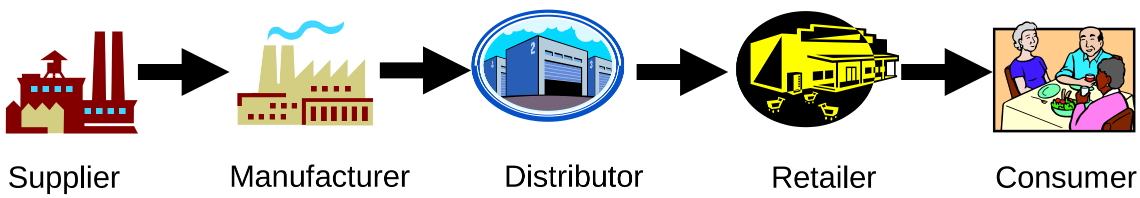
Sustainable Supply Chain Basics

While intended to supplement the class presentation, Sustainable_Supply_Chains.ppt, this document can also serve as a stand alone as an introduction on how sustainability can be infused into traditional supply chain management, and how to use models to measure and improve logistical networks.

1. Supply Chains

Before we can discuss supply chain management, we must first define what is meant by "supply chain." A supply chain is a sequenced network of facilities and activities that support the production and delivery of a good or service. Given the obvious importance of the supply chain, this field is rife with terminology and buzzwords, many of which are synonymous. For instance, supply chains are sometimes referred to as "demand chains" or value "chains". Regardless of what it is called, a supply chain starts with basic suppliers and extends all the way to consumers via *stages*. Supply Chains are inherently directional; *downstream* refers to flows towards the end consumer, while *upstream* refers to looking back towards initial suppliers. Stages may include such facilities as suppliers, factories, warehouses, distribution centers, and retail outlets. Figure 1.1 shows a sample supply chain, where the arrows denote the flow of a product towards the consumer:

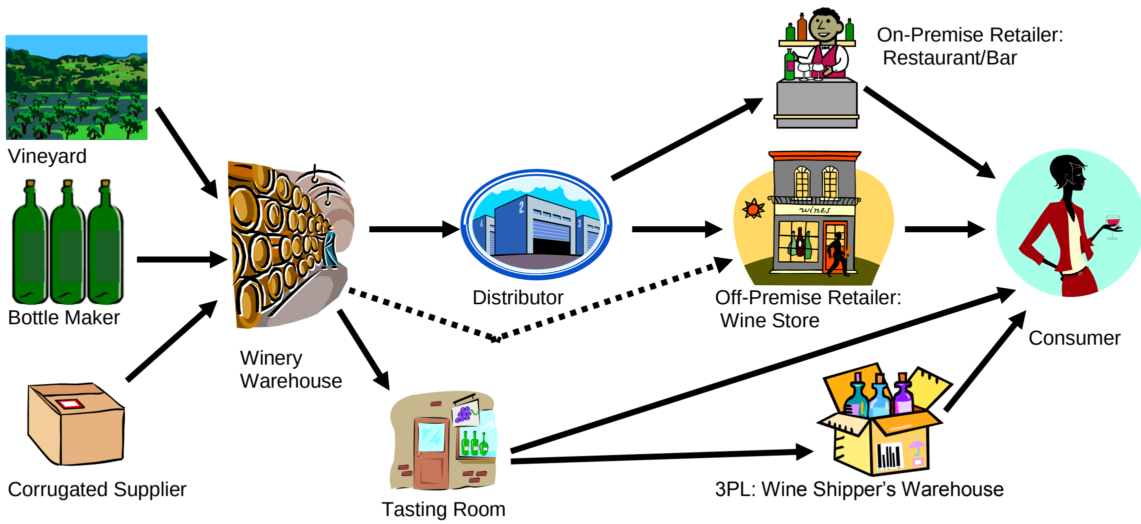
Figure 1.1: A Simple Supply Chain



However, not all supply chains include all stages, and these relationships are often more complex. All supply chains do have one aspect in common, in that they terminate with a consumer. Supply chains may be interlinked. One supply chain's end consumer may form an intermediate link of another supply chain, such as a firm that buys components for assembly into its own product. For instance, a consumer for cylinders of compressed CO_2 could be a soft drink producer, which then uses the gas to carbonate its products.

Supply chains go beyond manufacturing, and include such functions as: Demand Forecasting, Purchasing (also known as Sourcing), Customer Relationship Management (CRM) and Logistics. Logistics concerns the movement and storage of goods, services and information. It is an umbrella term for such important functions as Transportation, Inventory Management, Packaging and Returns/Reverse logistics. As we will shortly see, these activities are often complex and interdependent. Figure 1.2 is an example of a complex supply chain (or, more accurately, a network) with differing number of intermediary stages and several retail channels. It illustrates our convention for modeling supply chains as network diagrams, where self-contained transport activities are links, and storage and processing facilities are nodes, even if the storage time is minimal, such as at a cross-docking facility. Figure 1.2 depicts both the *Inbound Logistics*, the delivery of any raw materials and packaging to the winery, as well as the *Outbound Logistics*, the transportation and storage of the *finished good* (wine) to the end consumers.

Figure 1.2: The Supply Network for a Winery



Much supply chain complexity results from the fact that few supply chains are completely *vertically integrated*, controlled by one firm. For example, manufacturers and retailers are not typically owned by the same firm. Companies may outsource supply chain activities. Tech and electronics firms often use *Contract Manufacturers*; though Nintendo is headquartered in Japan and Apple in California, many of the components of both the Wii and the iPhone are made in Shenzhen (China) by Foxconn, a Taiwanese firm.

Transport and storage functions may be handled more effectively by *Third Party Logistic Providers* (3PLs). Outside firms that form part a company's supply chain are *channel partners.* A network of channel partners is sometimes termed an *Extended Enterprise.* Supply chains clearly require collaboration across organizations.

2. Supply Chain Management and Strategy

Many definitions exist for Supply Chain Management (SCM), such as those by APICS and the Council of Supply Chain Management Professionals, both respected professional societies this field. We shall define SCM as the coordination of business functions within an organization and its channel partners in order to provide goods and services to fulfill customer demand *responsively*, *efficiently* and *sustainably*. Supply Chain Management is in itself an important subset of the broad field of Operations Management.

Supply Chain Management involves three levels of decision making: Strategy, Planning and Operations. The highest level, supply chain strategy, concerns designing and building the appropriate supply chain for the good or service to be provided. Supply chain planning involves leveraging the existing supply chain, as created during the strategy phase, to support medium-term goals, typically yearly or quarterly production needs. Supply chain operations covers the short-term monitoring and control that is necessary to support the supply chain plan, including any plan revisions.

Supply chain strategy involves weighing inherent tradeoffs. The traditional focus, such as seen in Chopra and Meindl's classic textbook, is to craft a supply chain strategy with the appropriate mix of *customer responsiveness* and *cost efficiency*, consistent with the firm's overall competitive strategy. Consumers of commoditized products are typically more concerned about price. In contrast, customers of luxury, innovative, or otherwise highly differentiated products likely care more about service levels, fast delivery, and customization than about cost. Thus, the supply chain for an iPhone will differ greatly from one for laundry detergent. Even within this framework there is room for variation. For instance, Method Home's laundry soap is much less commoditized than other detergents and does not need to compete in the marketplace solely on cost.

3. Sustainability

An effective supply chain strategy must also explicitly address sustainability. Sustainability is an emotionally charged word that means different things to many people. Webster's Dictionary defines sustainable as "able to keep in existence, maintain." Our definition of a sustainable firm is one able to produce and deliver its goods or services for the foreseeable future without causing degradation. This definition is inspired in part by environmental economic theory, namely that the rate of usage of a resource should not exceed than the rate of replenishment, and that externalities, costs not directly incurred by a firm for its activities, should be considered in decision making. We leave questions about exactly how long of a time horizon to consider to experts like Glaser.

One way to examine sustainability is through the lens of the *Triple Bottom Line* (3BL), which defines three pillars: Social Responsibility, Environmental Stewardship, and Economic Viability. These pillars are sometimes termed "People, Planet, Profits," as first coined by Shell. *Social Responsibility* deals with such concerns as whether the firm provides a safe working environment, with fair compensation and benefits. Does the firm avoid child labor, forced labor or discrimination in hiring or promotion? Does the firm make a positive contribution to the communities in which it is located? *Environmental Stewardship* addresses how can a firm avoid depleting resources, prevent pollution, or otherwise reduce its ecological footprint. How is the product able to be reused, recycled or ultimately disposed of? Can the total cost of ownership be reduced? Finally, we must consider *Economic Viability*; is the firm is profitable, and can it be expected to grow and prosper, providing returns to investors? A firm that is deficient in any of these three facets is ultimately not sustainable.

Alas, there is no one universally acknowledged path to sustainability. Sustainability of businesses emerged as a mainstream topic only recently, and is just now gaining emphasis in the classroom and boardroom. Researchers such as Carter and Rogers (2008) define a universal framework, but such work is still at the conceptual level. Several frameworks for measuring facets of sustainability are discussed as follows.

Total Cost of Ownership (TCO) was first popularized in the 1980's for information technology investments, predating much of the current sustainability movement. TCO is a financial measure, the estimated sum of all costs: procurement, manufacture, distribution and usage (operation) to disposal and even beyond. The frame of the analysis must be set. For instance, cradle-to-grave is not as encompassing as cradle-to-cradle.

A *Life Cycle Assessment* (LCA) is an analysis of the environmental aspects and potential impacts associated with a product, process, or service. Despite the inclusion of environmental management standards into ISO 14000, no single universal standard exists for the impact categories evaluated. Typically the following are included: global warming, acidification, smog, ozone layer depletion, eutrophication, toxin release, habitat destruction, desertification, land use issues, and resource depletion. Some categories are more relevant for certain firms than others. For instance, agricultural products are likely to have more of an impact on land use and habitat preservation than products from industries with a smaller physical footprint, like semiconductors and electronics, which may themselves have higher toxicity problems. LCAs may occasionally have a social component. The frame of the analysis must be defined and appropriate for the situation. If, as with tech products, increasing recycling or re-use over disposal has huge benefits: cradle-to-grave analysis may be more appropriate than cradle-to-gate. The EPA provides a comprehensive guideline to LCAs on their website.

The *Ecological Footprint* as first defined by Wackernagel and Rees (1996) quantifies the land and water area a population requires to produce the resources it consumes and to absorb its wastes. They assert that Earth's "carrying capacity" is currently being exceeded. This framework is similar to that of the LCA, except with a focus on consumers instead of producers. Measures are broken in to water usage, resource usage and other categories, with carbon being the largest component, at over half the total footprint. A U.N. study shows that development and footprints are highly correlated, but some countries with a High Development Index (HDI) have a much lower footprint than their peers. For example, although the USA and Switzerland have a similar HDI, the ecological footprint of the average American is approximately twice than of a Swiss. Aggregate measures by definition will over-generalize; city dwellers typically drive less than rural or suburban Americans, and those living in milder climates will use less fuel to heat or cool their homes.

The *Carbon Footprint* is a component of both LCAs and Ecological Footprints, and as it is one of the larger impacts it is often considered on its own. While other gases such as methane and nitrous oxide may contribute to global warming, aggregate greenhouse gas measures are typically reported in CO_2 equivalents (CO_2e) Carbon dioxide is the dominant greenhouse gas; according the WRI, 95% of greenhouse gas emissions are CO_2. Some points of confusion in carbon measures exist. For instance, many US organizations report tons (2000 lbs) emitted, whereas most of the world measures in SI (metric units) and reports in tonnes (1000 kg), which are about 10% different. Emissions are colloquially called carbon emissions, which can lead to confusion as some older studies only weigh the carbon component of the gas, 30% of the total mass of CO_2. We also need to know the scope. According to the GHG Protocol website, *Scope 1* includes only direct emissions, while *Scope 2* also includes indirect emissions from any consumption of purchased electricity, heat or steam. *Scope 3* is the broadest, including all other indirect emissions, such as the extraction and production of purchased materials and fuels, all outsourced activities, and waste disposal. We may or may not include the substantial impact of radiative forcing from the contrails for measuring airplane emissions.

The popular press often discusses *Food Miles*, defined as the distance between the production source and the retail store. The basis of this concept is a simple calculation: the further food travels, the more energy and emission result. Researchers have shown that in the US domestically produced food items average over 1000 miles traveled before reaching consumers, and there is increasing reliance on imported produce. Proponents of food miles labeling share many ideas with the Slow Foods Movement: supporting neighboring farms, access to fresher, less-processed foods and an encouragement of pride in regional cuisine and even a sense of *terroir*. Businesses are responding to consumer interest as more people try to become "locavores" at least for part of their food purchasing. More farmers' markets are springing up in the US. UK supermarket chain Tesco provides food mile information for many products. Safeway estimates up to 30% of produce is local in many stores. However, we will later see that this can be a controversial measure.

In summary, sustainability is a relatively new concept for the mainstream society and no one single approach dominates. As businesses discover consumers are concerned about this issue, lots of labels are popping up. It is estimated that there are over 300 eco-labels within the food industry. Even for as specific a category as wine produced in West Coast states, five different third party certifications and labels exist. Third party certifications hold more weight and recognition than company-created labels or other self-assessments and may lessen the risk of "greenwashing." In order to make sense from all this confusion, we need to be able to critically understand and analyze the situation. This brings us to our next topic.

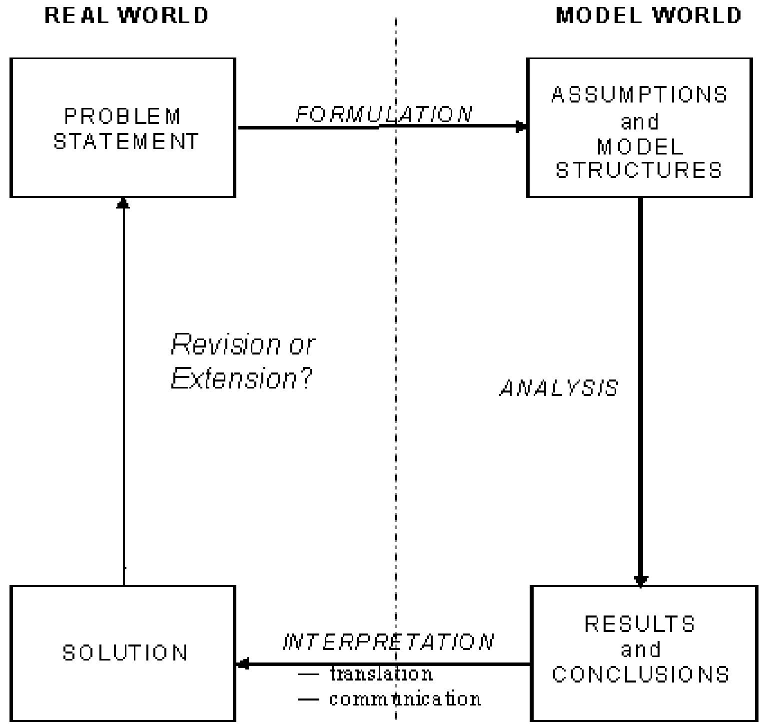
4. Review of Modeling Fundamentals

This goal of this guide is to help readers analyze supply chains to make decisions that will improve sustainability. This analysis will involve modeling the supply chain and measuring aspects of it. But before we start rolling up our sleeves and building models, we need to establish some fundamentals, such as defining our inputs, decisions and outputs. We must state our assumptions, set our frame, and understand how the results will be used. Thus, an overview of modeling basics is presented. Those who already have a lot of modeling experience may be able to skim this section.

Models are quantitative, simplified representations of real-world complex systems. Scientists often model systems that are not subject to much human input, such as the planetary solar system. However, business practitioners tend to consider problems where change is possible. The appropriate model will represent critical characteristics of the decision problem, ignoring irrelevant or less relevant details in favor of simplicity.

Modeling involves a process, as shown in figure 4.1. We first define our problem. This will include setting the frame. We then state our assumptions, gather data and build the structure. Once the model is constructed we perform an analysis to get results. We then interpret these results, translating them to something that is understandable to non-modelers. We make a recommendation for a plan of action: our solution. This process is often iterative - a solution may raise questions that require the initial problem to be revisited, perhaps to fix errors if we think our model is not accurate, or perhaps to consider a different or larger scope problem if we think our model works well.

Figure 4.1 The Real World and the Model World

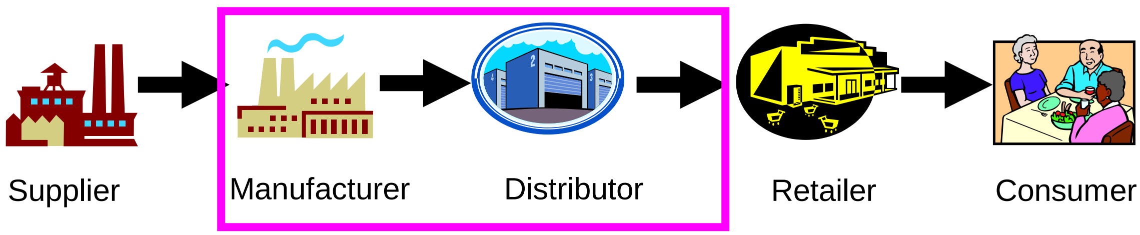


Model **inputs** are *parameters*, universal information such as fuel usage rates, and *data*, information specific to our problem, such as the locations of facilities and distances between them. If we do not have exact knowledge of these, we may have to make approximations. The **Decision variables** represent the possible choices or actions to take such as what type of transport to use and should be something we have some control over. Our model's **output** would be the consequences of the decisions: for example, costs incurred, total energy used and resulting emissions. The logic and relationships that link the elements (inputs, decision variables, output) of the model together comprise the model **structure**.

The **frame**, or scope, of a model may have multiple dimensions: geographic, temporal, and structural boundaries. For example, we may select the following: a single product, a 2 year time horizon, and an analysis limited to manufacturing activities and including only US facilities. Inside the frame we have visibility and presumably some ability to affect change. Anything outside the frame is *exogenous* and is treated beyond our control, at least for our current decision process.

As an example, imagine we want to enhance company sustainability. We decide what aspects of sustainability we will consider and what areas of the business are most suited for improvement. For example, we could decide to reduce carbon emissions in the manufacturing and outbound logistics phases because we have control over those functions and suspect they may be problematic. We set the frame to start with our manufacturing facilities and to terminate with delivery to the retail stores, as seen by the pink box in figure 4.2. We may have choices as to how and where we manufacture, how we route our product, what transport mode we use and how frequently we make shipments. Our contracts with suppliers are taken as fixed, as is retailers' demand. We do not consider how efficiently retailers may store the product or how consumers transport it home.

Figure 4.2: Framing the Supply Chain: an Example



Different decision making processes may require readjusting the frame. If we were deciding merely how to best fulfill retailer orders from our manufacturing warehouses, we would shrink the frame in Figure 4.2, excluding manufacturing and treating production activities as fixed inputs.

There is a difference between having direct control and influence. Wal-Mart estimates they own less than 10% of their supply chain. But they have more power to encourage channel partners to change than do independent retailers. Monitoring and enforcement becomes more difficult when the supply chain is not under direct ownership. For instance, IKEA and Nike have faced child labor allegations in the past as they rely on foreign manufacturers in developing nations. Framing is especially crucial in assessing sustainability impacts. In Life Cycle Assessments, a full view is typically from cradle-to-grave. When significant reuse, remanufacturing or recycling is possible, cradle-to-cradle may be better. However, if we have control or influence over a small part of the supply chain, then a fully encompassing frame may be distracting.

In short, if we set too large a frame, we will be swamped with details, and we even risk falling into "analysis paralysis" because the problem seems too big to solve. Conversely, using too small a frame may lead to sub-optimal decisions, sometimes referred to as "silo-ing." It is tempting to set the frame to include only what we have firm data for, but we may miss real opportunities, as we lose the "big picture." Compromise is necessary. Pilot studies may involve a small part of the supply chain, with limited scope. It is easier to start from a simple model. If the pilot is successful, we may chose to expand our model to include more detail or to broaden the scope.

Now that must determine what we are measuring. **Metrics** allow us to translate supply chain performance into simple numbers and benchmark to a standard. The more widely used a metric, the more authority it carries. Traditional supply chain management is rife with metrics. The Supply Chain Council has defined the SCOR reference model, which has over 150 performance indicators. Depending on the supply chain strategy, some metrics may be more important to a firm than others. For instance, a firm that emphasizes responsiveness may care more about increasing *Perfect Order Fulfillment* as opposed to minimizing *Cost of Goods Sold*. The latest iteration of SCOR has incorporated some environmental and risk-management measurements. However, there is not yet one universally adopted approach to measuring sustainability.

It is important to consider the logic behind the numbers. For instance, the previously mentioned metric of *Food Miles* is easily understood, measuring distance traveled from "Farm to Fork." The underlying premise is that lower mileage is better; the shorter distance food has to travel, the less energy is wasted in transit. However, this metric ignores the energy used to transport supplies to the farm and that from processing or storage. For example, AERU researchers estimate that for British markets, grass-fed lamb from New Zealand produces lower emissions overall than locally raised lamb from a feed-lot. Transport modes such as ocean shipping and rail are efficient on a per-weight basis, even over long distances. Considering another dimension of sustainability, many African and South American farmers derive their livelihood on servicing export markets. Simple metrics may be misleading, especially when used in isolation.

In working with our model output and drawing conclusions, it is important to consider the level of enforcement. The strictest is mandatory regulation: satisfying rigid standards defined by a governmental agency such as the EPA, which is typically involved in oversight and enforcement. Failure to comply will result in fines or worse. For example, California Air Resource Board (CARB) issues thousands of dollars in fines to businesses that fail to inspect their trucking fleet or otherwise obey rules. CARB's reach extends nearly every adult Californian; cars must pass a smog test every two years for registration renewal. Mandatory compliance is prevalent in industries with highly toxic pollutants, but government agencies have started to consider carbon dioxide emissions as well.

The next level, voluntary participation, includes such certification programs as LEED (eco-friendly building), EnergyStar (energy efficiency), and SmartWay (fuel saving practices). A company will typically undergo an audit to pass certification, enabling it to use a logo or be listed in a directory of other compliant practitioners, both of which may help generate business. Companies that fail to meet standards risk losing their certification. Such programs may be developed by government agencies or partnerships with businesses and government agencies as was SmartWay. They can be initiated by businesses and industry organizations without government help as was the California Sustainable Winegrowing Alliance (CSWA).

The level with the least enforcement is that of internal initiatives. Companies define their own goals and measures of success. For instance, a company may set a goal to increase the percentage of post-consumer recycled content in its packaging to 20%. Such efforts may or may not be published. If the company is able to increase recycled content to 10%, it would be unlikely to issue a press release bemoaning its inability to reach its goal. Or it may publicize the 10% figure without mention that the original goal was much higher.

Use of external agents to validate compliance is important at the levels of mandatory regulations and voluntary participation. Such validation typically entails measuring to an objective standard. Inability to meet this standard must result in either improving performance or incurring a penalty. Programs where enforcement is lax will lose credibility. For example, the EnergyStar program has drawn criticism over how inefficient products may still receive good ratings. Internal initiatives typically self-monitor results and, consequently, do not tend to hold a high level of public credibility.

Before deciding upon which enforcement level is appropriate for a particular situation, it is important to consider context. Most people would agree that strict rules are necessary to limit toxic waste emissions. However, efforts involving newer technologies, products or markets may need time to develop and mature before regulations are imposed. A company may perceive an opportunity for improvement before it is mandated by law and is usually better at innovating cost-effective solutions than a government agency would be. Likewise, a group of firms within a specific sector may be better able to determine where improvements are feasible than outsiders with little business knowledge of that sector. For example, it is likely too early to mandate all US consumer goods providers must have at least 20% post-consumer recycled content in their packaging. The appropriate level of enforcement may evolve over time; individual company initiatives may lead the way for a consortium of companies to define industry-wide guidelines, which, in turn may lead to their being codified into regulation.

What level of enforcement is necessary is open for debate, and we do not address that here. After all, that level is not typically under our control to change. However, we must know what this level will be when we build our model. For example, if a firm's carbon emission levels are mandated by law, it will be crucial to measure emissions to a very rigid benchmark and make very few assumptions about our inputs, or at least use approved standards, such as government certified parameters for fleet mileage. If, however, the firm is engaging in an internal initiative to reduce emissions, more leeway is permissible. It may even be more useful to know the relative rather than absolute results of a choice. For example, a 10% reduction in emissions, rather than a decrease by 4.321 tonnes, may be more informative.

5. Logistics, Energy and CO_2 Emissions

Paraphrasing CSCMP.org, logistics involves "the management of the flow of goods, services and related information between the point of origin and the point of consumption, in order to meet customer requirements." More succinctly, logistics deals with the movement and storage functions of the supply chain. The energy used in transport and in controlled climate storage is often substantial. The DOE estimates that US transportation-related CO_2 emissions in 2007 surpassed 2.0 billion metric tons, one-third of total national emissions and the largest end use contributor. Yet a survey by Golicic et al. (2010) of Fortune 500 companies found that fewer than 10% of them have addressed the environmental impacts of transportation, and even fewer are actively implementing improvements. The focus of the rest of this module is on logistics and its requisite energy usage, and, hence, resultant carbon emissions. We must still remember speed and cost considerations.

Some terminology will help in understanding who is doing what. The *carrier* is the party that does the actual moving of the product. The *shipper* initiates the movement of the product forward into the supply chain, which the *consignee* receives. These parties may all be different entities. In particular, *Third Party Logistics Providers* (3PLs) are carriers, warehouse owners or even coordinators who arrange for transport or storage services.

Within the developed world there are four basic transport modes for shipping large quantities of packaged products: Barge/Ship, Rail, Truck and Air. Comprising over 75% of the total US freight transit bill, trucking dominates. There are different types of trucks, ownership models (3PL verses own fleet) and loading options: less-than-truckload, LTL, verses full truckload, TL.

Transport mode usage has shifted over time. The first transport revolution occurred when inland water transport, either by river or canal, replaced animal caravans. In the 1800's railroads displaced inland water as the dominant form of cargo transport and a century later trucking displaced railroads. Use of air cargo is small but growing, as it is popular for short life-cycle products like flowers and luxury foods. Airplanes account for 9% of US transportation fuel usage. Interestingly, water has started to make a comeback. On inland waterways Tesco uses barge transport for many beverage products in the United Kingdom. Also, Short Sea Shipping, using ocean-going vessels for domestic cargo, is popular in Europe and holds promise for replacing some truck routes in the US.

Let us compare transport modes on resultant emissions. Using SI units, we define a tonne-km as moving 1 tonne of cargo 1 kilometer. Figure 5.1 is based on data from Weber& Matthews (2008), showing these modes differ in resultant emissions. While caveats abound as to how accurate these figures are, with other studies showing different emissions factors, the main point of this comparison is the order of magnitude difference between transport modes: air-freighting is very emission intensive, while water and rail are the least. Figure 5.1 includes relative pricing, showing that decisions taken to reduce emissions associated with transportation can often result in lower costs, as energy usage is a large component of transportation cost. Clearly, reducing the amount of distance a vehicle has to travel has both environmental and economic benefits, and the most emissions intensive modes are also the most expensive. However, transportation costs are dependent not only on distance and mode, but on additional overhead (insurance, legal fees, etc.) needed to make sure the delivery actually happens in a manner that the goods are delivered on-time and intact, with guaranteed speedy delivery typically costing extra. Furthermore, clients with frequent, high-volume shipments, will negotiate more favorable rates with carriers, especially in markets with many competing carriers. Such considerations prevent definitive cost definitions.

Figure 5.1: Comparing Modes by Emissions and Relative Costs

Transport mode	kg CO2e per tonne-km	cost per tonne-km
Water	0.14-to-0.21	Inexpensive
Rail	0.18	Inexpensive
Truck	1.8	Moderately expensive
Air	6.8	Expensive!

Before we choose one mode over the other, we should consider intermodal transport. Defined as using more than one transportation mode to move a shipment between two points, an intermodal route might involve shipping cargo via water, then by rail, then by truck. Intermodal transport became practical with containerization, where products stay in a container through their entire journey. Containerization itself was made possible through global standardization of containers (ISO.org) and also has the benefit of reducing unloading time at ports, boosting cost-efficiency of international trade. From a sustainability viewpoint, the advantage of intermodal is that we can utilize more efficient modes for major transport corridors, and then unload to trucks for transport to more remote destinations. Shippers can also use a 3PL to oversee the complete service. However, intermodal's disadvantages include the inherent complexity of coordination, requiring greater IT support and further costs. Also, the movement and repositioning of empty containers may be an issue, and we may need to consider security. Some high value cargo, such as a container full of prescription drugs or video game consoles are worth millions of dollars, and thus prone to theft. Container shipping even raises homeland security problems, although certification programs like C-TPAT have been developed to help combat terrorism issues.

Many energy and carbon calculators primarily consider transport mode and distance traveled. We will take into account two additional factors: how highly vehicles are *utilized* and whether the vehicle makes the return journey while carrying freight, *backhaul*. While fully laden vehicles use more fuel than nearly empty ones, most of a trip's energy is expended in moving the vehicle itself. Under-utilized vehicles waste energy, as do vehicles return empty. Both weight and volume limits must be respected, and all but the lightest and bulkiest cargo loads tend to "weigh out" rather than "cube out." That is, they tend to reach their effective weight limit before all cargo space is used.

It can be difficult to determine what utilization and backhaul rates are, as they may vary with each trip. Such information is even more challenging to obtain when transportation functions have been outsourced. However, some assumptions are logical. Vehicles chartered by 3PLs are likely to be carrying multiple companies' cargos. Third party logistic providers (3PL) have strong incentives to maintain high utilization, especially for long distance routes, since transportation is their core competency and main service, with poor utilization greatly reducing profitability. During the most recent economic downturn, many ocean carriers removed cargo ships from active service, anchoring them near Singapore, rather than running them half-empty. Likewise, logistics providers will also seek to maximize backhaul rates. Firms that use their own vehicles in shipping products downstream are more likely to return empty.

The need for climate control increases energy usage and resulting emissions. Foods often require cooling, refrigeration or even freezing in transport. Climate control will also increase the energy usage associated with warehouse storage, and even the location of facilities within the supply chain can effect emissions. For example, Sim et al (2007) find that locating processing and storage facilities in countries where more electricity is generated from renewable fuels or cleaner energy can significantly reduce overall carbon emissions.

6. Analyzing a Supply Chain's Energy and Emissions

Now that we have reviewed some basics about supply chains (especially logistics), sustainability and model building, it would seem we are ready to use some web-based software and come up with a definitive answer to "How much carbon does our supply chain emit?" Before we start building our model and broadcasting results with conviction and certainty, let us consider a cautionary tale.

Consider traveling from San Francisco to New York and purchasing offsets for the round trip flight. The web has many free online carbon calculators, typically with donation links for offsetting one's carbon footprint. We investigate a few that target the typical US consumer, so we will work in the same (English) units and also avoid any exchange rate effects, such as would happen if we included British or continental European calculators. While this list is not exhaustive, it represents 5 well-established sites that provide easy access to simple calculations. Some let the user pick whether the flight is Nonstop, service class flown, and whether radiative forcing should be included.

Figure 6.1 shows that even for a well-defined trip, a variety of emissions estimates result, translating to wildly divergent offset recommendations. Yet most of the calculators report results to 2, 3 and even 4 decimal places- only NativeEnergy.com rounds calculations to whole tons. These results vary for both logical reasons, such as whether radiative forcing is included, and obscure reasons, such as why JetBlue should be almost twice as efficient as United. Note that we did not even consider other factors like plane age and model, weather, utilization, and backhaul. Figure 6.1 also shows that even for the same amount of emissions, the websites recommended different carbon pricing.

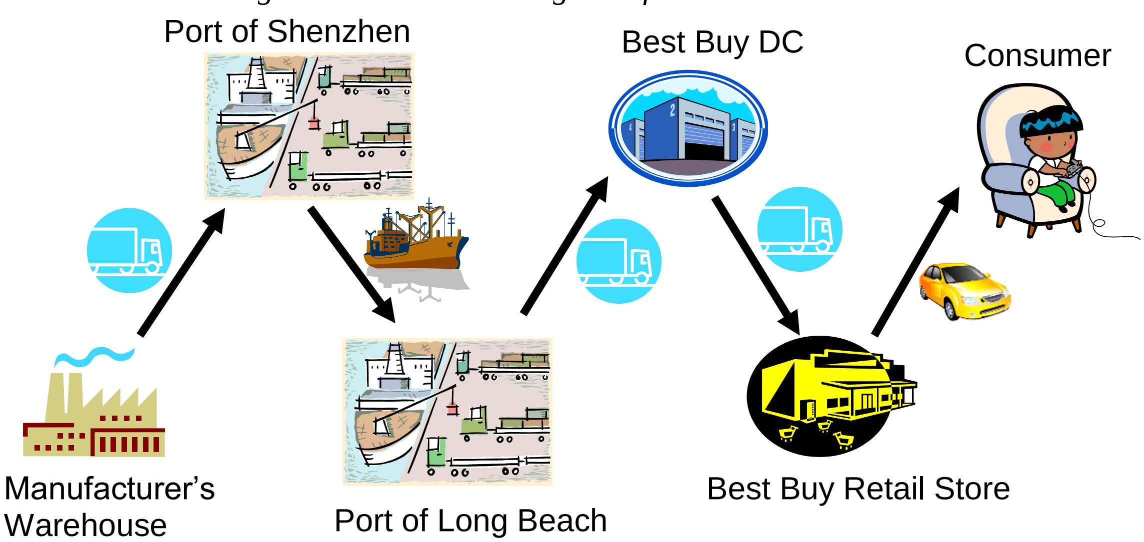
So what lessons can be learned? First, expecting high **accuracy** for emissions may be beside the point- and reporting high **precision** results is likely to be inappropriate. We should always be **consistent**, avoiding using different tools, techniques, frames or assumptions when comparing scenarios. An *Energy Policy* article recommends that definitions should be **sensible** and **transparent**, especially when no definitive standards prevail. Lastly we should consider our **audience.** Who are they and what do we want them to learn from the analysis? In providing consumers with recommendations for assessing personal transportation footprints, acknowledging the disparities between calculators and providing a range of recommended offsets may be appropriate. Otherwise we might risk backlash if consumers go to other websites and discover how divergent results can be. It should be noted that of the 5 calculators, 4 have links to assumptions and many report the formula and underlying standards used for calculations, a shift from when we first examined these websites in 2009.

Figure 6.1: Carbon Calculator Confusion: Emissions and Offsets for a Trip

Website	assumptions/options	tons CO2e, precision defined by website	website-recommended offset, $	effective $ per ton
Terrapass.com	Nonstop flight, economy (business an option)			
	via Jetblue	1.462	$11.90 for 2 tons	$5.90
	via Virgin	1.813	$11.90 for 2 tons	
	via United	2.109	$17.85 for 3 tons	$5.95
Carbonfund.org	Can opt to include radiative forcing.... Without:	0.93	$ 9.34	$ 10.04
	with:	2.52	$ 25.22	$ 10.01
b-e-f.org (Bonneville Environmental Foundation)	Air mileage only	4.192	$ 56.00	$ 13.36
Nativeenergy.com	Coach class (business costs more)	3	$ 42.00	$ 14.00
Sustainabletravelinternational.org	Coach class (business and first cost more)	1.8663	$ 47.31	$ 25.35

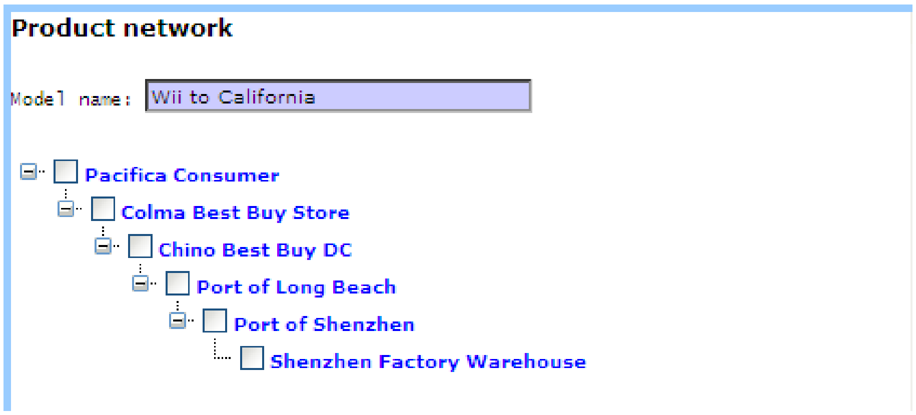
Bearing such caveats in mind, we are now ready to tackle the task of formulating and analyzing a supply chain using CargoScope. CargoScope is not the only energy and emissions calculator available, but we use it because it is easily configured, and it is reasonably transparent and documented in its assumptions and architecture. We will consider the distribution of the Nintendo Wii gaming console, as destined for a Northern California consumer, as shown in Figure 6.2. A complete description of this example is available in a separate document: *Wii-CaseStudy.doc*.

Figure 6.2: Outbound Logistics for the Nintendo Wii



While Figure 6.2 illustrates the supply chain from the perspective of the product flowing from the producer to the consumer, effective use of CargoScope necessitates modeling this system from the opposite viewpoint, starting downstream and looking upstream, towards the point of origin, as seen in Figure 6.3.

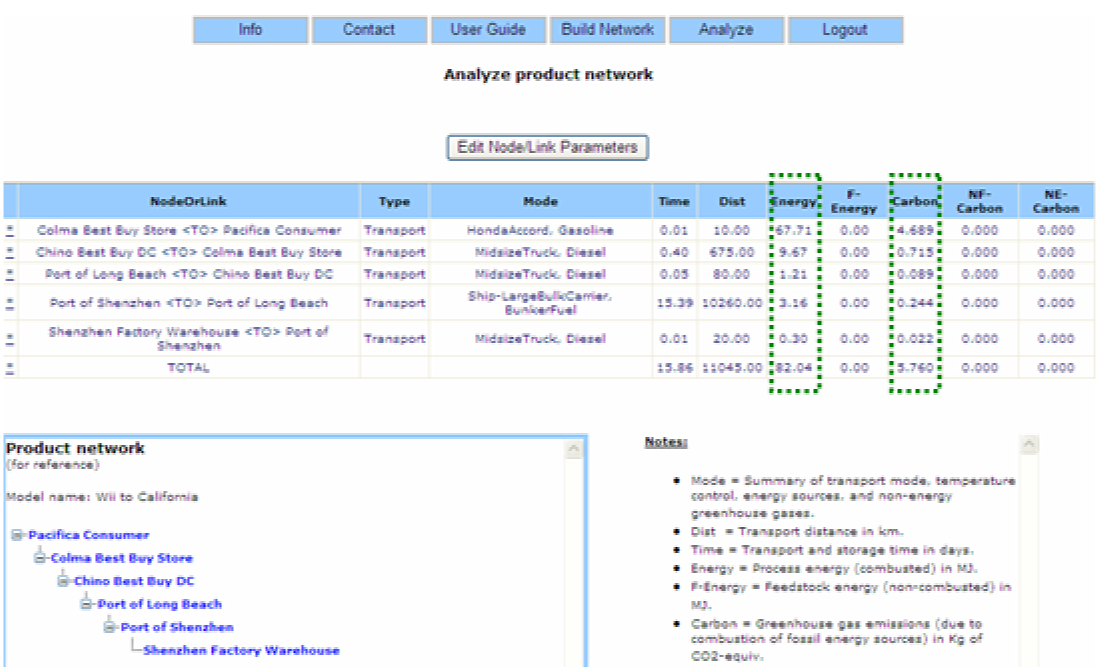
Figure 6.3: The Pull View of the Supply Chain in CargoScope



The upstream view also better enables us to calculate the emissions associated with a single unit (one Wii gaming console) rather than an entire truckload. These perspectives showcase the dichotomy between a Push verses a Pull view of the supply chain. We shall categorize nodes as storage or processing functions. We will define intra-node links by distance, transport type, temperature control, utilization, and backhaul rates.

Once we have constructed the supply chain structure and provided estimates for parameters and data, CargoScope will then provide energy usage and emissions, boxed in green in Figure 6.4. An interpretation of these results, conclusions and steps forward are best saved for class discussion after you have read and worked through the case study.

Figure 6.4: CargoScope Output



NodeOrLink	Type	Mode	Time	Dist	Energy	F-Energy	Carbon	NF-Carbon	NE-Carbon
Colma Best Buy Store <TO> Pacifica Consumer	Transport	HondaAccord, Gasoline	0.01	10.00	67.71	0.00	4.689	0.000	0.000
Chino Best Buy DC <TO> Colma Best Buy Store	Transport	MidsizeTruck, Diesel	0.40	675.00	9.67	0.00	0.715	0.000	0.000
Port of Long Beach <TO> Chino Best Buy DC	Transport	MidsizeTruck, Diesel	0.05	80.00	1.21	0.00	0.089	0.000	0.000
Port of Shenzhen <TO> Port of Long Beach	Transport	Ship-LargeBulkCarrier, BunkerFuel	15.39	10260.00	3.16	0.00	0.244	0.000	0.000
Shenzhen Factory Warehouse <TO> Port of Shenzhen	Transport	MidsizeTruck, Diesel	0.01	20.00	0.30	0.00	0.022	0.000	0.000
TOTAL			15.86	11045.00	82.04	0.00	5.760	0.000	0.000

References and Further Reading

This document is intended as an introduction to supply chains and how they may be managed to improve substantiality. By definition such overviews are cursory and may over-simplify complex issues. Those seeking a more thorough study can refer to the following books, journal articles and websites used in preparing this document and gain more insights into supply chains, sustainability and supply chain management issues.

<u>Books</u>: It is our opinion that no one teaching text yet satisfactorily addresses supply chains and sustainability issues. Instead, the following books have served as a source of inspiration and information in preparing this document and the teaching materials.

Chopra S and P Meindl (2004) *Supply Chain Management, 4th edition*, Upper Saddle River, NJ: Prentice Hall.

Davis E and R Spekman (2004) *The Extended Enterprise: Gaining Competitive Advantage through Collaborative Supply Chains*, Upper Saddle River, NJ: Prentice Hall.

Glaser B (2002) Efficiency Verses Sustainability in Dynamic *Decision Making: Advances in Intertemporal Compromising*, New York, NY: Springer-Verlag.

Jacobs R and R Chase (2010*) Operations and Supply Management: the Core, 2nd edition*, New York, NY: McGraw Hill/Irwin.

McDonourgh W and M Braungart (2002) *Cradle to Cradle*: *Remaking the Way We Make Things,* New York, NY: North Point Press.

Wackernagel M and W Rees (1996) *Our Ecological Footprint: Reducing Human Impact on the Earth*. Gabriola Island, BC (Canada): New Society Publishers.

<u>Journals:</u> Peer-reviewed journal articles highlight some of the academic and industry research in the field, and trade journal and popular press articles showcase how aspects of sustainable supply chains have been implemented or are being perceived by business leaders and the general public.

Blanke M and B Burdick (2005) Food (miles) for thought: energy balance for locally-grown versus imported apple fruit. *Environmental Science and Pollution Research* **12**(3):125-127.

Carter CR, and DS Rogers. (2008) A framework of sustainable supply chain management: moving toward new theory. *International Journal of Physical Distribution & Logistics Management* **38**(5): 360-387.

Cholette S and K Venkat (2009) The Energy and Carbon Intensity of Wine Distribution: A Study of Logistical Options for Delivering Wine to Consumers, *Journal of Cleaner Production* **17**(16): 1401-1413.

Golicic S, C Boerstler, and L Ellram (2010) Greening Transportation in the Supply Chain, *MITSloan Management Review* **51**(2).

Johnson E (2008) Disagreement over carbon footprints: a comparison of electric and LPG forklifts, *Energy Policy* **36**(4): 1569-1573.

Martin A (2007) If It's Fresh and Local, Is It Always Greener? *The New York Times*, Dec. 9th, Available online: www.nytimes.com/2007/12/09/business/yourmoney/09feed.html?_r=2

Milà i Canals L, SJ Cowell, S Sim, L Basson (2007) Comparing Domestic verses Imported Apples: A Focus On Energy Use, *Environmental Science and Pollution Research* **14**(5): 338-344.

Sim S, M Barry, R Clift, SJ Cowell (2007) The relative importance of transport in Determining an Appropriate Sustainability Strategy for Food Sourcing, *International Journal of Life Cycle Assessment* **12**(6): 422-431.

Weber C and H Matthews (2008) Food-Miles and the Relative Climate Impacts of Food Choices in the United States, *Environmental Science Technology* **42** (10): 3508–3513.

Websites do not have the permanence or carry the same validated authority as do published books and journals. However, through judicious selection of appropriate sources, the internet can be a useful resource for supplemental information, especially on work in progress, recent news and industry trends. Below are some relevant websites from respected organizations:

www.APICS.org An acronym for Advancing Production, Innovation and Competitive Success, this professional society offers certification and other educational opportunities within the field of Operations Management.

www.bohemian.com/bohemian/01.06.10/eats-1001.html The online version of a newspaper article showcases the wine industry and how recycling is not always as green as people may think. Subject to proper operations and sorting, reuse is more sustainable than recycling.

www.capitalpress.com/california/ws-Sustainable-metrics-112709 This site describes a collaborative effort project currently underway (as of 2010) to create an industry recognized standard, or at least guideline, on sustainability metrics.

www.Cleanmetrics.com Cleanmetrics is a company devoted to measuring and improving firms' environmental performance. In addition to hosting the educational online carbon footprinting tool, CargoScope, the site provides a list of resources for the budding sustainability analyst, including links to existing and developing standards.

www.CSCMP.org The Council of Supply Chain Management Professionals is the largest professional organization for supply chain practitioners. Local chapters (roundtables) organize speaker events that are worth attending for educational content and networking potential. Interesting facts about logistics can be found at: cscmp.org/press/fastfacts.asp

www.eia.doe.gov/ This is the website for the US Energy Administration (DOE), which houses an extensive repository of reports filled with useful facts. One such report, published May 2009 and entitled "US CO2 emissions from Energy Sources 2008 Flash Estimate" provided data for this document.

www.epa.gov/nrmrl/lcaccess/ The EPA's overview on LCAs is found here, including a link to a multiple chapter PDF document on performing such an assessment.

www.footprintnetwork.org Rees and Wackernagel's website on ecological footprints includes topical updates of their 1996 book.

http://www.ghgprotocol.org Sponsored by the World Resource Institute (WRI), this site provides news of US-based initiatives and downloadable tools for carbon footprinting. (free, but registration required for most tools).

http://www.leopold.iastate.edu/pubs/staff/ppp/index.htm This university-sponsored site is a source for many pro-"local" food studies, such as Pirog R, T Van Pelt, K. Enshayan and E Cook (2001*) Food, Fuel and Freeways: An Iowa perspective on how far food travels, fuel usage, and greenhouse gas emissions*.

http://www.lincoln.ac.nz/Research-at-Lincoln/Research-centres/Agribusiness-and-Economics-Research-Unit/AERU-publications/ This university research site a source of many studies that refute many of the claims that local foods are always more sustainable. For example: Saunders C, A Barber and G Taylor (2006) *Report 285- Food Miles-Comparative Energy/Emissions Performance of New Zealand's Agricultural Industry.*

www.shell.com/shellreport Shell was of the first large companies to embrace 3BL principles, document and publish the effort. Their latest annual report is available here.

www.sustainablewinegrowing.org Formed by growers, vintners and an industry advocacy group, the California Sustainable Winegrowing Alliance (CSWA) is a good example of an industry attempting to self-regulate itself through voluntary participation and outreach. While specific to the wine industry, website documentation can be understood by the general public. This is one of the sustainable programs mentioned by http://www.winereviewonline.com/caputo_sustainable_viticulture.cfm#

http://www.supply-chain.org/ The website of the Supply Chain Council, the organization behind SCOR, the predominant suite of supply chain metrics. See also Blanchard D (2008) SCOR Goes Green: Updated Supply Chain Operations Reference Model addresses environmental sustainability efforts while expanding risk management capabilities, *Industry Week*, May 1st.