paper. According to *Science World* (2008), the production of every tonne of paper bags consumes four times more energy than the production of plastics bags, the production of paper bags produces more air and waterborne pollution than the production of plastics bags, and furthermore, the recycling of paper consumes 85 times more energy than the recycling of plastics bags. Packaging using plastics contributes to about 63 per cent of the end-of-life quantity of wastages for products such as processed food, vegetables and fruit (PlasticEurope, 2009).

The use of plastics has increased because they are durable, strong, resist corrosion and above all require low maintenance. Plastics are used for making packaging materials, in building and construction, electrical and electronics, automotive and many other products (Wong, 2010). There are several basic types of plastics: polyethylene terephthalate (PET), high density polyethylene (HDPE), polyvinyl chloride (PVC), low density polyethylene (LDPE), polypropylene (PP) and polystyrene (PS). They are used to manufacture the following products:

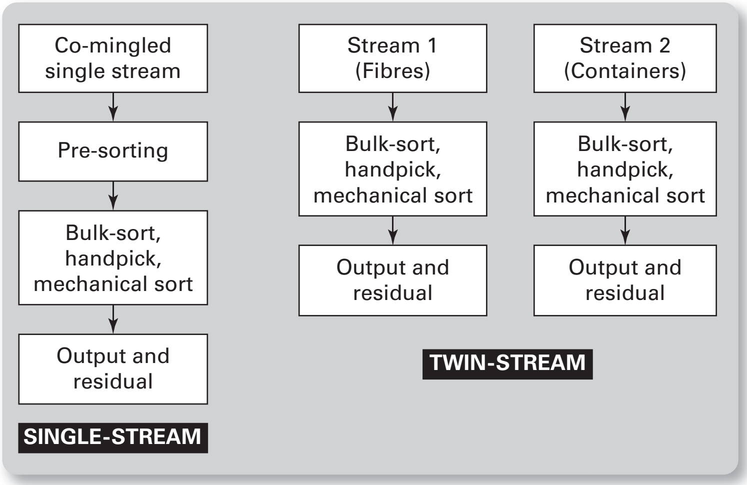
- PET is typically used to make soft-drink bottles, cooking oil bottles and peanut butter jars.
- HDPE is one of the most recycled plastics; it is used to make bottles, milk jugs, detergent bottles, margarine tubs, grocery bags, nursery pots, pesticide, and oil containers.
- PVC (or vinyl) is used to produce pressure pipes, outdoor furniture, food packaging, shrink-wrap and liquid detergent containers.
- LDPE is used to produce films or bags, bin liners, food storage containers and stretch-wrap, and to make clothing.
- PP is used in products such as yarn, fabrics, food packaging, meat trays and nursery pots.
- PS is used to make yogurt pots, egg cartons, meat trays, and disposable utensils, video cassettes, televisions, packaging pellets or Styrofoam peanuts.
- Several types of the above plastics can be combined together to make different products, such as Tupperware.

Plastic waste can be recycled by two major processes – mechanical recycling and feedstock recycling. Mechanical recycling involves melting, shredding or granulation of plastic waste. Feedstock recycling breaks down polymers into their constituent monomers, which in turn can be used again in refineries, or petrochemical and chemical production. Plastic bottle recycling (eg HDPE and PET bottles) has been quite successful but other rigid plastics composed of PP and PS are not yet widely recyclable.

Plastics recycling in the United Kingdom

In the UK, post-consumer plastics are largely collected by local authorities, and recycling of plastic bottles from households is one of their most significant solid waste collection activities. Based on responses of

FIGURE 7.3 Household recycling in the UK



380 local authorities in the UK, WRAP (2008b) reported that 525,300 tonnes of plastic bottles were consumed in households throughout the UK in 2007 and the total quantity of plastic bottles collected was 181,887 tonnes. That means 35 per cent of plastic bottles consumed by households are collected. Since there has been a considerable increase in the total quantity of plastic bottles collected since 2007, mainly due to the increasing number of local authorities offering plastic bottle collection, the percentage of plastic bottle collection is expected to rise.

In some European countries, plastic bottles are collected by retailers. In the United Kingdom, plastic waste is not managed by retailers and manufacturers of products. Local authorities typically collect dry recyclables from households using kerbside collection schemes and 'bring' schemes. Figure 7.3 illustrates how the single and twin-stream collection schemes work. For the kerbside sort collection scheme, householders are asked to sort recyclables into different groups. If it is difficult to get households to do the sorting, local authorities will then offer two collections systems. A single-stream system collects or co-mingles all dry recyclables in one container/vehicle. Co-mingled dry recyclables are then sorted and washed manually and/or mechanically. In some instances pre-sorting is required. In a twin-stream system there are two co-mingled containers, usually one of co-mingled fibres (paper, card, etc) and another for bottles (HDPE, PET bottles, etc). It is possible to avoid pre-sorting and cross-contamination between fibre-based materials and containers in a twin-stream system.

A study of the cost of different collection schemes by WRAP (2008c) indicated that the net cost of twin-stream co-mingled collections was similar to the net cost of a kerbside sort scheme. A kerbside sort scheme potentially has a lower cost than a single-stream scheme, taking into account the sales of recovered materials. There is no systematic advantage for one recycling system for the 'urban' and 'rural' nature of the areas served.

The UK's local authorities use different plastic bottles collection schemes. In 2007, approximately 147,450 tonnes (81 per cent) of plastics were recovered through kerbside collections, an increase of 77 per cent on 2006. In 2007, 14.4 million households were given kerbside collection services by 304 local authorities (WRAP, 2008b). Other collection schemes such as the 'bring' scheme are less popular. At the moment the main reason for not having a kerbside collection scheme for plastic bottles is lack of spare compartments in kerbside collection vehicles. Due to cost pressures, local authorities prefer to use a single vehicle to collect as many types of waste a possible, but the need to collect plastic bottles and other plastic waste separately would mean investment in new vehicles and added cost. Another reason for the lack of investment in plastics collection schemes is the focus on heavier materials to hit recycling targets set by central government. Recycling targets are set in terms of tonnage and plastic waste is lighter than other types of solid waste. Local authorities in the UK collected approximately 3.9 million tonnes of recyclables in 2007 of which only about 5 per cent was plastic bottles (WRAP, 2007, 2008b). That explains why local authorities complained that their plastic bottles recycling schemes were a significant additional cost to their activities.

Each UK local authority typically collected 1 to 2,562 tonnes of plastic waste each year (WRAP, 2008b). Some local authorities own and operate their own kerbside collection facilities and material recovery facilities (MRFs). Many local authorities contract sorting and baling operations to waste management companies or MRFs. Local authorities pay a 'gate fee' and 'sorting fee' for every load of waste sent to the MRFs. Gate fees are influenced by factors such as competition, landfill tax, quality and quantity of material, energy cost and size of facility (WRAP, 2008a). Some local authorities have a contract with their MRFs and use spot markets to sell their plastics. Usually the contractors sell plastics on behalf of local authorities; in some cases income from sales of plastics goes to the local authorities so contracted MRFs may not have an interest in selling the plastics at the best price. Some local authorities have revenue-sharing contracts with their MRFs and, to further encourage recycling, some local authorities pay their MRF contractors extra for any shortfall between the actual market price paid by the contractors for the recycling of sorted materials and the landfill charge. Another way to improve recycling quality is to charge MRFs extra for materials rejected from the material reprocessors. (The report about contractual arrangements between local authorities and MRF operators published by AEAT on behalf of WRAP provides more detail information about this issue; AEAT, 2006.)

Another good example of waste recycling is Germany's recycling system. Since 1991, Germany has been developing a comprehensive infrastructure called the 'Dual System', which ensures nationwide collecting, sorting and recycling of used sales packaging in densely populated cities and rural areas. A viable finance model called the 'Green Dot' gives industry an incentive to develop and produce recycling-friendly packaging and so reduce consequential ecological costs.

Source: Wong (2010)

Regulations

The effectiveness of reverse logistic and recycling systems depends partly on regulations. So far the United States does not have a national recycling law, although there is a national solid waste management law called Resource Conservation and Recovery Act (RCRA). In practice, state legislations are the main regulators for recycling in the United States.

The European Commission (EC) has been instrumental in setting up regulations driving the reverse and recycling movements in Europe. For packaging materials, EU Directive 94/62/EC of 20 December 1994 on packaging and packaging waste set targets for Member States to return/collect 60 per cent of glass, paper and board, 50 per cent of metals, 22.5 per cent of plastic, and 15 per cent of wood, by 2008. In addition to recycling, the incineration of waste for energy recovery is regarded as contributing to the realization of these objectives. Directive 2008/98/EC in 2008 further increased the targets. By 2020, preparing for reuse and the recycling of waste materials such as paper, metal, plastic and glass from households and possibly from other origins similar to waste from households, is to be increased to a minimum of 50 per cent overall by weight. In addition, the EU Landfill Directive drives the reduction of the use of landfill (Defra, 2010). Each Member State is required to reduce biodegradable municipal waste landfill by 50 per cent of that produced in 1995 by 2013, and 35 per cent of that produced in 1995 by 2020.

Both EU Directives on packaging waste and landfill are putting immense pressure on local authorities and government. In June 2008, a compromise agreement was reached between the Council of Environment Ministers and the European Parliament on revisions to the Waste Framework Directive. The main changes include EU-wide targets for reuse and recycling of 50 per cent of household waste by 2020, and for reuse, recycling and recovery of

70 per cent of construction and demolition waste by 2020. There is also a requirement for separate collection of paper, glass, metals and plastic by 2015 where this is technically, environmentally and economically practicable. A new waste framework Directive establishing a binding five-step waste hierarchy was implemented in 2008, bringing waste prevention, recycling and other recovery to the fore, with a view to achieving higher resource efficiency. The emphasis is on European Union Member States developing waste prevention programmes by December 2013, taking into account the full lifecycle of products. The following are some examples of regulations governing reverse logistics and recycling activities.

WEEE (Waste electrical and electronic equipment) Directive

- The WEEE Directive aims to reduce the amount of electrical and electronic equipment being produced and to encourage everyone to reuse, recycle and recover it. It also aims to improve the environmental performance of businesses that manufacture, supply, use, recycle and recover electrical and electronic equipment.
- A distributor may offer 'take-back' on WEEE with a fee or free of charge. In the United Kingdom a distributor will also be required to record the amount of WEEE returned in accordance with Regulation 34. Alternatively, distributors are responsible for providing information to customers directing them to their nearest recycling facility.
- Producers are required to join an approved WEEE Producer Compliance Scheme, provide arrangements for the management of WEEE and provide their registration number to distributors.
- For equipment bought after August 2005, the producer is required to finance the collection, treatment, recycling and recovery of WEEE that the purchase replaces, on a one-for-one, like-for-like basis.

EuP (Energy using Product) Directive

EuP considers energy consumption from the mining of the raw material through to recycling at end-of-life.

Batteries Directive

A new battery directive with substance restrictions and labelling requirements has a focus on reducing the number of batteries that finish up in landfill.

Basel Convention

The Basel Convention on the Control of Trans-boundary Movements of Hazardous Wastes and Their Disposal, usually known simply as the Basel Convention, is an international treaty designed to reduce the movements of hazardous waste between nations, and specifically to prevent transfer of hazardous waste from developed to less developed countries.

Increasingly, commercial companies (producers) are expected to become responsible for the lifecycle impacts of their products. In the past producers were only required to provide information about methods to recycle their products to the wholesalers and distributors, under the scheme called 'collective producer responsibility'. Some OEMs have already established voluntary product recovery schemes, ahead of the new regulation. The new Extended Producer Responsibility (EPR) programmes typically hold the producer – a single actor defined by the regulator – responsible for the environmental impacts of end-of-life products (Jacobs and Subramanian, 2009). Producers will be required to provide and pay for take-back schemes for their products (the take-back obligation); this has started to put more responsibility onto producers.

Summary

Reverse logistics and recycling are crucial for maintaining a healthy environment, not only because of the increasing scarcity of natural resources, but also because of the adverse effects of putting end-of-life products into landfill. However, due to the lack of regulatory and competitive pressure not every producer is seriously engaging in reverse logistics and recycling of their products. Not all end consumers are participating in reverse logistics and recycling, or are aware of the consequences of their throw-away habits. Due to the lack of involvement of original producers, many reverse logistics and recycling activities are carried out by the governments instead.

In recent years, due to increasing regulatory and competitive pressures, some industries have started looking into alternatives to simply allowing end-of-life products to be landfilled. More companies are now building the reverse logistics infrastructures and practices required to reduce, reuse, recycle and recover their products. Some companies embracing environmental leadership have demonstrated that it is possible to create a truly closed-loop supply chain without becoming more expensive than competitors. The regulation on extended producer responsibility will further drive investment in reverse logistics and recycling, which in turn will drive further innovation and investment. Consumers' purchasing and recycling behaviours will change when they realize they need to pay for reverse logistics and recycling of the products they dispose of.

Risk, corporate social responsibility and ethics

Background

Extending supply chains globally is an effective way to expand a customer base as well as gain access to cheaper materials and labour. However, such global supply chains are now facing greater risks and ethical dilemmas. Sometimes it is inevitable to source raw materials and products from countries facing more frequent natural disasters or man-made disruption. This can be very costly. For example, the lightning strike on 17 March 2000 that caused a fire at a local plant owned by Royal Philips Electronics, NV led to a loss of US $400 million in sales of its major customers, Telefon AB LM Ericsson (Chopra and Sodhi, 2004). Others find themselves losing billions of dollars due to negligence in managing safety. For example, the accident at an oil rig at Deepwater Horizon not only caused BP billions of dollars in legal fees, compensation and fines, but it also severely damaged its brand reputation. Since then more research has gone into establishing a more proactive approach to managing supply chain risk.

Even though economic benefits due to global sourcing and distribution are irresistible, the companies involved are facing a lot of ethical issues. This is particularly true for companies operating in countries troubled by internal conflicts and the lack of regulation to protect workers, society, children and the environment. Such problems are normally revealed by non-governmental organizations (NGOs) and create a new type of risk – 'reputational risk'.

Cases such as the use of child labour at Nike's factories in Indonesia and its suppliers' factories raise the question about who should be responsible for the welfare of the children when a company sources a product from such countries. The issues of child labour in the chocolate industry are further revealed by various reports such as the *'Schmutzige Schokolade'* (The dark side of chocolate). Issues about animal welfare have also been highlighted. For example, the 'Kit Kat Killer' campaign by Greenpeace accused Nestlé of cutting down trees causing animals such as the orang-utan to lose their habitat (see the case study on the chocolate industry, pages 186–88).

Then there are issues concerning how natural resources such as water and land should be used for whose benefit. The use of water resources by the production facilities of Coca-Cola in India raises the question about who should be responsible for the depletion of natural resources that lead to difficult living conditions for local communities. Furthermore, it is unclear who should pay for the pollution created by the part of supply chains where regulatory enforcement is rather weak. While global clothing brands make profits from the cheap clothing they source from China, Bangladesh and Indonesia, the cost of the serious pollution problems in the major rivers in these countries due to the use of chemicals by textile plants has been paid by the workers, local communities and the governments. Consequently, reports such as 'Dirty Laundry' and the 'Detox' campaign by Greenpeace (Greenpeace, 2011) are putting pressure on global clothing brands to clean up their supply chains. This is why corporate social responsibility (CSR) becomes important and managers need to understand and learn how their decisions can be more ethical.

This chapter first explains how risks in logistics and supply chains can be managed. Some of the risks originate from the markets but others are related to social, ethical and environmental issues. To better understand and manage these latter issues the chapter provides some frameworks for managing corporate social responsibility and business ethics.

Risk in logistics and supply chains

Risk can be understood from different perspectives. Potential danger, probability of occurrence, and variability of outcomes are among the key elements of risk. From a business management point of view, risk involves variability in terms of returns or outcomes of a particular decision or action. A frequently cited definition of risk in the academic literature is 'the variance of the probability of the distribution of outcomes'.

One way to understand risk in a supply chain is to identify the sources of risk, which can be atomic or holistic. Atomic sources of risk affect a limited part of a supply chain. This may involve the breakdown of a production facility for a component that will not disrupt the operations of the entire supply chain. Holistic sources of risk involve widespread disruption of a supply chain, which is a rather more complex problem facing the multiple participants in the chain.

Table 8.1 provides a comprehensive list of the different types (sources) of risk in a global supply chain. Most operations and logistics literature focuses on demand, supply and operational risks but this list also includes risks originating from parties outside of a supply chain such as policy risk, macro-economic risk, reputational risk, corporate fraud and criminal risk, and environmental (sustainability) risk. For example, the German engineering group Siemens had to pay a record level fine of US $800 million (£523 million) to the US authorities in December 2008 to settle a bribery and corruption scandal, and another €395 million (£354 million) to settle a case in Munich (*The Guardian,* 2008). In China, a China Mobile executive received a death sentence due to a bribery scandal involving Siemens. Similar risks can be found in the banking industry. Barclays Bank was asked to pay at least US $450 million to US and British authorities to settle a probe into manipulation of the key interbank lending rate known as Libor.

Reputational risk and resource (sustainability) risk are new risks facing global multinationals, especially those with famous household brands involved in serious fraud and criminal activities and causing serious health and environmental damage and social problems. Once trust with customers is broken, there is a tendency to boycott the brands, leading to a fall in market share. This is why such risk is connected to corporate social responsibility (CSR), which is a way to reduce such risk.

These are the typical five steps for identifying and mitigating supply chain risk:

1 *Identify risk* – different sources of risk (see Table 8.1) can be formally identified by a team of selected managers and experts. It may be beneficial to divide the team into those focusing on operational, supply and demand risks and those focusing on other macro external risks. It is a good practice to invite experts from outside and to gather relevant case studies from within and beyond the industry/country.

2 *Assess and evaluate risk* – the selected team can be asked to assign the likelihood (frequency of occurrence) and the consequences in

TABLE 8.1 Types of logistics and supply chain risk

Type of risk	Sources	Consequences
Demand risk	Uncertainty in demand owing to variation in demand (fashion, seasonality, new product launch), demand distortion (or Bullwhip effect).	Variation in demand could mean higher cost of inventory and obsolete inventory, and lost sales.
Supply risk	Uncertainty or disruption in supply chain owing to breakdown at supply sides, design changes, quality issues, price fluctuation, supply shortage, and shipping schedules.	This risk could lead to breakdown of production and inability to supply to customers on promised delivery dates, and escalating costs to find and expedite alternate supply.
Operational risk	Breakdown of operations, poor production planning, changes in technology, process variability, industry action (strike), accident, power shortage, etc.	This could lead to inability to supply to customers on promised delivery dates, and escalating costs to find alternate capacity.
Competitive risk	Innovation from competitor, competitor's aggressive moves (discounts, special offers, price war), competitor's influence on customers.	Innovative products or changes in buying behaviour could lead to the unpopularity of a product, with serious market share impacts.
Security risk	Infrastructure security, information security, terrorism, vandalism, crime, sabotage.	This risk could lead to the loss of sensitive data and crucial operating data, disruption of production, and employee safety.

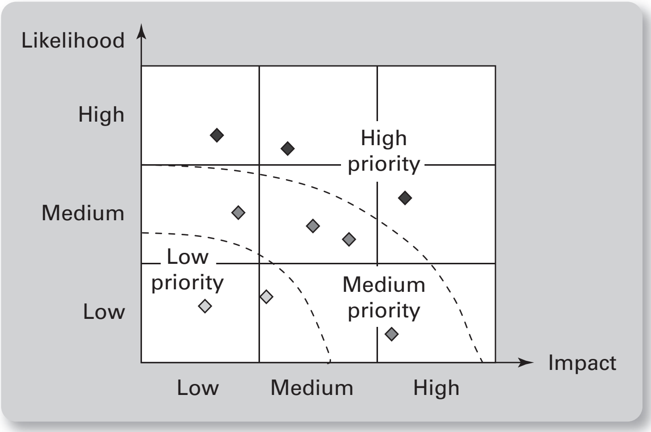
Macro-economic risks	Economic downturn, governmental financial crisis, problems in capital markets, changes in wage rates, interest rates and costs.	This risk could lead to a drop in demand and price, escalating costs, and a shortage in money supply. Although this risk cannot be avoided there are ways to anticipate its occurrence and magnitude.
Policy risk	Changes in policies by national and international governmental bodies (treaty currency, quota restriction, taxation, sanction, advertising restriction, trading licence, environmental responsibility).	This risk could lead to changes and restriction of market access, escalating costs, loss of market share, tax advantage, cost/profit from currency exchange, increased competition.
Reputational risk	Public distrust, negative customer reactions, boycott and bad brand reputation created by serious misconduct or breach of trust with customers.	This risk could lead to difficulties in getting capital, liabilities and legal penalties. Poor brand image could lead to serious loss of market share.
Corporate fraud and criminal risk	Serious fraud, bribery, corporate crime, corporate shake-up, accounting fraud, unfair/illegal trading practices, misuse of corporate finance.	This risk could lead to heavy liability and penalty costs, as well as reputational damage. It could also lead to management shake-up which further disrupts the recovery of the organization.
Resource (sustainability) risk	Shortage or depletion of rare natural resources (water, metals, minerals, trees, fish stock, farms), man-made and natural disasters; resources from politically unstable regions.	This risk could lead to escalating costs of acquiring natural resources and frequent supply shortages. Also, it creates the need to operate in regions that are politically unstable and marred by bad business practices.

terms of the impact (seriousness of damage, in financial terms if possible) of a particular risk based on past experience, historical data, case studies and external experts. The Delphi method can be used to reveal the perceptions of each member of the team. To avoid over-reliance on past events, there is a need to identify future changes in the business environment that may change the likelihood of occurrence and impact.

3. *Choose appropriate risk management strategies* – the appropriate risk management strategies depend on the types of risk, likelihood of occurrence and extent of potential damage. For supply, demand and operational risks, dual sourcing and subcontracting for seasonal demand changes are often used. For macro-economy, competitor and policy risks, environmental scanning (eg market intelligence) are appropriate. Corporate fraud and criminal risks require a robust corporate governance system. Sustainability risks cannot be addressed by a single corporation alone – industrial collaboration and multi-stakeholder initiatives with policy makers is the way forward, in addition to implementing codes of practice and governance structure. Reputational risk depends on all of the above.
4. *Implement supply chain risk management strategies* – most companies tend to create new programmes to respond to risks that had already led to serious damages. The trick is to make risk management strategies part of routine, not a separate programme. Even though sometimes it is necessary to invest in physical infrastructure as part of the risk management programmes, it is important to make sure the implementation programmes take into account the need to change the culture within the corporation. Some industries need certain levels of risk taking to be successful but there is a need to understand and clarify what types of risks are worth taking and what types of risks are not allowed.
5. *Mitigate risk and further identify risk* – the nature of risk is that it is always unpredictable, and the best way to deal with it is to create a learning culture and the ability to confront and review one's assumptions. Together with a robust risk identification process and system, this will help to respond to the damage and recover as quickly as possible – being resilient.

The assessment and evaluation of risk is one the most difficult tasks within the risk management process. One major problem is the assignment of the probability of occurrence of a risk and estimation of the potential damage, liability

FIGURE 8.1 Risk likelihood-impact graph



or cost of the risk. For example, past experience shows flooding in a factory occurred every 4 to 10 years during the monsoon session; however, the damage varied significantly. In this case there is a need to refer to the studies of weather, climate change and flood defence upgrades by the relevant agency.

Another main problem is choosing or prioritizing the types of sources of risk to be addressed. A more pragmatic approach is to use rough estimation. Another common approach is to compare the relative scores of likelihood x impact. A risk that has a high likelihood of occurrence but relatively low impact may be less critical than another risk that occurs less frequently but potentially leads to very serious consequences. Alternately, one can plot the likelihood and impact scores for each type of risk onto a risk likelihood-impact graph (see Figure 8.1).

Corporate social responsibility

The concept of corporate social responsibility (CSR) can be traced back to 1950s in the book by Bowen (1953), *Social Responsibility of the Businessman*. It was recognized that large businesses should consider what is desirable in terms of the objectives and values of society. The earlier concept of CSR argued that production should be executed so that total socio-economic welfare is enhanced. CSR is concerned with business ethics: businesses with CSR consider the ethical consequences of their actions on society. Even governmental agencies are involved in defining CSR: the Committee for

Economic Development (CED) views business corporations as 'business functions by public consent and its basic purpose is to serve constructively these needs of society to the satisfaction of society'. In the public sector literature, 'public responsibility' rather than 'social responsibility' is used to stress the importance of the public policy process and its impact on the public.

It is worth noting that CSR is not just about charity. Businesses and individuals who donate a lot of money to charity after they have acquired a lot of wealth do not necessary qualify as socially responsible. What really matters is that the money is earned in a responsible manner. To be truly socially responsible they should be meeting social objectives while they are doing business. Also, meeting social objectives mainly for the purpose of meeting legal requirements is not the same as meeting social objectives voluntarily. When social objectives are imposed on the corporation by law, it exercises no responsibility when it implements them just to meet the legal requirements (Manne and Wallich, 1972). Social responsibility is not an obligation; it is not just about responding to market forces or legal constraints. Self-regulation is always more progressive (King and Lenox, 2000). To qualify as socially responsible, a business must voluntarily allocate corporate expenditure to meet the objectives and values of society. The gradual acceptance of the importance of CSR among large corporations only started in the 1970s. The main purpose of most commercial companies in the past was 'to make as much money for their stockholders as possible', according to Friedman's (1962) view, and in the recent past large corporations were told they may engage in social responsibility, and then 'better try to do so'. Today, CSR is a must for all large and small corporations.

The reality is that businesses cannot just focus on social responsibility; they have to simultaneously consider multiple business objectives including market share, revenue, profit, competition, regulation, environment and social responsibility. To reflect this, Johnson (1971: 50) in *Business in Contemporary Society* refers to the conventional wisdom for socially responsible firms as 'one whose managerial staff balances a multiplicity of interests. Instead of striving only for larger profits for its shareholders, a responsible enterprise also takes into account employees, suppliers, dealers, local communities, and the nation'. Understandably, many businesses still consider profit maximization as their most important objective. Under fierce competition business managers have to make decisions to remain cost-effective and competitive, in many circumstances trading-off social and environmental responsibilities.

It is therefore argued that the definition of CSR should not ignore the responsibility to make profit, obey the law, and go beyond these activities

(Carroll, 1979). Based on this argument, 'the social responsibility of business encompasses the economic, legal, ethical, and discretionary expectations that society has of organizations at a given point in time' (Carroll, 1979: 500). The inclusion of economic performance in CSR reflects the responsibility to produce goods and services that society wants and to sell them at a profit. A corporation that makes money will be able to continue providing employment and pay tax to the government.

Businesses are expected to operate legally as well as responsibly. While society expects businesses to obey the law, ethical responsibility goes beyond legal requirements. Ethical responsibility is often left to individual managers' and corporations' judgement and choice, because society does not always provide clear-cut expectations. Ethical responsibility encompasses those standards, norms or expectations that reflect a concern for what consumers, employees, shareholders and the community regard as fair, just, or in keeping with the respect or protection of stakeholders' moral rights (Carroll, 1991). 'Discretionary expectation' and responsibility refer to activities that help society, such as philanthropic contributions, training the unemployed, and conducting programmes to help disabled people. This is called 'philanthropic responsibility'. Table 8.2 further provides examples of the four responsibilities.

To make sure managers take into account all these responsibilities in their day-to-day decisions, they must be embedded in the corporation's values and managerial practices. The pyramid of CSR proposed by Carroll (1979) attempts to illustrate how corporations view CSR in terms of a hierarchy of responsibilities:

- *Economic* responsibility is the foundation on which all other responsibilities rest. Economic responsibility means corporations need to be profitable.
- *Legal* responsibility is the second hierarchy of responsibility. Corporations need to obey the law because it is society's codification of right and wrong.
- *Ethical* responsibility is the third hierarchy of responsibility. It is about the obligation to do what is right and fair and to avoid harm.
- *Philanthropic* responsibility is the highest hierarchy because it is about being a good corporate citizen.

While the pyramid of CSR helps to provide new meaning to CSR, it also exposes a complicated trade-off problem. Unfortunately there has been

TABLE 8.2 Different types of corporate social responsibility

Economic responsibility	Legal responsibility	Ethical responsibility	Philanthropic responsibility
Maximize earning per share.	Comply with expectations of government and law.	Meet expectations of societal mores and ethical norms.	Meet philanthropic and charitable expectations of society.
As profitable as possible.	Comply with federal, state, and local regulations.	Recognize and respect new and evolving ethical moral norms.	Participate in voluntary and charitable activities within the local communities.
Maintain strong competitive position.	Be a law-abiding corporate citizen.	Prevent ethical norms from being compromised by other corporate goals.	Assist private and public education and improvement of the quality of life.
Achieve high level of efficiency.	Fulfil legal obligations.	Make corporate integrity and ethical behaviour beyond mere compliance with law and regulation.	
Consistently profitable.	Provide goods and services that at least meet legal requirements.		

an over-emphasis on profit maximization. Drucker (1954) suggested turning social problems into economic opportunity, economic benefit, productive capacity, human competence, well-paid jobs and wealth. Johnson (1971) perceived social responsibility as a way to achieve long-run profit maximization. The trade-off between economic responsibility and ethical responsibility is still an ongoing debate. For example, the construction of production facilities in low-cost countries makes sense because it helps access to natural resources and low-cost labour, in addition to the creation of jobs and wealth. But, if the production facilities pollute the surrounding environment, disturb the communities' access to natural resources, threaten the health of the communities, provide poor working conditions to workers and pay workers unfair wages, this can be perceived as socially unfair and ethically wrong, even though these practices are considered legal in the countries involved. To reduce such harmful impacts the cost of the production facilities would increase, and subsequently competitiveness and profitability could be jeopardized. To constantly reduce costs (materials, labour, energy, legal compliance, ethical responsibility, etc) corporations tend to move their production facilities from one location to another, leaving behind pollution, unemployment, and related social problems. This may also be perceived as ethically wrong.

The other trade-off concerns the amount of profit a corporation should make, as opposed to the amount of wages its workers and suppliers should receive. Fairtrade is an example where large corporations pay at least the Fairtrade minimum price to Fairtrade certified producers. This price aims to cover the costs of sustainable production for the producer. It's a safety net for the producers when market prices fall below a sustainable level. When the market price is higher than the minimum price, corporations must pay the market price. Producers are able to negotiate better prices based on factors such as quality. We have seen the emergence of a range of Fairtrade products including fruit, vegetables, tea, coffee, fruit juice, beverages, chocolate, confectionery, cotton, beauty products and even gold.

There is emerging pressure on some electronics manufacturers, who are accused of making very large profits while paying the lowest possible amounts to workers and suppliers from low-cost countries. As with the questionable roles of exporters and traders in the chocolate case study, people have started to ask the question – who actually adds value and who gets (fairly) paid?

Sustainability and corporate responsibility issues in the global chocolate industry

To understand the issues of sustainability and corporate responsibility facing the chocolate industry, we need to trace the supply chain of cocoa beans from the farms where they are grown. Cocoa is the main ingredient for making chocolate. One kilogram of cocoa beans produces approximately 40 bars of chocolate. Cocoa trees can be best grown in countries within 10° south and 10° north of the equator. Eighty five per cent of the world's cocoa tree plantations are on farms of less than two hectares with average production of around one tonne per year (Fold, 2001); global production is 4 million tonnes per year (www.fao.org). Africa (countries such as Ivory Coast, Ghana, Nigeria, Cameroon) remains the world's leading cocoa growing area. Indonesia, Brazil, Ecuador, Dominican Republic are other large plantation countries.

Chocolate production starts with harvesting cocoa. The seed pods of cocoa will first be collected manually and transported to the nearby processing sites. Each pod may contain up to 50 cocoa beans. They are collected by splitting open the pods and the beans are selected and placed in piles. They are placed in trays or covered with large banana leaves to undergo fermentation for five to eight days. During this process the beans turn brown. They are then dried and packed into sacks ready for selling/shipping. Until this stage, cocoa beans are largely processed by small growers. Due to the lack of volume, market knowledge and finance, most growers are incapable of selling cocoa beans to the producer directly. Large exporters such as Cargill, ADM and Sal-Cacao are responsible for sourcing and washing of cocoa, and sell the cocoa to the exchange market.

The remaining processes of cocoa bean production are predominantly undertaken in Europe and North America; the Netherlands and the United States are the leading countries and Ivory Coast is becoming a major producer. Typically most cocoa processing factories use machines to break down the cocoa beans into cocoa butter and chocolate in a process called 'grinding'. During this stage cocoa beans go through winnowing and roasting processes and are heated and melt into chocolate liquor. Sugar and milk are added, then blended together with the chocolate liquor. There are millions of cocoa growers, but 10 cocoa processors (mainly multinational companies) dominate about 70 per cent of the grinding process (www.fao.org). It is important to note that some processors source cocoa directly and trade cocoa as well. The liquid chocolate is stored or delivered to the chocolate companies (Kraft Foods, Ferrero, Mars, Nestlé, etc) by tankers where flavouring, moulding and packaging of the chocolates will take place.

Child labour is the major problem facing the chocolate industry. Responding to the problem, the main chocolate producers signed the 'Harkin-Engel-Protocol' in 2001 (World Vision Australia, 2011). This was a voluntary commitment that addressed the problem of forced child labour in West Africa and aimed to implement standards of public certification that cocoa had been grown without any of the worst forms of child labour by July 2005 (Chocolate Manufacturers Associations, 2001). This deadline was not met and a second deadline (2008), was again not met. Failing to meet these deadlines has resulted in a loss of trust between the chocolate companies and their stakeholders, and has attracted the attentions of the media and NGOs (see '*Schmutzige Schokolade*').

In fact, the chocolate industry has made some progress in addressing the child labour issue. Cadbury and Nestlé in the United Kingdom have begun certifying their Dairy Milk and Kit Kat bars as Fairtrade. Mars has announced its plans to use only sustainable cocoa for its products by 2020. Barry Callebaut, the world's largest chocolate producer, also announced it would focus more on certified Fairtrade products. However, Fairtrade chocolate accounts for only around 1 per cent of the global chocolate market.

Another critique of cocoa production concerns the lack of ecological sustainability: the expansion of land used by farmers had led to monocultures, and this has been identified as the principal driver of the deforestation of the Guinean Rain Forest (GRF) of West Africa (Gockowski and Sonwa, 2010). The famous 'Kit Kat killer' video clip produced by Greenpeace clearly highlights this issue. Today, the environmental sustainability of the chocolate industry is still an unresolved problem. The sustainability challenge facing the chocolate industry is very similar to other industries which involve farming and mining. Basically such supply chains are controlled by large multinationals such as intermediaries, exporters, commodity exchanges, producers and chocolate companies. Like many other commodities, cocoa beans are traded in many different complex trade channels but they are grown mainly on small farms.

The cocoa exporters and traders make a lot more money than the growers but the real value they add to the supply chain is questionable. No one is responsible for the damage to the environment caused by the production of chocolate. While global chocolate companies are facing a lot of pressure, the exporters, traders and grinders are 'invisible' and they have not yet participated in efforts for a sustainable supply chain. Furthermore, they are so dominant even large chocolate companies are not able to influence or put pressure on them. The formation of cooperatives is a way to break down this power structure. Cooperatives such as 'Cacaonica' consists of 350 members, receiving prices about 50 per cent higher than the market price due to the elimination of intermediaries. However, this solution is only partial: there are many other ethical and corporate responsibility issues facing the industry. In some cocoa growing countries, illegal trafficking of child labour is a more complex problem. It takes many years to establish certified products, and the chocolate companies remain unconvinced that there is a high demand for Fairtrade certified chocolate.

Although Fairtrade appears to be beneficial to small growers, these growers are facing other more serious problems, eg security, fair and transparent legal systems, access to health and education, fair prices and timely payment, competitive wages for workers and freedom from harassment and intimidation (Thomas, 2011). These problems are not directly created by the multinationals that source cocoa beans from these regions but should they not be responsible for providing a better life and working environment for the workers?

Ethical framework and codes of conduct

Should the goal of a business be solely to maximize shareholder value or profit? How about the health and safety of society, consumer and worker? The tainted milk incident in the People's Republic of China in 2008 demonstrates the serious consequences of running a business without ethical consideration and is a perfect example of corporate social responsibility and ethical and supply chain risk.

The incident affected thousands of victims, with some infants dying from kidney stones, other suffering from kidney damage and many others being hospitalized (*The Telegraph,* 2009). Melamine, an organic-based chemical used in the production of plastics and fertilizers, was added to the milk to indicate a higher apparent protein content. It can cause kidney stones and kidney failure. Apparently, two milk dealers/middlemen sold milk containing melamine to some major dairy companies in China which then failed to test if the milk was pure and safe for human consumption. Furthermore, the chairperson of one of the dairy companies involved actually knew what was illegally added to the milk. As a consequence, several criminal prosecutions took place, with two people being executed, another given a suspended death penalty, while three others received life imprisonment, two received 15-year jail terms, and seven local government officials, as well as the Director of the Administration of Quality Supervision, Inspection and Quarantine (AQSIQ) were forced to resign. Over 20 companies implicated in the tainted milk were ordered by the Chinese government to pay a total of

1.1 billion Yuan (US $161 million; £97.5 million) to hundreds of thousands of consumers involved (*The Telegraph*, 2009).

To be truly ethically responsible there is a need to understand the concepts of business ethics and morals. Ethics is generally defined as the 'inquiry into theories of what is good and evil and into what is right and wrong, and into what we ought and ought not to do' (Beauchamp and Bowie, 1983: 3). It is about what constitutes good and bad human conduct, including related actions and values (Barry, 1979). The main tools we need are guiding principles.

There are many ethical theories and here are some that may be useful for business managers. The first group, called consequential theories, urges managers to examine the consequences of their decisions and actions (Tsalikis and Fritzsche, 1989). The consequential theories (egoism) argue that an act is ethical when it promotes the individual's best long-term interests. If an action produces a greater ratio of good to evil for the individual in the long run than any other alternative, then that action is ethical. The consequential theories (utilitarianism) suggest that we should always act so as to produce the greatest ratio of good to evil for everyone. This perspective emphasizes the best interests of everyone involved with the action. The main problem is that every individual has different views on what is good and evil, who is everyone and how long is long term.

Alternately, there are theories that do not consider the consequences of the decision/action made by an individual (Tsalikis and Fritzsche, 1989). They are called non-consequential theories:

- The single rule of non-consequential theories (golden rule) can be represented in the commonly accepted axiom – do unto others as you would have them do unto you. The main guiding principle is to treat others the way we would want to be treated.
- Single-rule non-consequential theories (Kant's categorical imperative) suggest that only when we act from duty do our actions have moral worth; we should act in such a way that we could wish the maxim or principle of our action to become a universal law.
- Rawl's principle of justice suggests that each person participating in a practice or affected by it should have equal right to the greatest amount or liberty that is compatible with a like liberty for all.
- Ethical relativism argues that moral principles cannot be valid for everybody, and people ought to follow the convention of their own group.

In addition, there are theories suggesting the need to look at consequences as well as the rules, social norms and social obligations that decision makers ought to follow. Multiple-rule non-consequential theories argue that it is necessary to introduce consequences into ethical decision making but consequences alone do not make an act right. There are duties and obligations that bind us morally. Managers should be aware of the most obligatory duties (eg not to lie, gratitude, justice, beneficence, self-improvement, non-injury). Garrett's principle of proportionality (Tsalikis and Fritzsche, 1989) suggests that any moral decision involves three elements: what we intend, how we carry out the intention, and what happens (intentions, means, and ends). In additional to legal sanctions, business people should consider the impacts of their actions on their integrity and professionalism. A business person may have the duty to maximize profit and, at the same time, be obliged to refrain from injuring people.

The terms 'ethics' and 'moral' are often used interchangeably. Taylor (1975: 1) defines ethics as an 'inquiry into the nature and grounds of morality'. According to DeGeorge (1982: 13–15), morality is used to cover those practices and activities that are considered importantly right and wrong, the rules which govern those activities, and the values that are embedded, fostered, or pursued by those activities and practices. From a morality perspective there are three kinds of business managers – immoral, amoral and moral:

1. *Immoral managers* are those whose decisions, actions and behaviour are opposed to what is deemed right or ethical. Such managers actively ignore what is moral in their decisions. Often, they care only about the profitability and success of their organizations or themselves and they prioritize gains for the management group over even the shareholders. They see legal requirements as barriers that restrict their achievement of economic goals. Their strategy is dominated by the exploitation of opportunities for personal or corporate gain. The tainted milk incident above provides a good example of the behaviour of such managers.
2. *Amoral managers* are neither moral nor immoral. They are simply insensitive to the moral obligations of the decisions they make. They lack ethical perception or awareness and they often choose to meet only the minimum legal requirements. Some of these managers may become amoral unintentionally: they may have good intentions but their decisions and actions could harm others. There are also those who choose to be amoral intentionally because they believe ethical considerations are for private life, not for business. The selling of

alcohol and cigarettes without providing adequate warning to consumers is an example of the behaviour of intentionally amoral managers. They believe it is the consumers who should be responsible for the way they consume the products they chose to buy.

3 *Moral managers* are those who adhere to high levels of ethical norms. Moral managers aim to be profitable while meeting legal requirements and ethical norms. They conform to high levels of professional conduct and apply sound ethical principles such as justice, rights and utilitarianism to guide their decisions. They prioritize short- and long-term shareholder interests and treat all stakeholders fairly and ethically. To achieve this they demonstrate true commitment by establishing an ethical and responsible culture throughout the whole organization using ethics committees, codes of conducts and other management practices. They also provide leadership on ethical issues at the organizational and industrial levels.

To reduce immoral and amoral managers and to create more moral managers, corporations need to embed social responsibility, environmental responsibility and ethical culture into their organizations and their suppliers' organizations. Many commercial and non-commercial organizations and industrial associations have now developed their own ethical codes or codes of conduct. Codes of conduct comprise business principles a corporation expects its employees (and suppliers) to follow and may cover:

- *Labour practices* – employment (no forced labour, terms for termination), child labour, living wages, working hours, working condition, health and safety, medical care, discrimination, human rights, gender equality, training, etc (one may refer to the ILO's labour principles for multinationals – the 'Tripartite Declaration of Principles concerning Multinational Enterprises and Social Policy').
- *Corporate governance* – mutual respect, honesty, integrity, political contributions, charitable donations, legal compliance, bribery, corruption, fair competition, money-laundering, working with governments and suppliers, conflicts of interest, executive pay and bonuses, management of shareholder assets, confidentiality, share market trading rules, environment and safety, reputation, etc (eg refer to Siemens' compliance system at http://www.siemens.com/).
- *Supplier practices* – supplier responsibilities including contractual, labour, health and safety, environment and society, legal

compliance, transparency, reporting, confidentiality, etc (see the case study about the electronics industry in this chapter).

- General morals and ethics – honesty, integrity, professionalism, mutual respect, collegiality, fairness, justice, legal compliance, etc.

Codes of conduct cannot be effective if the top management teams are unable to demonstrate real example and commitment by putting effort into any necessary changes in culture within businesses and industries. Top management teams need to redefine the vision and mission of the corporates by incorporating profit, people and planet (3Ps) or economic, environmental and society issues (triple bottom line). These have to be filtered down to business objectives and targets with well-defined performance measurements for each metric, and there is a need to train employees to engage in moral reasoning, and create a corporate culture in which ethical behaviour is both encouraged and rewarded. All these can increase the likelihood that a company's employees with act ethically. The following case study demonstrates how a company attempted to implement this new paradigm.

The Green Cargo story

Green Cargo (www.greeencargo.com) is an international logistics company. The company has about 2,800 employees in over 100 locations throughout the Nordic region and Europe. It provides mainly rail-based logistics for business in the Nordic region. Most of its revenue is generated from rail-based freight, and electric-powered vehicles. About one-fifth of its revenue is generated from road transportation and third-party logistics services. As a transport company, environmental impact and social responsibility are two important issues. In addition, Green Cargo's business concerns many stakeholders: customers, employees, trade unions, suppliers, partners, government agencies, organizations, municipalities, neighbours and the media.

The core value of Green Cargo is sustainable development, reflected in its value statement: 'We should pervade everything we do: our products, our means of expression, the treatment of our customers and our conduct towards each other as employees.' To truly demonstrate commitment in social and environmental responsibility, the company has defined three routes (scoreboard) towards sustainable development:

1 *Profitability* – measured in terms of finance (operating result, cash flow, return on capital, debt/equity ratio, cost per unit, efficiency) and customer performance (arrival reliability, customer index, availability).

2 *Social concern* – measured in terms of employee (employee index, sick leave), safety (safety index, accident cost) and society performance (impacts on society).

3 *Environmental performance* – measured in terms of environmental performance (carbon dioxide, energy consumption, environmental image).

Having set targets for these performance metrics the company developed several action programmes in 2002 and 2003. The goals included the improvement of financial results through increased revenues and reduced costs. However, this also meant staff needed to increase revenue through intensified sales operations such as offering road-based and third-party logistics services to the rail-based customers, and vice versa. If not carefully managed, this could potentially increase the emission of carbon dioxide and non-renewable energy consumption.

To reduce operating costs, the company focused on cutting administrative costs through coordination and centralization. Next, it optimized road-based operations through increased usage of vehicles and a viable balance of owned and leased vehicles. To achieve efficient use of fuel and assets they established a Full Load Centre. The entire Green Cargo road-based operations were reviewed in terms of cost-effectiveness, customer needs and environment. The company also attempted to optimize its production resources through train 'pathing' and shunting to even out the 24-hour traffic flow and reduce production peaks. It attempted to fill more wagons by mapping out the empty wagon flow to identify business opportunities on sections running empty.

Constant attempts to improve the scoreboard made a big contribution to the success of the action programmes. Performance measurements and key ratios have been integrated into targets at business unit level, and activities that can lead to target fulfilment are defined in a clearer and more specific manner. Improvements in one target area have knock-on benefits for other areas and spur on the entire company to further efforts.

In terms of implementation, there is a need to fine-tune procedures for reporting, follow-up and controlling the decision-making processes. There is also a need for a continuous improvement culture, in addition to the action programme. Such a culture makes for further improvement and fine-tuning of procedures and tools for reporting, follow-up and control. This helps to shape guidelines for financial control within Green Cargo and the role of every business unit in the drive to achieve long-term sustainable profitability.

Global and industrial initiatives

While corporations learn to establish and implement codes of conduct and embed a CSR culture, one can learn from multi-stakeholder initiatives and broad-based alliances at industrial and global levels. For example, the Global Compact is an initiative of the UN Secretary General that promotes corporate responsibility by seeking to advance universal values. The underlying objective of the Global Compact is to enhance economic progress, foster corporate responsibility, global citizenship and institutional learning in addressing a variety of present day issues. By its efforts, the Global Compact creates a common forum for enterprises, labour and civil society organizations with the aim of expanding the benefits of economic development as well as limiting its negative impacts.

Global Compact provides business with the challenge to adopt and apply 10 universal principles in the areas of human rights, labour and the environment and to integrate these principles into daily practices and management systems. The principles are based on the UN Universal Declaration of Human Rights, The International Labour Organization's Declaration on Fundamental Principles of Rights at Work, and the Rio Principles on Environment and Development. The 10 principles, shown below, have been adopted by various organizations as the basis for their ethical frameworks:

1. Businesses should support and respect the protection of internationally proclaimed human rights.
2. Businesses should make sure that they are not complicit in human rights abuses.
3. Businesses should uphold the freedom of association and the effective recognition of the right to collective bargaining.
4. Businesses should support the elimination of all forms of forced and compulsory labour.
5. Businesses should support the effective abolition of child labour.
6. Businesses should support the elimination of discrimination in respect of employment and occupation.
7. Businesses should support a precautionary approach to environmental challenges.
8. Businesses should undertake initiatives to promote greater environmental responsibility.

9 Businesses should encourage the development and diffusion of environmentally friendly technologies.

10 Businesses should work against corruption in all its forms, including extortion and bribery.

Another new initiative concerns the disclosure of social and environmental impacts of a company's activities. Back in the 1980s the financial sector initiated a Social Investment Forum (SIF) to incrementally reform the existing economic system towards greater social responsibility through broad-based collaboration and alliance among investors, non-governmental environmental organizations, labour unions, etc. One of the initiatives of SIF was to develop, in partnership with environmental activist organizations, explicit codes of environmental conduct for industry, and ask companies to formally endorse them and report their performance on a regular basis. Some of the SIF activities later contributed to the establishment of the Global Reporting Initiative (GRI).

The GRI is a non-profit organization that promotes economic, environmental and social sustainability. GRI (www.globalreporting.org) aims to harmonize, standardize, clarify and unify practice of non-finance reporting, and to empower various societal actors, by ways to access to relevant information, to use market and political mechanisms to demand from companies a certain level of accountability. GRI provides all companies and organizations with a comprehensive sustainability reporting framework that is widely used around the world. In the United States, other reporting initiatives such as the Public Environmental Reporting Initiative (PERI) and Global Environmental Management Initiative (GEMI) are used. Websites such as Accountability (www.accountability.org.uk) and CSRwire (www.csrwire.com) provide links to many corporations' CSR reports and case studies. There are also carbon disclosure initiatives focusing on reporting carbon emission. Such reporting initiatives can be beneficial to the companies as well as the public when there are clear guidelines on stakeholder inclusiveness, sustainability context, completeness and report quality (including balance, comparability, accuracy, timeliness, reliability and clarity). They can also be used as part of a company's corporate responsibility strategy, management approach and performance indicators.

The Global Compact 10 principles and reporting principles can be adopted by companies on a voluntary basis. There is no regulation covering all the principles as such. For companies truly serious in achieving sustainability leadership there is a need to develop integrated management systems and processes for sustainable development. For example, the 10 Ceres Principles (www.ceres.org) not only take into account the principles on human rights and sustainable natural resources, but also highlight the need for disclosure, management commitment, audits, reporting, and reducing the environmental, health and safety risks to their employees and the communities. The international non-governmental organizations (INGOs) are also contributing to the development of codes of conduct for different industrial sectors, in addition to balancing the power between corporations and non-governmental or public interests. Instead of purely providing awareness and public education, and engaging in lobbying and adversarial actions, INGOs work in partnership with companies to create initiatives such as Marine Fisheries Councils, Rainforest Alliance, and many others. Many companies are participating in some of these initiatives to develop their codes of conduct and improve their sustainable performance.

When it comes to supply chain risks and sustainability issues originating with suppliers, there are a lot of new approaches. Demanding that suppliers obtain certifications (eg ISO 14001) is an example; demanding they implement codes of conduct is another. This, followed by training and collaboration with suppliers, can help mitigate risks and/or address sustainability issues.

Suppliers' codes of conduct in the electronics industry

Global electronics original equipment manufacturers (OEMs) have traditionally sourced the production of components from manufacturers in various countries. Health, safety and working conditions are critical issues for companies such as Hewlett-Packard (HP), Apple, etc. Even though such companies have codes of conduct their social and environmental performance targets cannot be achieved without the involvement of their suppliers. The electronics industry's Electronic Industry Code of Conduct (EICC) was developed by, among others, Dell, Hewlett-Packard (HP), International Business Machines (IBM) and the electronic manufacturers Solectron, Sanmina-SCI, Flextronics, Celestica and Jabil.

This case study illustrates how HP implements the EICC to ensure that working conditions in the electronics industry supply chain are safe, that workers are treated with respect and dignity, and that business operations are environmentally responsible. The HP Suppliers Code of Conduct is based on the EICC and is independently maintained and updated to reflect HP standards and supplier operations. The scope of the codes is very wide – all suppliers involved in HP's manufacturing processes or in manufacturing HP's products, packaging, parts, components, sub-assemblies, and materials, or that provide services to or on behalf of HP, must comply with the EICC. It also applies to a contingent worker – a non-HP employee performing services at the direction of his or her respective employer for or on behalf of HP. The code is made up of five sections:

> *Section A:* Labour including freely chosen employment, child labour avoidance, working hours, wages and benefits, human treatment, non-discrimination, freedom of association, etc.
>
> *Section B:* Health and safety including occupational safety, emergency preparedness, occupational injury and illness, industry hygiene, physically demanding work, machine safeguarding, sanitation, food and housing.
>
> *Section C:* Environmental including environmental permits and reporting, pollution prevention and resource reduction, hazardous substances, wastewater and solid waste, air emission, product content restriction, etc.
>
> *Section D:* Ethics including business integrity, no improper advantage, disclosure of information, intellectual property, fair business, advertising and competition, protection of identify, responsible sourcing of minerals, privacy, non-retaliation etc.
>
> *Section E:* management system including company commitment, management accountability and responsibility, legal and customer requirements, risk assessment and risk management, improvement objectives, training, communication, worker feedback and participation, audits and assessment, corrective action process, documentation and records, supplier responsibility, etc.

HP provides training on the codes to its suppliers, and expects them to train their suppliers in turn. Suppliers are expected to sign a supplier social and environmental responsibility agreement with HP. Basically, suppliers are responsible for identifying any areas of operations that do not conform to HP's Supplier Code of Conduct and HP's General Specification for the Environment and for implementing and monitoring improvement programmes designed to achieve those requirements. HP may request suppliers to submit a report describing actions taken and progress made and suppliers may be required to perform a self-assessment of their practices against the five sections of the codes. HP requires access to supplier's relevant records insofar as they relate to supply contracts, to verify information provided in the supplier's report. HP in turns promises to use the reports and records only for assessing the suppliers' progress in accordance with HP's codes.

The EICC Group further established a partnership with the Global eSustainability Initiative (GeSI) in 2005, which represents information and communications technology (ICT) companies in Europe, North America and Asia. The partnership was formed to develop common implementation tools for supply chain management and broaden the impact of this collaborative effort. With this technology it is now possible for electronics OEMs to perform supplier risk assessment and self-assessment, apply a common audit methodology and use a web-based platform to facilitate efficient and transparent information sharing among participants.

Supplier auditing is important in the electronic industry. The following example of Apple's approach illustrates how the audit may be conducted. Normally, an Apple auditor leads every on-site audit, supported by local third-party auditors who are experts in their fields. These experts are trained to use Apple's auditing protocol and assess requirements specified in Apple's supplier codes of conduct. There are annual audits for final assembly manufacturers and additional audits for suppliers posting certain risk levels. The auditors examine records, conduct physical inspections of manufacturing facilities, and evaluate management policies and procedures. The audits also take into account feedback from the community. There are surprise audits. Great emphasis is put on the correction and prevention of any violation of the supplier codes. Core violations such as involuntary labour, falsifications of audit materials, worker endangerment, intimidation or retaliation against workers participating in an audit, and significant environmental threats, could lead to termination of contracts and relationships with the suppliers involved.

In addition, Apple reports its environmental footprint. The total environmental footprint considers manufacturing, transportation, product use, recycling and facilities. Apple applies comprehensive lifecycle analysis to determine where its GHGs come from. The mapping of GHGs points to the need to address the manufacturing and product use processes. Manufacturing processes, including extraction of raw materials and product assembly, account for over 60 per cent of the total GHGs, so a lot of collaboration with suppliers is required to address this issue.

Summary

Globalization means supply chains are facing greater risk and ethical dilemmas. New types of risks such as reputational and resource (sustainable) risks are becoming more critical. There is an emerging realization that the types of businesses seen as desirable by society are those which are responsible for the shareholders, stakeholders, society and the environment. The public has started to realize the consequences of natural resource depletion. Companies are increasingly finding themselves competing for scarce resources. There are plenty of examples of companies being punished by government and legislative authorities, NGOs and customers for being negligent in taking care of health, safety, society and the environment. Companies realize that the pursuit of profits has to be balanced with the needs of society and the sustainability of the environment.

Even though some industries choose to create their own codes of conduct voluntarily, progress is not always satisfactory. One of the main obstacles is that companies tend to see regulations as a cost. Many managers see making money as their main job and few companies see corporate responsibility and sustainability as a means to achieve sustainable competitive advantage. Most managers still see damage to the environment from their supply chain activities as a reputational risk that could eventually reduce profitability, but do not appreciate that such damage will eventually make the supply chain or business unsustainable. Incentives, regulations and pressure from NGOs do push industries forward. However, when social responsibility is not viewed only as an obligation but as part of the values of a corporation, great progress can be made. Without such values, codes of conduct and regulation would not make much difference.

Sustainable logistics and supply chain management strategy

09

Concepts of corporate strategy

Corporate strategy is defined as 'the direction and scope of an organization over the long term which achieves advantage for the organization through its configuration of resources within a changing environment, to meet the needs of markets and fulfil stakeholder expectations' (Johnson and Scholes, 1999: 10). It is accepted wisdom that if managers do not understand corporate strategy, they will be unable to make decisions that are consistently in the best interests of the firm as a whole. Thus, a corporate plan will always need to be developed to execute strategy and monitor progress against objectives.

Corporate plans usually contain three hierarchical levels. At the uppermost level a firm's *strategic* plan considers its overall corporate mission objectives, service requirements, and how management intends to achieve its mission over the long term, ie greater than five years. This plan is very general and usually includes projected revenues and expenses, markets to enter or leave, lines of business or strategic business units (SBUs), expected relative share of business within the market, and sales and profits from existing lines of business compared to new lines.

At the next level a *tactical* plan is often more specific in terms of product lines and may be broken down into detailed quarterly revenues and expenses. A tactical plan usually has a time horizon of one to five years and should include a capital expenditure plan to indicate how much the firm will invest each year in new plant, equipment and other capital expenditure items.

Finally, the most detailed and lowest level plan is the *operating* or annual plan. This plan breaks out revenues, expenses, associated cash flows and activities by month for a one-year period. The operating plan is derived to guide the firm for the following year. Actual performance is monitored and compared to planned performance to anticipate problems and respond accordingly, and to communicate results to the firm's management.

The strategy planning process allows firms to develop their strategic, tactical and operational plans and consists of three elements: an analysis of its current situation, the implementation of its strategic choices, and its control and feedback mechanisms to ensure its strategy is working successfully. The current situational analysis involves the firm considering its internal strengths and weaknesses and its external opportunities and threats, and is commonly known as a SWOT analysis. The external analysis also requires consideration be given to the following environments: political, economic, social technological, and legal, commonly known by its acronym PESTL. However, as noted in Chapter 2, firms are now giving more consideration to the natural or ecological environment; this aspect is included in the mix of external environments and the acronym has been amended to PESTLE. This analysis is often referred to as the 'where are we now' stage in the planning process.

After a situational analysis the firm will develop various strategic, tactical and operational options for its business; these comprise 'where are we going' and 'how do we get there' stages in the planning process. The firm then selects those options that best meet its selection criteria, which include return on investment, risk, and access to financial and non-financial resources, eg labour or human resources. Finally, the firm will implement these options and monitor and control its three plans to address the 'are we on course' stage of the planning process.

Much academic and practitioner work has been done on corporate strategy, and strategic theories are replete in the literature including examining competition through the threats of new entrants or substitutes, or the bargaining power of customers or suppliers, considering product or SBU strategies relative to potential market growth rates and a firm's relative market share, and focusing on low-cost leadership or market differentiation (Johnson and Scholes, 1999; Porter, 1980). An example of strategic, tactical and operational options related to the three major logistics and SCM activities of

TABLE 9.1 Example of corporate strategy plans in logistics and SCM

Activity	Strategic	Tactical	Operating
Transportation	Choosing transport modes	Re-drawing warehouse delivery areas	Undertaking load planning or container fill decisions
Warehousing	Selecting the number, size and locations of warehouses	Redesigning internal warehouse layouts	Undertaking individual order picking and packing
Inventory management	Choosing a replenishment system and IT support	Adjusting safety-stock levels based on supplier risk profiles	Fulfilling individual orders

transportation or 'Go' and warehousing and inventory management or 'Stop' is given in the matrix in Table 9.1.

Natural environmental concerns or criteria related to the activities in Table 9.1 include the effect of different transportation options on emissions, fuel use and road congestion, energy use, emissions and land use related to warehousing and inventory management options. The complexity of these concerns or criteria is noted in the following box. Such complexity leads to a debate as to which concerns are the most important from both a firm's and the natural environment's perspective. Further, firms need to know if there are existing frameworks or tools to evaluate these concerns properly.

Strategic sustainable choices for container shipping lines

The growth of container shipping over the past 30 years has meant an increase in non-sustainable activities. What are some of the strategic choices and hence trade-offs facing shippers and ocean shipping lines as they endeavour to become more sustainable? Sustainability here means reducing the amount of CO_2 emissions from shipping activities, both in port and on the high seas, and which results from shipping fewer numbers of containers, increasing container fill, shipping containers more efficiently and reducing movements and amendments, slow steaming, and switching fuels to lower sulphur diesel.

McKinnon (2012) argued that by packing more products into containers shippers could reduce the number of container movements and related CO_2 emissions. The pressure to minimize shipping costs would also give these firms a strong incentive to maximize fill. However, there are virtually no statistics in the public domain on the weight or cubic container (or cube) utilization of deep-sea containers.

McKinnon surveyed 34 large UK shippers and found that inbound flows into the United Kingdom were of predominantly low density products bound for retail stores that 'cubed-out' before they 'weighed-out;' ie 46 per cent of respondents importing containerized freight claimed that 90–100 per cent of containers received were 'cubed-out'. On the other hand, weight restrictions were more of a problem for UK exporters with 25 per cent of respondents reporting that 90 per cent or more of outbound containers were weight constrained, with 33 per cent of respondents 'weighing-out' with more than 70 per cent of their containers. However, the composition of McKinnon's sample reflected a huge imbalance in UK deep-sea container trade, with inbound containers outnumbering exports five to one. Thus, market flows inhibit the ability of shipping lines and customers to be more efficient in this area.

McKinnon also found that only around 40 per cent of the shippers have so far measured the carbon footprint of their deep-sea container supply chains, with just 6 per cent implementing carbon-reducing initiatives. The firms surveyed also assigned a relatively low weighting to environmental criteria in ocean carrier selection. So, while many shippers have the means to influence the carbon footprint of their maritime supply chains, the survey suggested that they are not currently using them explicitly to cut carbon emissions.

However, many of the measures that the UK shippers and their ocean carriers are implementing to improve economic efficiency, most notably slow steaming, are assisting carbon mitigation efforts. Slow steaming involves reducing the speed of a ship while at sea to reduce engine load and emissions. Slow steaming was mooted by the Maersk Line as a response to the 2008 economic recession as the spot-market price it received in late 2008 for shipping containers from Asia to Europe or North America was around US $500 below its operating costs (Kolding, 2008). The relationship between ship speed and fuel consumption is non-linear and Maersk Line calculated that by redesigning their shipping schedules, using nine ships instead of eight to ensure customer volumes were handled, and slowing their vessels' sailing speeds from 22 knots to 20, they could reduce annual fuel consumption from 9,500 to 8,000 metric tonnes (Mt) and thus also reduce carbon emissions by 17 per cent from 30,000 to 25,000 Mt of CO_2. Maersk Line was also looking to make client processes more efficient as it had to make 1.6 million shipping amendments per year at that time; 80 per cent were due to client requests including booking cancellations of 20 per cent per year.

Finally, sulphur emissions as part of overall shipping-related particulate matter emissions are a problem for ships in port (Corbett *et al*, 2007). Around 18 shipping lines signed the Fair Winds Charter (FWC) in 2010, which is an industry-led, voluntary, unsubsidized fuel-switching programme for ocean-going vessels calling at Hong Kong. The shipping lines are using fuel of 0.5 per cent sulphur content or less; but, if they all switched to the cleanest type of fuel available with 0.1 per cent sulphur, SO_2 emissions would drop by 80 per cent. In return, ship operators get a 50 per cent reduction on port and navigation charges if registered vessels switch to burning low-sulphur diesel while berthed or anchored in Hong Kong. However, low-sulphur diesel is about 40 per cent more expensive than more heavily polluting marine 'bunker' diesel and the scheme only covers between 30 and 45 per cent of this higher cost. Thus, while shipping companies including Maersk Line, Orient Overseas Container Line (OCCL), Mitsui OSK Lines and Hyundai Merchant Marine have registered fleets of 10–90 ships, other cost-conscious carriers have been more reticent. APL and Hanjin Shipping were among the firms that signed the Fair Winds Charter, but neither has registered any ships with the incentive scheme.

Thus corporate strategic decision making for shippers and ocean shipping lines is not easy when it comes to sustainability in the face of thin profit margins, rising fuel and other operating costs, and global economic uncertainty.

Sources: Corbett *et al* (2007); Kolding (2008); McKinnon (2012); Wallis (2013)

Theoretical motivations underlying corporate and sustainable strategy

There are several theoretical motivations that underlie corporate and sustainable strategy, particularly in logistics and SCM, and the two major motivations are presented here. One is transaction cost economics (TCE) which contains four key concepts of bounded rationality, opportunism, asset specificity and informational asymmetry (Halldórsson *et al*, 2007):

1 Bounded rationality suggests that managers, while willing to do so, cannot evaluate accurately all possible decision alternatives to make a rational decision due to physical or other constraints.

2 Opportunism considers that managers will exploit a situation to their own advantage. This does not imply that all those involved in transactions act opportunistically all of the time, rather, it recognizes that the risk of opportunism is often present.
3 Asset specificity arises when one manager in an exchange invests resources specific to that exchange, which have little or no value in an alternative use, and another manager in the exchange acts opportunistically to try to appropriate economic rent from that investment; economic rent being the additional amount over the minimum return the focal partner requires from the specific investment.
4 There is a relaxation of the perfect information assumption of neoclassical economic theory; many business exchanges are characterized by incomplete, imperfect or asymmetrical information.

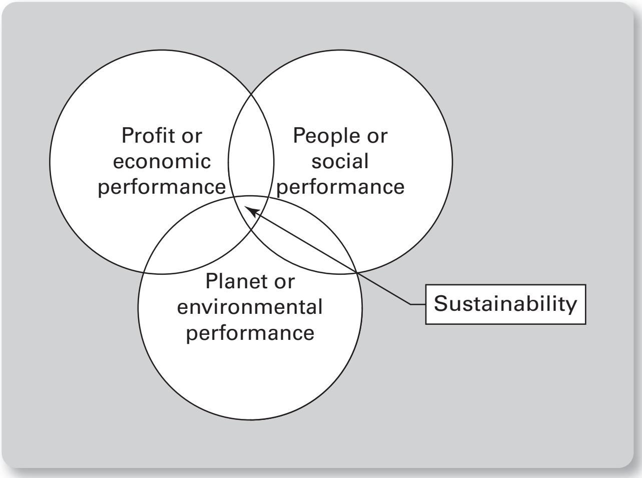
Essentially, TCE describes the firm in organizational terms, or as a governance structure where decision makers respond to economic factors or transaction costs within the firm that affect both the structure of the firm and the structure of the industry within which it operates (Williamson, 1999). The increasing division of labour in a supply chain is determined by governance mechanisms and has been recognized as a means of competitiveness through terms such as 'strategic sourcing' or 'outsourcing'.

TCE, and the means of creating and developing resources and capabilities, can be applied to achieve supply chain improvement as the level of analysis moves away from the firm to inter-organizational relationships (Halldórsson *et al,* 2007). This wider context of logistics and the supply chain, and in particular the ability to adapt organizing economic activities under different economic conditions, has been investigated by Williamson (2008), focusing on outsourcing. He considers how TCE should be operationalized, emphasizing the efficient alignment of transactions with alternative modes of governance. This cost-benefit view of governance and relationships supports the concepts of lean and agile logistics and supply chains presented in Chapter 1.

Another theoretical motivation is the resource-based view of the firm (RBV) from Penrose (2009), who defined a firm in 1959 as a collection of resources where growth is limited by its resource endowment. As the nature and range of these resources vary from firm to firm, so do the respective resource constraints. RBV suggests that a firm's resources and its capability to convert these resources to provide sustainable competitive advantage are the keys to superior performance (Grant, 1991).

In general, resources are referred to as the physical, financial, individual and organizational capital of a firm and are necessary inputs for producing

FIGURE 9.1 The 'triple bottom line'



the final product or service and form the basis for a firm's profitability. They may be considered both tangible assets such as plants and equipment and intangible assets such as brand names and technological know-how. Resources can also be traded, but few resources are productive by themselves. They only 'add value' when they are converted into a final product or service (Grant, 1991).

Resources are also finite within the firm and are usually financed from internal resources, ie shareholder subscription or retained equity, or from external resources, ie debt financing. However, another option for developing more resources involves establishing relationships with supply chain partners to share resources or develop joint-resource activities to achieve a greater gain for both, ie the '1 + 1 = 3' notion of synergistic addition. This finite aspect of resources relates well to issues of sustainability.

The two motivations of TCE and RBV, while appearing dissimilar, come together in John Elkington's (1994) model of the triple bottom line (TBL) of profits, people and planet, as shown in Figure 9.1. The TBL posits that firms should focus not only on the maximization of shareholder wealth or economic value that they create in economies, but also on the environmental and social value that they add – or possibly destroy – in order to achieve long-term environmental security and egalitarian living standards for all people. The overlap of these three elements in the Venn diagram represents true sustainability from an economic, ecological and human perspective.

People or social performance pertains to fair and beneficial business practices towards labour, the community and region in which a firm conducts its business. Planet or environmental performance refers to sustainable environmental practices. A TBL firm endeavours to benefit the natural order as much as possible or at least do no harm and curtails its environmental impact. Finally, profit or economic performance is the bottom line shared by all commerce, conscientious or not. In the original concept, within a sustainability framework, the 'profit' aspect needs to be seen as the economic benefit enjoyed by the host society and is the lasting economic impact the firm has on its economic environment. This is often seen as being limited to the internal profit made by a firm, so a TBL approach cannot be interpreted as traditional corporate accounting plus social and environmental impact. The concept of TBL demands that a firm's responsibility should be to *all* stakeholders rather than only to shareholders.

Carter and Rogers (2008: 368) defined sustainable supply chain management (SSCM) as:

> the strategic, transparent integration and achievement of an organization's social, environmental, and economic goals in the systemic coordination of key inter-organizational business processes for improving the long-term economic performance of the individual company and its supply chains.

Their definition is based on the TBL as well as four supporting facets: risk management, transparency, organizational culture and strategy. Risk management must go beyond managing short-term profits within an operational plan to manage risk factors in the firm's products, waste, and worker and public safety through contingency planning and managing supply disruptions and outbound supply chains. Transparency not only includes reporting to stakeholders but also actively engaging them and supplier operations. Organizational culture for sustainability must be deeply ingrained and respect organizational citizenship, values and ethics. Lastly, sustainability must form part of an integrated corporate strategy. These four facets are not intended to be entirely mutually exclusive and interrelationships will exist among them.

It thus becomes clear that a firm's sustainable, environmental or 'green' agenda and corporate strategy will need to contain elements of the TBL and possibly other facets within whichever motivation a firm uses: TCE or RBV. However, it is also clear that an additional 'green' aspect, ie the colour of money, will emerge from achieving cost reductions through energy and emissions savings. Thus, like any other strategic business decision a firm will make, a sustainable or environmental agenda will be subject to its own cost-benefit trade-offs. But, how can a firm calculate all true and total costs and benefits? Some form of performance measurement is required to fit into the three strategic plans.

Sustainable logistics and supply chain performance measurement

An old adage notes that 'you cannot manage what you cannot measure' and hence performance measurement is a staple in business for managing and navigating firms through turbulent and competitive global markets. It allows firms to track progress against their strategy, identify areas of improvement and acts as a good benchmark against competitors or industry leaders. The information provided by performance measures allows managers to make the right decisions at the right times (Shaw *et al,* 2010).

Logistics and supply chain performance measures have conventionally been oriented to cost, time and accuracy. However, firms are now looking to include measures related to sustainability, ie the natural environment and corporate social responsibility (CSR). And yet, there has only been limited research into incorporating a sustainability measure into the existing bank of logistics and supply chain performance measures.

Traditionally, logistics and supply chain performance measures have been quantitative and based on measuring cost, time and accuracy. Gunasekaran and Kobu (2007) identified almost 90 logistics and supply chain metrics, many of which overlap. The most widely used were financial (38 per cent), but 60 per cent of all measures were functionally based. The proliferation of logistics and supply chain measures is a symptom of how supply chains are managed. Supply chains are complex structures and as a consequence practitioners have created numerous metrics to manage them, often duplicating the same metrics within and across supply chain nodes or sites.

Sustainable supply chain performance measures (SSCPM) have focused on greenhouse gas (GHG) emissions due to the importance attached to them in the fight against climate change that has developed from a historical perspective, as discussed in Chapter 2. To wit, the 1997 Kyoto Agreement legally bound industrialized nations to reduce GHG emissions, particularly CO_2 by an average of 5.2 per cent below 1990 levels by 2012.

The UK Department for Environment, Food and Rural Affairs or Defra (2009) identified 22 sustainability performance indicators in four key categories that are considered to be significant to UK businesses: emissions to air; emissions to water; emissions to land; and natural resource use. To help manage these four categories, firms can adopt an environmental management system (EMS).

Environmental management systems

EMSs include the International Organization for Standardization's ISO 14001 introduced in Chapter 6 (ISO, 2009) or the European Union's eco-management and audit scheme (EMAS, 2009) to provide guidance on mitigating their impact on the environment.

ISO has also developed ISO 14031:1999, an environmental performance evaluation tool, which provides firms with specific guidance on the design and use of environmental performance evaluation and on the identification and selection of environmental performance indicators. This allows any firm regardless of size, complexity, location and type to measure its environmental performance on an ongoing basis (ISO, 2009). ISO 14031 divides environmental performance indicators into three classifications (Shaw *et al,* 2010):

1. *Management Performance Indicators (MPI)*: an indicator of a firm's effort in influencing its environmental performance; for example environmental costs or budget (dollars per year), percentage of environmental targets achieved, and time spent responding to environmental incidents (person-hours per year).
2. *Operational Performance Indicators (OPI)*: an indicator of an organization's operational environmental performance; for example raw materials used per unit of product (kilograms per unit), hours of preventive maintenance (hours per year), and average fuel consumption of vehicle fleet (litres per 100 kilometres).
3. *Environmental Condition Indicators (ECI)*: an indicator of local, regional, national or global conditions of the environment that are useful for measuring the impact of an organization on the local environment; for example frequency of photochemical smog events (number per year), contaminant concentration in ground or surface water (milligrams per litre), and area of contaminated land rehabilitated (hectares per year).

EMAS is the second most popular EMS standard in Europe. Structurally the ISO 14001 and EMAS standards are very similar but there are some fundamental differences between them (Murphy, 2012). For example, EMAS firms must be compliant with relevant environmental rules and regulations to guarantee their certification, but ISO 14001 states that a commitment to compliance is required in the policy but compliance is not essential to keep certification. Further, the evaluation of the EMAS standard is guaranteed by obligatory three-year audits where all cycles are checked and a statement is made public. ISO 14001 audits check for environmental system performance against internal benchmarks, with no penalties for no improvements, and the frequency is left to the discretion of the individual firm. These differences are perhaps the reason that the number of ISO 14001 certifications in the United Kingdom is far greater (14,346 in 2010) than EMAS registrants (289 in 2012). ISO 14001 appears to be the less demanding of the two standards.

There are a number of factors to consider when designing, implementing and evaluating an EMS. The most important factor is that no single approach is suitable for every firm; each firm has its own management systems and environmental impacts, organizational culture and structure. Further, the approach selected must be responsive to all possible audiences such as management, employees, shareholders and the public.

Many of the systems proposed by regulatory bodies are based on a plan-do-check-act framework. The planning stage is to set the targets and objectives and to detail how these will be attained through assigning individual responsibility. Implementing or 'doing' the system means providing the necessary resources to accomplish the objectives that have been set. Checking and correcting areas that require attention include monitoring and measurement to determine how well the organization is achieving stated environmental goals. Finally, there needs to be a periodic review of the actions to ensure progress is as expected; the results from these reviews should be documented as a log for continuous improvement (Murphy, 2012).

Lifecycle assessment

The all-encompassing method proposed for environmental performance measurement is the lifecycle assessment (LCA), also introduced in Chapter 6, which is a 'cradle-to-grave' approach for assessing industrial systems and supply chains (Curran, 2006). The LCA approach begins with the extraction of raw materials from the Earth to create products for consumption, ie the premise behind the definitions of logistics and supply chain activities provided in Chapter 1, and ends at the point when all materials are returned to the Earth, ie the premise of reverse logistics and product recovery management discussed in Chapters 1 and 5.

LCA evaluates all stages of a product's lifecycle from the perspective that they are interdependent – one stage leads to the next. LCA also enables the estimation of cumulative environmental impacts resulting from all stages in the product lifecycle, often including impacts not considered in more traditional analyses; for example raw material extraction, material transportation and ultimate product disposal. By including these impacts throughout the product lifecycle, LCA provides a comprehensive and holistic view of the environmental aspects of the product or process and a more accurate picture of the true environmental trade-offs in product and process selection (Grant, 2012).

The ISO 14000 series of standards formalize LCA components; according to ISO 14040, LCA consists of four phases: goal and scope definition for the LCA, ie can a firm do a true cradle-to-grave analysis; inventory analysis at each node in the industrial system or supply chain; the impact assessment at each stage; and interpretation of the findings. These phases are not simply followed in a single sequence as LCA is an iterative process in which subsequent iterations can achieve increasing levels of detail or lead to changes in the first phase prompted by the results of the last phase. LCA has proven to be a valuable tool to document and analyse environmental considerations of product and service systems that need to inform decision making for sustainability, and ISO 14040 provides a general framework for LCA.

However, no firm has complete visibility of its entire supply chain. Indeed, the simplified supply chain shown in Figure 1.1 (see page 9) represents a linear supply chain with only one tier 1 customer and supplier for the focal firm. In reality the focal firm will have many tier 1 relationships, as will all the tier 1 customers and suppliers, and the concept of a focal firm's supply chain explodes into operational complexity. Further, the impacts of globalization discussed in Chapters 1 and 2 add geographical and cultural complexity. Thus, a focal firm may only be able to perform an LCA across two tiers in either direction.

The UK retail grocery trade association, IGD, has developed an environmental sustainability matrix to assist the grocery sector in looking at important sustainability aspects across several tiers (IGD, 2012). Its four key aspects are GHGs, water, packaging and waste, and its six supply chain components are raw materials, manufacturing, storage, transport, wholesale and retail, and end user and end-of-life. These aspects and components are quite specific to this sector as food production and sales are about a 'plough to plate' perspective.

GHGs come from a variety of sources in food production and manufacturing such as fertilizers, animal methane gas and fossil fuels. For example, embedded GHGs in bread are comprised of 45 per cent for raw material production, eg wheat, 23 per cent in manufacturing, eg baking, 6 per cent in logistics, distribution and retail, 23 per cent in consumer use, and 3 per cent in recycling and disposal. Water of course is used heavily in agriculture and production but also in cleaning, cooking and sanitation by consumers. For example, one 150 gram hamburger, the same size as the yogurt pots discussed in Chapter 1, requires 2,400 litres of water. As noted in Chapter 2, IGD has been at the forefront of water stewardship.

Packaging and raw materials waste from the UK food and drink sector is estimated to be 5.1 million tonnes per year. Efforts have been undertaken by IGD in conjunction with food manufacturers and retailers to reduce the amount of packaging waste used in the food supply chain. The use of reusable packaging and transport devices, such as plastic totes for fresh produce and roll cages for milk, has helped this situation. However, cardboard used in shelf-ready packaging for products such as crisps and snacks lend credence to the notion that efficient consumer response (ECR) initiatives and the need to time-compress replenishment of store shelves, ie logistics and SCM objectives, have driven the packaging agenda.

Finally, food waste that is discarded throughout the supply chain amounts to 11.3 million tonnes per year, with 8.3 million tonnes or 74 per cent of such waste being generated by households. The box in Chapter 2 discussing social supermarkets presents one way of ensuring edible food is not wasted; another use for waste food is given in the following box.

Anaerobic digestion

Governmental waste policies, the increasing environmental agenda, the spectre of peak oil and rising fuel prices have focused attention on green methods of energy generation such as wind, solar and anaerobic digestion. Anaerobic digestion is a resource recovery technology that allows organic matter, eg food waste, to decompose, generating biogas and digestate that can be then utilized for energy and fertilizer respectively. Anaerobic digestion thus has an additional benefit over other renewable energy sources as it helps reduce the amount of waste going to landfill.

The use of anaerobic digestion to produce biogas energy from food waste is a practical way to mitigate between 100 and 160 kilograms of CO_2 equivalent per tonne of food waste. The total renewable gas supply from UK-available biodegradable resources that could be recovered by anaerobic digestion represents 10 per cent of total UK energy demand and two-thirds of the UK government's 2020 renewable energy target.

North Lincolnshire and North East Lincolnshire Councils in England requested a study of possible sites to build an anaerobic digestion plant (ADP) to service both councils and to minimize the costs involved in collecting and transporting food waste to the site as opposed to either incinerating it or delivering it to a landfill. A research team from the Logistics Institute at Hull University Business School used standard logistics, supply chain network and centre of gravity location modelling techniques to determine an optimal location that was cost-efficient and operationally effective regarding customer service and food waste 'feedstock' availability.

The team first identified 1,394 firms within the two councils' areas that could provide appropriate feedstock for the ADP, including major firms such as educational establishments, hospitals, hotels, restaurants and cafes, and then qualified by a survey those firms that would be able to provide such feedstock. Two major food conurbations have evolved around the port towns of Grimsby and Immingham and the inland town of Doncaster, but businesses, motivated by cost reduction, are already very good at waste reduction; so households appear to provide the largest source of feedstock. The amounts of food waste at postcode sector level were then used in the modelling process.

The logistics and supply chain decision factors for the ADP included locations of supply sources, locations of a potential ADP plant, supply forecast by source of supply, transportation costs between pairs of sites, and desired response time. Three potential locations were identified based on the availability of land, and the need to be close to a substation to feed energy into the UK national energy grid. Feasibility scenarios were then modelled based on prices from feed-in tariffs (FITs) from the operators of the energy grid, and the costs to build and operate the ADP including costs to obtain and transport feedstock.

The study showed that North Lincolnshire and North East Lincolnshire councils could have separate, feasible, anaerobic digestion facilities as long as the costs of additional collections were avoided. However, the best solution appeared to be a combined site feeding biogas into the grid with the site located at the centre of gravity for one of the councils.

This study is an example of how logistics and SCM can make a positive impact on sustainability.

Source: Menachof *et al* (2010)

Assessing sustainable choices and initiatives

Once a firm selects a framework or technique to include sustainability in its corporate strategy, eg a TBL, EMS or LCA approach, it will then need to assess such matters as the economic viability, technological feasibility and environmentally sustainability of that strategy.

Economic development, for example a port expansion, will invariably increase environmental pressure, some of which will be ameliorated through specific management actions. For example, increasing a port's area will cause the loss of estuarine habitats such as mudflats or salt marshes or disturb overwintering wading birds or fish such as eels and salmon migrating between the sea and the catchment. Such relationships between society and in this case logistics and SCM's impacts on the environment, and responses to such impacts, can be formalized through the development of a systems-based approach such as DPSIR (Atkins *et al,* 2011).

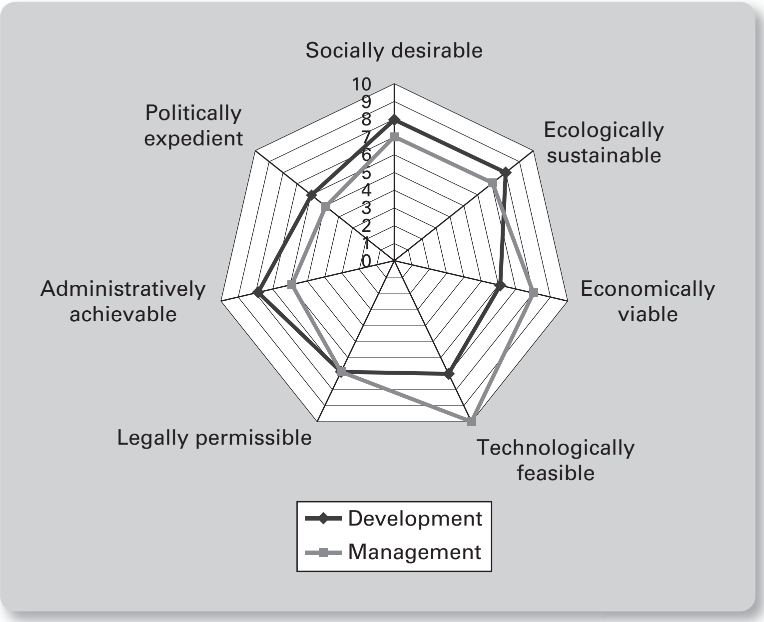
In essence, the DPSIR framework encompasses *Drivers*, which are the key demands by society (for example a desire for economic growth) and which are responsible for creating *Pressures* (for example a proposed port development and the associated changes such as loss of habitat, influences on water quality, stressors such as noise or light pollution, etc). Such *Pressures* in turn give rise to *State changes* in the environment, such as a loss of habitat and ecological structure and functioning. If these adverse changes are not addressed they lead to *Impacts* on the human use of ecosystems and on the societal benefits provided by ecosystem services, for example a loss of habitats such as salt marshes which may store carbon and the loss of fish populations which may later be taken as food. To prevent or remedy these adverse changes requires a *Response* by society, such as economic instruments or legal constraints. Hence the DPSIR approach is a framework for defining, scoping and then addressing environmental problems.

Further, in terms of their relationships, the Pressures, State changes and Impacts that are linked to any one single Driver may be linked to those Pressures, State changes and Impacts emanating from other Drivers (Atkins *et al,* 2011). For example, changes to habitats from port and navigation activity are also linked to those from industrial, urban and agricultural inputs both around the port and in the catchment area. The consideration of these relationships gives rise to assessing whether the strategy or strategic option fulfils the 'seven tenets of sustainable management' (Elliott, 2011) and by doing so the management of, and solution to, an environmental problem will be sustainable and not environmentally deleterious but, within what is possible in the real world, taking note of the socio-economic and governance aspects. Also, and in addition to achieving sustainability, fulfilling the seven tenets would mean that the environmental management would potentially be seen by wider society as achieving sustainability (eg it would become more visible and communicable) and in turn would be more likely to be accepted, encouraged and successful. The seven tenets are:

1. *Socially desirable/tolerable:* environmental management measures are as required or at least are understood and tolerated by society as being required; society regards the protection as necessary.
2. *Ecologically sustainable:* measures will ensure that the ecosystem features and functions and the fundamental and final ecosystem services are safeguarded.
3. *Economically viable:* a cost-benefit assessment of the environmental management indicates (economic/financial) viability and sustainability.
4. *Technologically feasible:* the methods, techniques and equipment for ecosystem and society/infrastructure protection are available.
5. *Legally permissible:* there are regional, national or international agreements and/or statutes that will enable and/or force the management measures to be performed.
6. *Administratively achievable:* the statutory bodies such as governmental departments and environmental protection and conservation bodies are in place and functioning to enable successful and sustainable management.
7. *Politically expedient:* the management approaches and philosophies are consistent with the prevailing political climate and have the support of political leaders.

As originally presented, the seven tenets relate to actions or management measures. That is, human Responses include a set of tools that are available for managing systems and so may be regarded as having to meet the tenets for environmental management (Atkins *et al,* 2011). However, while State changes and Impacts together represent the receiving environment, direct human interaction with the environment is represented not just by Responses but also by Pressures. As the proposed tenets for sustainable management apply as much to society and the economy as to the natural environment, assessment cannot be restricted solely to natural environmental aspects of the Pressures (ie the management measures introduced in response to the State changes) but must also encompass the human consequences

FIGURE 9.2 Example of a radar plot for the seven tenets



(ie the Impacts). Consequently, it is not just management (ie the Responses) that should be considered when assessing sustainability through the application of the seven tenets but also those activities (for example estuarine port developments) that are represented by the Pressures.

To move from a set of concepts to a practical application of these to aid environmental management, a quantitative scoring system has been developed. This allows assessing each tenet against a common rating from minimal to full compliance on a 10-point scale; this normalization removes the potential problem of mixed metrics or different scales adversely influencing, or skewing, any subsequent assessment. Definition of minimal and full compliance in 'absolute' terms for each tenet (ie not solely related to the specific geographic area under consideration) allows for subsequent comparisons to be made, not only between different activities within one area but also between activities in different geographic areas.

These data in turn can be reproduced as a sustainability or radar plot showing both development (Pressure) and management measures (Response) scores to indicate the level of compliance with each of the tenets. An example of such a radar plot is shown in Figure 9.2 for illustration purposes and indicates that the potential project or strategy shows a reasonably good compliance with the seven tenets relevant to the Pressure but less good compliance with four of the tenets as applied to the Response. The shortcomings for the Response, ie where the management area of the diagram is 'squeezed in', are associated mainly with the measures' ecological sustainability, social desirability, political expediency and administrative achievability. That is, while the development itself (the Pressure) generally satisfies five of the tenets for sustainability, measures that are likely to be put in place by way of Response may not be fully supported by all sectors of society or are politically expedient in the short term, and may not be ecologically sustainable or administratively achievable in the long term, suggesting that the benefits they are intended to bring about may only be short-lived.

The corporate strategy that a firm develops should include sustainability to meet increasing business, societal and governmental requirements as part of a good CSR policy. There are a number of frameworks and techniques that a firm can use to consider sustainability holistically within its corporate strategy such as TBL, EMS and LCA. Further, the DPSIR and seven tenets assessment tools discussed in this section allow the firm to ensure that its sustainability strategies meet its objectives and those of its stakeholders. While this section has discussed these latter tools at a conceptual level, the following box provides a concrete example of their use for an upcoming major offshore wind farm that is intended to provide increased renewable energy in the UK market by 2020.

Assessing offshore wind energy in the United Kingdom

The UK government's 2009 Renewable Energy Directive set a target for the country to achieve 15 per cent of its energy consumption from renewable sources by 2020, compared to 3 per cent in 2009. Offshore wind is expected to contribute to that energy target and the sector has made steady progress in 2011, meeting 12 per cent of the UK's electricity demand. At the end of 2010, the European Wind Energy Association reported that, of the 3 gigawatts (GW) of offshore wind capacity in Europe, 46 per cent was in UK waters.

Four new offshore wind farms are being planned for the North Sea off the UK: Dogger Bank, Hornsea, Humber Gateway and Westermost Rough and are expected to produce 13.5–17.3 GW of renewable energy. Several manufacturers have expressed interest in developing manufacturing facilities in the Humber River Estuary for the wind turbines required for these farms. A study carried out as part of a University of Hull research project investigating the Humber's economic future found that increased economic activity in the Yorkshire and Humber region due to offshore wind developments is estimated to be £4–10 billion gross value-added (GVA) per year and 8–15,000 new jobs through to 2020 (Wong *et al*, 2013).

The study considered this potential development in terms of six of the 'ten tenets for development and environmental management' developed by Barnard and Elliott (2012). This recent work adds three new tenets to the 'seven tenets' contained in Elliott (2011): culturally inclusive (ie local customs and practices are protected and respected), ethically defensible or morally correct (ie the wishes and practices of individuals are respected in decision making), and effectively communicable (ie all horizontal links and vertical hierarchies of governance are accommodated and decision making is inclusive). Following are the assessment of the six tenets:

1. *Ecological sustainability:* different impacts on the environment were identified: impacts on marine mammals (mortality through collision with increased ship traffic, leaving the area due to disturbances, noise damage, and disruption of normal behaviour); fish (electromagnetic field, habitat loss, alteration of species composition); and birds (mortality through collision and disruption of feeding grounds, disruption of migration routes). Wind energy is unlimited, unlike fossil fuels, non-polluting and safe, and eventual environmental disruptions are almost all site-specific and temporary. Thus, a development score of 7 was awarded. On the other hand, habitat re-creation (creation of seabed/surface area, water column and air space) is a valid compensation scheme and if supported by specific implementation characteristics (providing shelters as a fish aggregating device, turbine installation in areas with low levels of bird movements and away from conservation zones) positive effects can be greatly enhanced. Similar methods have been used in the past, tested on similar offshore structures (oil rig platforms) and in similar environmental circumstances. Moreover, costs related to site preparation are capital and require little maintenance. Thus, an environmental management score of 7 was awarded.
2. *Social desirability:* there is a general perception that an offshore wind farm is less constrained by social acceptance because visual impacts and noise problems, if sufficiently distant from the coast, are minimized. Although offshore sites are not simply and automatically preferred to onshore sites, approval rates for offshore wind farms have been around 90 per cent and consent periods were 22 months compared to 51 per cent and a range of 20–52 months for onshore wind farms. Moreover, offshore wind is generally seen as an unrepeatable opportunity to generate an increase in jobs and investment in the Yorkshire and Humber region where the unemployment rate is among the highest of the English regions at 9.9 per cent compared to a UK

average of 8.4 per cent. It therefore seems plausible to affirm that the development of the proposed offshore wind farms (development score: 8) and relative measures for habitat recreation (environmental management score: 10) would be considered positively by the local population, although eventual public inquiries resulting in consent delays should be taken into account.

3. *Ethical defensibility:* offshore wind power, like other renewable sources of energy, offers security against energy shortcomings from other sources being clean, domestic, carbon dioxide emission free and not contributing to climate change. Moreover, it is capable of generating remarkable allied industries and activities both at regional and national level. Therefore, it is not an exaggeration to assume a high ethical defensibility value (development score: 8, environmental management score: 10).
4. *Cultural inclusivity:* site selection undertaken by the UK Crown Estates is based on a zonal approach (awarded to one development partner) and cumulative impact is calibrated on an ongoing basis engaging holistically with stakeholders. Moreover, the marine resource system model (MaRS) used is a robust, transparent and rational approach to site selection and capable of identifying and resolving eventual planning conflicts and assessing the suitability of sites for specific projects by identifying areas of opportunity and constraint, and detecting how different activities would interact in a particular area. It is thus clear that cultural traditions and local needs are taken into account before a final decision is taken and that, given the numerous variables and interests involved, changes although minimal should be considered unavoidable (development score: 8, environmental management score: 9).
5. *Effective communicability:* relevant documentation and updates are posted on websites of the industrial consortia developing the proposed offshore wind farms, and local media, especially newspapers, constantly disseminate updates. Moreover, public consultations have been undertaken to ensure not only the social acceptability but also effective communication and wide public participation. Therefore, a high compliance is suggested (development and environmental management scores: 8).
6. *Political expedience:* national and local political commitment is clear and a deliberate support to the development of offshore wind farms is being pursued (development score: 8, environmental management score: 9).

While readers may want to deconstruct the scores and their respective rationales based on their own cultural values and beliefs, this analysis nevertheless provides a good illustration of the application of the assessment and management tenets that have been developed for just such a purpose.

Sources: Barnard and Elliott (2013); Wong *et al* (2013)

Summary

Logistics (and SCM since the 1980s) has been recognized as an important business function over the past 50 years and has grown from a transaction-oriented, tactical function to a process-oriented, strategic function. Today, logisticians and supply chain managers have greater opportunities to participate actively in setting strategy, meeting challenges and contributing to the success of the firm. The two major strategic motivations are transaction cost economics and the resource-based view of the firm.

However, a strategic imperative to include sustainability as part of the 'triple bottom line' means that logistics and SCM firms will need to incorporate these three motivations in future. To operationalize this third motivation, firms will first need to develop sustainable logistics and supply chain performance measures. One way to do so is to adopt an environmental management system through ISO's 14000 series or the European Union's eco-management and audit scheme. Further, using tools such as a lifecycle assessment and confirming that any strategic option fulfils criteria such as the 'seven tenets of sustainable management' will allow a firm to ensure it is properly addressing the three mandates in the 'triple bottom line': sustainable maintenance of the natural environment, economic growth and development, and a regard for societal and human concerns on this fragile planet.

The rewards for recognizing and accepting these challenges in a creative and proactive manner should prove to be substantial. It is the hope and sincere desire of the authors that we have presented the materials in this book in such a way as to encourage readers to properly recognize and strongly consider these issues that are before us.

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Sustainable Logistics and Supply Chain Management is the essential guide to the principles and practices of sustainable logistics operations and the responsible management of the entire supply chain. It offers practitioners and students a comprehensive overview of sustainability science, as well as an understanding of sustainability as it affects the supply chain. Based on extensive research by experts in the field, this new book provides carefully reviewed, research-led applications and case studies that have been specially developed for this revised edition.

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