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.

Examining the subject in an integrated manner from a holistic perspective, this book examines all the key areas in sustainable logistics, including:

- sustainable product design and packaging
- sustainable purchasing and procurement
- cleaner production
- environmental impact of freight transport
- sustainable warehousing and storage
- sustainable supply management
- reverse logistics
- recycling
- supply chain management strategy

Additionally, this revised edition of Sustainable Logistics and Supply Chain Management includes valuable supporting online materials, including:

- chapter summaries
- learning objectives
- tips for teaching
- in class activities
- PowerPoints of figures and tables

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Logistics and supply chain management

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.
Sustainable Logistics and Supply Chain Management

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 reverse 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 fulfillment, 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
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.
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 CO₂ 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 CO₂ 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.
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.

Sources: AEA Technology (2005); Shaw et al. (2010); Whitty, J (2012)
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
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 life-cycle 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
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.

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**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...
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

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Sources: The Economist (2012); Sandberg and Kalman (2005)
8 per cent of the UK’s total CO₂ 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.
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

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Description</th>
<th>Supply chain applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dematerialization</td>
<td>Substitution of material flows with information flows</td>
<td>Substituting information for inventory so as to avoid premature deployment of goods before demand is known</td>
</tr>
<tr>
<td>Product customization</td>
<td></td>
<td>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</td>
</tr>
<tr>
<td>Production loop closure</td>
<td>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</td>
<td>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</td>
</tr>
<tr>
<td>Service extension</td>
<td>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</td>
<td>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</td>
</tr>
</tbody>
</table>

(Continued)
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
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 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)
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.
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.

Examining the subject in an integrated manner from a holistic perspective, this book examines all the key areas in sustainable logistics, including:
- sustainable product design and packaging
- sustainable purchasing and procurement
- cleaner production
- environmental impact of freight transport
- sustainable warehousing and storage
- sustainable supply management
- reverse logistics
- recycling
- supply chain management strategy

Additionally, this revised edition of Sustainable Logistics and Supply Chain Management includes valuable supporting online materials, including:
- chapter summaries
- learning objectives
- tips for teaching
- in class activities
- PowerPoints of figures and tables

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