other considerations, impact the path forward. Those who closely watch these developments agree on this much: Packagers can take many different directions in addressing packaging's impact on the environment, and all of them can be debated with both advantages and flaws found.

Manufacturers are well underway with many sustainability initiatives. In the beverage industry, for example, emerging initiatives include reducing plastics, increasing recyclable/biodegradable content, switching to other materials, incorporating more postconsumer-recycled (PCR) material, introducing returnables and exploring paper-based bottles. In medical devices, manufacturers are working with suppliers and end-users in facilities such as operating rooms to reduce packaging where possible and to put surgical instruments into doctors' hands faster while also keeping them sterile until the time of use. The industry also is beginning to discuss where and how packaging at hospitals might be recycled rather than discarded.

Across packaging, many companies have created departments or teams to address packaging and sustainability. More recently, professionals with sustainability-facing titles are beginning to have a seat in the C-suite.

While these initiatives are positive developments, it is important to understand there is no silver bullet for packaging and optimal environmental impact reduction.

The purpose of this chapter is not to debate approaches or determine correct or incorrect paths but rather to ground packaging professionals in the key concepts and considerations they need to understand to help shape meaningful collaborative discussions and make informed decisions. Informed, well-reasoned decisions will move packaging toward the development of sound technical, end-of-life and infrastructure solutions that reduce packaging's footprint while allowing it to perform all its other essential functions.

Only then can the packaging professional on the front lines of sustainability begin to collaborate and "do something" that advances the industry's role in protecting our planet.

The Four Rs

The guiding principles for designing environmentally responsible packaging are embodied in the four Rs hierarchy developed in the early 1990s and still valid today:

1. **Reduce:** Packaging designs should use the minimum amount of material consistent with fulfilling their basic function. A reduction in material use will diminish further considerations of reusing, recycling or recovering other value.
2. **Reuse:** Where practical, containers or packaging components should be reused.
3. **Recycle:** Where practical, packaging should be collected and the materials recycled for further use.
4. **Recover:** Finally, before consigning packaging to a landfill, some thought should be given to possibly recovering other value from the waste.

Recycling is the R that has caught the imagination and devotion of great parts of the consuming public. Despite its many problems, few public figures would risk anything other than positive commentary. However, many public myths exist about recycling, perhaps the greatest being that placing material in a collection box

Figure 5.1
A code identifies the main packaging plastic families. PETE usually is abbreviated PET and V is usually abbreviated PVC. Less commonly used plastics and mixed-plastic constructions are classified as "other." (Source: Society of the Plastics Industry, now the Plastics Industry Association.) Note: PET is a registered company trademark. When appearing on a package, the acronym PETE was selected to avoid a trademark infringement. PETE is not different from PET.

constitutes recycling. Recycling does not occur until someone uses the material collected.

A second myth presupposes that since the recycled material is recovered from discards, it should be economical. In most instances, using recycled material offers little if any economic advantage. The cost of landfilling municipal solid waste is still less than that of recycling in most areas. The bulk of the recovered material is paper and has low value. Aluminum, the material with the highest value, represents as little as 2% of the collected weight. Revenues generated from the sale of recyclable materials do not always recover collecting and recycling costs. Obviously, someone has to make up the shortfall.

Other myths propose that one or another of the packaging materials is more environmentally friendly. There is no magic material. Packagers select appropriate materials to contain, protect/preserve, efficiently transport and sell the product most cost-effectively. Laminate constructions, a favorite target for critics, are designed to combine the best characteristics of several different materials, offering properties not available with any single material. Their design is based on the most cost-effective and material-efficient method of achieving the needed result. They are, in fact, environmentally preferable.

Other impediments are the development of markets for PCR materials and the guarantee of a consistent and reliable supply of the recovered material.

Paper products vary considerably in fiber makeup and quality. However, reasonably efficient sorting systems are in place, and some cross-contamination of paper types is not a serious problem. On the negative side, paper fiber quality deteriorates with every recycling; so, paper cannot be recycled indefinitely.

Plastic materials pose some serious recycling problems. Many different plastics are used in packaging, and many are not mutually compatible. Identifying and sorting the plastic materials by appearance alone is beyond the abilities of even a conscientious consumer. The plastics industry developed a code for identifying the six most commonly used packaging plastics, plus an "other" category as a seventh code. (See Figure 5.1) The code identifies only the general plastic family; significant variations can occur within each family.

The resin code, which now is administered by ASTM International as the Resin Identification Coding System, or RIC, specifically identifies six plastic material families. However, only polyethylene terephthalate (PET) and high-density polyethylene (HDPE) are collected and recycled by most municipal recycling programs. The reason is they represent the bulk of plastic packaging. The remaining four together represent only a small fraction of the plastics used in packaging. The economics of collecting and sorting these small quantities currently is prohibitive.

The frequently used phrase “plastic will last a thousand years in a landfill” has introduced a perceptual problem in the eyes of the general public. Glass also will last a thousand years in a landfill, but that does not seem to be an issue. It would be nice if all plastic (or glass) could be composted into mulch, but the fact that they cannot be is not necessarily a major problem.

Most waste management issues fall under local and regional jurisdictions rather than national jurisdiction. The problem this poses for industry is that every state or province can pass its own packaging regulations or mandates, which can take many forms. Examples of past and current regulations in North America include:

- Recycling mandates/recycled-content requirements.
- Material bans or restrictions; for example, heavy metals or polyvinyl chloride (PVC).
- Green labeling requirements/prohibitions.
- Purchasing preference mandates.
- Tax incentives/penalties.
- Deposit laws/advance disposal fees.
- Volume-based household garbage removal fees, such as paying by the bag or can.
- Extended producer responsibility (EPR)/stewardship laws where the producer is responsible for the product and package up to and including proper disposal.

Developing packages able to meet dozens of differing waste-management requirements would present a formidable challenge.

Energy is one value that is recovered from waste in many parts of the world (as high as 70% in some countries). However, with not-in-my-backyard attitudes and a negative position held by environmental groups, incineration is highly politicized in North America. It is not likely that this useful technology will be employed in the near future, even though many authorities agree that incineration can make a positive contribution to waste management.

A life cycle that includes incineration of polyolefin plastics such as PE and polypropylene (PP) is referred to as the cascade model. (See Figure 5.2) PP, for example, is made by joining molecules of a gas related to propane. It can be regarded as propane in a solid form. Propane gas can be burned for its energy value directly, or it can be reformed into PP.

The plastic can be used as a food container and recycled, perhaps to become an office letter tray. After several useful reincarnations, when incinerated, it still will have a large percentage of its original propane energy content. Combustion by-products are water and carbon dioxide.

Germany’s Packaging Ordinance was the first national action where EPR was enacted. The ordinance’s basic principle is that manufacturers or distributors must take back used packaging for reuse or recycling. The collection could be done by the company or the company could contract an outside source to do this for them. Industry established a comprehensive collection system for those who paid a collection fee, as signified by a green dot on the package. Because of the two ways of

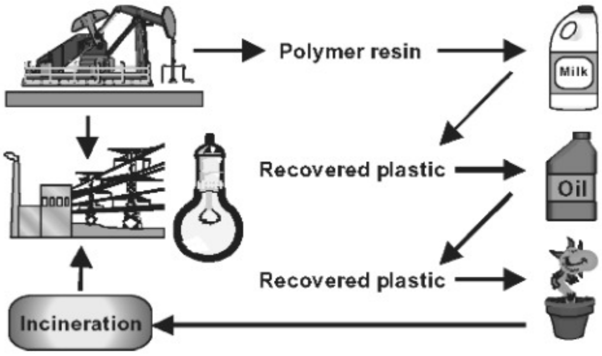


Figure 5.2
The cascade model proposes that monomer gases such as ethylene and propylene can be used to make useful plastics, recycled several times and still possess most of their energy value when incinerated.

collecting used packages, it is described as the "Dual System" (DS or DSD). European Union countries have since adopted variations or elements of the DSD system. In Europe, the EPR concept is being applied to other products as well as packaging.

In Canada, the provinces of Ontario and Quebec recently have started versions of EPR where brand owners pay a levy for packaging materials based on the cost of collecting and recycling a given material minus the revenue generated by the sale of the recycled material. If the recycling rate for a material increases or if revenue from the sale of recycled product goes up, then the material levy will be reduced proportionately. In the instance of Ontario, the generated revenues will be used to pay for 50% of municipal collection and recycling costs.

Many authorities concede that, in the long term, we will move to similar EPR programs.

The dilemma of packaging and waste management is complex and not amenable to simplistic solutions. Every packaging professional should be involved in educating the public about the real and vital benefits of packaging. Inflexible environmentalism needs to be replaced with a keen awareness of packaging's legitimate role and the difficult decisions that must be made. In the final analysis, the consumer makes the choices and will direct the course of the industry. The consumer deserves to have the correct information to make those choices.

Sustainability

Recycling packaging materials is an important issue that has occupied the public's attention since the late 20th century, but another, more serious, issue has crept up in more recent times: the issue of sustainability. The focus in the general press has tended to be on global warming and greenhouse gas (GHG) emissions, but this is only a small part of the picture.

- Despite replanting, global forest coverage is shrinking every year.
- Global fisheries are being depleted. Those such as the Grand Banks off North America's East Coast as well as others have already been essentially fished out.

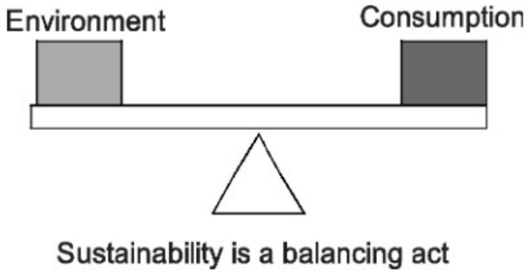


Figure 5.3 Sustainability strikes a balance between what resources the environment can supply and absorb back into itself and humanity's levels of consumption.

- Changing weather patterns have caused severe water shortages. (The Midwest United States and Canada, Southwest United States, Africa's Sahel region and Australia, to name a few).
- Arable cropland is shrinking. Food shortages are increasing.
- Petrochemicals, a primary global energy source, are becoming harder to come by, as are many other minerals essential to modern industry.
- Air, water and soil pollution is increasing, as is global temperature.
- The global economic model is based on continuous growth, while global resources are fixed.

Our consumption of resources has gone beyond the balance point at which the environment can accommodate and regenerate them. (See Figure 5.3) Meanwhile, the global population will grow by 1.7 billion people by 2025. Put in perspective, that's about six times the population of the United States. How are we going to feed, clothe and shelter 1.7 billion more people when we are unable to do so today?

In summary:

Consumption of life-sustaining resources is increasing while the availability of life-supporting resources is decreasing.

This is not sustainable.

Sustainability Definitions

The original definition of sustainability and sustainable development was issued by the Brundtland Commission (from Our Common Future) as: *"The concept of meeting the needs of the present without compromising the ability of future generations to meet their needs."*

The *Oxford Concise Dictionary of Ecology* defines sustainability as *"Economic development that takes full account of the environmental consequences of economic activity and is based on the use of resources that can be replaced or renewed and therefore are not depleted."*

Global Warming

The role of the scientist is to quantify the universe around us. Those measurements must be peer-reviewed and must be accepted by the general scientific community as being correct before they are accepted as truth. The scientific community is rarely wrong in their measurement; where debate occurs, it usually concerns implications of the new knowledge or its impact on future events. It should be noted that predicting the future is, strictly speaking, not science.

Global warming is not an issue that suddenly caught the scientific community by surprise. Swedish chemist Svante Arrhenius made the following statement in 1890:

> *"If you keep pumping carbon dioxide into the air the way humanity has been doing since the dawn of the industrial age, you can double the level of the heat-trapping gas in the atmosphere, raising temperatures dramatically."*

He spent a full year calculating what the global temperature would be when the carbon dioxide level doubled. His answer was within fractions of a degree to that developed by today's sophisticated measuring devices and computers.

Today the Intergovernmental Panel on Climate Change, an international scientific community of some 1,000 scientists, is unanimous in its conclusion that human activities are the cause of recent increases in average global temperatures. They may not be unanimous in some of the details, but on the matter of climate change, they are in total agreement. Unfortunately, many of the world's leaders (few with scientific training) have chosen to disregard or even dispute the seriousness of the findings and to varying degrees have not fully responded.

As a result of this disagreement, many states, provinces and even cities, as well as assorted industries and industry associations, have taken lead positions in developing programs that are sustainable for the long term.

Unlike programs related to waste management and recycling, sustainable development is not about some particular material, activity or location; it is a global problem and concerns all human activities. As such, its resolution requires a comprehensive and global response.

The difficulty of forming a global consensus is partly due to the great disparity in the economic status and population of different countries. The higher the per capita income, the higher the consumption rate of products and services, and therefore the higher the per capita carbon dioxide footprint. For example, according to the Carbon Dioxide Information Analysis Center, the per capita carbon dioxide footprint for an American is about 20 tons per year and for a Canadian about 17 tons per year. Compare this to developing countries: China at about 3 tons per capita and India at about 1 ton per capita.

If countries are compared on total emissions, then a country like China ranks as a major global contributor of greenhouse gases (GHG). Understandably, such countries protest when it is suggested that they should reduce their carbon dioxide emissions, while the citizens of developed countries are producing per capita GHG gases six or seven times that of a Chinese citizen.

SUSTAINABILITY AND PACKAGING

The packaging industry is a major consumer of materials and, as a result, a relatively significant producer of waste (while many consumers remain confused on how to properly discard packaging). Furthermore, it is a significant user of energy, both in the production of materials and packaging, as well as for transportation in a global economy. Today, nearly 140 developing countries are seeking ways to meet their development needs, and the packaging of goods has become more prominent for many, for example, as a way to reduce food spoilage and waste.

On the other hand, with the increasing threat of climate change, concrete efforts are necessary to ensure today's development does not negatively affect future generations. As previously mentioned, there is a considerable focus on the packaging industry to do something, and solutions fall along a spectrum where environmental concerns and business objectives meet. Packaging professionals are charged with the responsibility of ensuring that packaging is manufactured in accordance with sustainability principles. (See Figure 5.4)

PMMI Business Intelligence cites four ways in which companies strive for sustainability:

- **Through packaging**—environmental consciousness, convenience, innovative appeal and diversity in size and shape.
- **Through sourcing**—renewable resources, plant-based alternatives, production by ethical means and earth-stewardship responsibility.
- **Through manufacturing**—updating outdated technology, implementing smarter solutions, eliminating inefficiencies and maximizing quality output.
- **Through health**—adding nutritional functionality, including natural ingredients, introducing flavors from nature and reducing sugar.

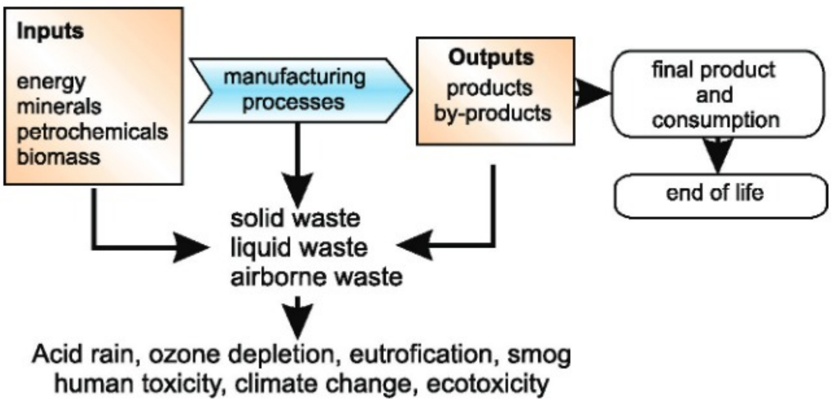


Figure 5.4
Manufacturing in accordance with sustainability principles requires that every phase of a product's manufacture be considered from the initial raw materials inputs to the final proper disposal at the product's end-of-life. No harmful waste or by-products should be released to the environment.

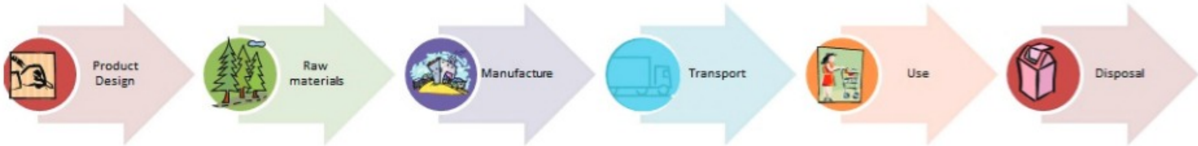


Figure 5.5
Cradle-to-Grave.

The challenge for packaging professionals and others responsible for a company's sustainability efforts is balancing all these influences while staying focused on the company goals. For the packaging professional, planning for a successful path forward starts with a look at the emergence and evolution of sustainability efforts.

Cradle-to-Grave

Until the latter part of the 20th century, a product manufacturer was concerned only with the manufacture of the product and didn't pay much attention to the downstream and upstream processes. By the late 1980s, waste management emerged as an issue, and manufacturers became concerned with end-of-life treatments of the package and product residues. This is what is commonly referred to as Cradle-to-Grave. (See Figure 5.5) At this point, they still did not concern themselves much with raw materials inputs, the conversion of raw materials into useful materials and the conversion of useful materials into packaging.

Solid waste, liquid waste and airborne emissions were treated casually for the most part. The casual disposal of solid waste has resulted in eco-toxic and human-toxic soils, leachable landfills that contaminate water sources and the emission of methane—a potent GHG—among other problems.

Cradle-to-Cradle

The Cradle-to-Grave paradigm that proposed that a producer should be responsible for a packaging material until it has been properly disposed of gave way to the Cradle-to-Cradle paradigm in the early 2000s. In this scenario, the objective is to recover used packaging material and return it into the manufacturing cycle to be manufactured into new packaging. (See Figure 5.6) Failing this, the producer should recover some other useful values such as energy or composting from the residues. Landfilling should be the option of last resort.

With heightened public awareness, product manufacturers were finding themselves having to understand the impact of their entire manufacturing process on the environment and the Cradle-to-Cradle paradigm supplanted Cradle-to-Grave thinking. (See Figure 5.7) The paradigm shift was greatly enhanced by the 2002 publication of *Cradle to Cradle: Remaking the Way We Make Things* by William McDonough and Michael Braungart.

(Further comparisons between Cradle-to-Grave and Cradle-to-Cradle are displayed in Figure 5.11.)

However, mainstream packaging today is still primarily a linear process. Raw materials are used in making product packaging, the product is used, and the packaging is discarded. This traditional model creates many challenges, particularly for plastics.

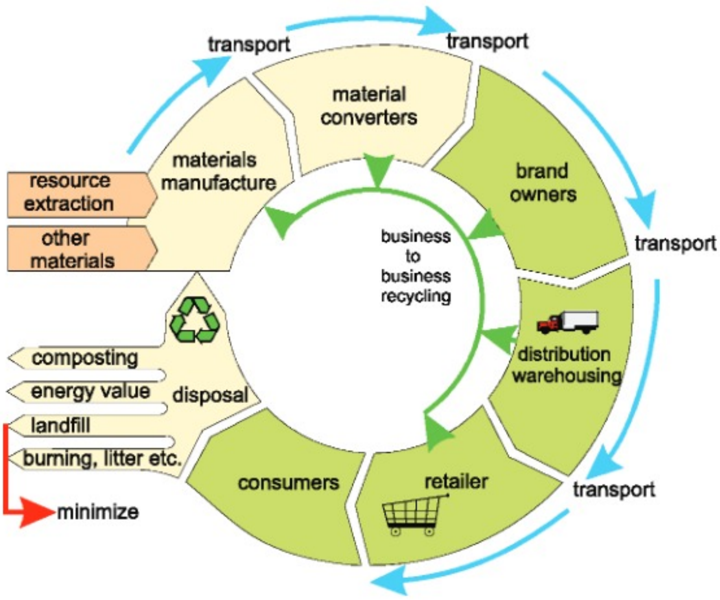


Figure 5.6
The use of packaging materials should ideally be within a closed-loop system where at end-of-life the material is returned into the loop to be reborn again as another package.

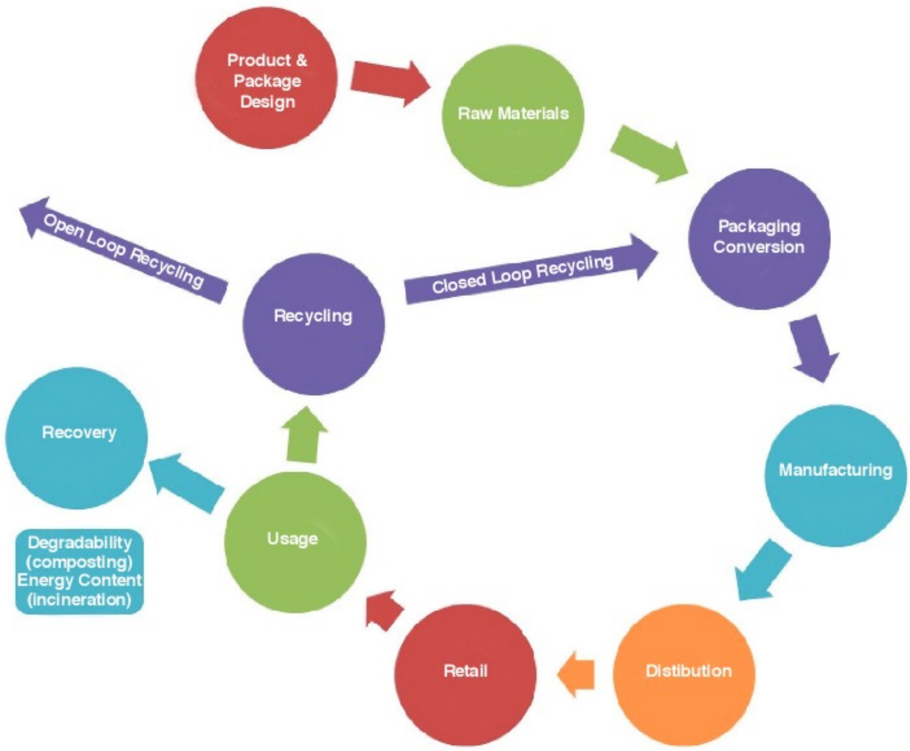


Figure 5.7
Cradle-to-Cradle.

The Circular Economy

More recently, the packaging industry focus has evolved to the Circular Economy. The broad concept of Circular Economy traces its roots to the 1960s and 1970s but first began circulating in packaging circles about 2015. In a Circular Economy as it relates to packaging, unwanted packaging is eliminated to ensure that packaging material stays in the economy and doesn't become waste. This occurs through innovative design in which packaging is optimized to be recycled, reused or composted. (See Figure 5.8)

Today, many organizations and thought leaders are investing in the development of Circular Economy packaging solutions. In these scenarios, packaging waste is either infinitely reprocessed, or it can re-enter the system as raw materials for other products. Not only is this a positive development for environmental reasons, but it also helps generate business value. Why? Because, according to a Unilever international study, "a third of consumers are now choosing to buy from brands they believe are doing social or environmental good." Recyclable packaging, for example, presents consumers with a tangible way in which they believe they can contribute—in particular as their increasing preference for online purchasing convenience has created a significant increase in single-use packaging generated by e-commerce.

Nearly one-quarter of consumers responding to the Unilever study said they would choose brands if they made their sustainability credentials clearer on their packaging and in their marketing. Furthermore, 78% of shoppers in the United States and 53% of shoppers in the United Kingdom (UK) say they "feel better" when they purchase products that are sustainably produced. The number rises to 88% in India and 85% in Brazil and Turkey. For product manufacturers, this way of thinking about packaging represents an area of significant potential opportunity for sustainable goods.

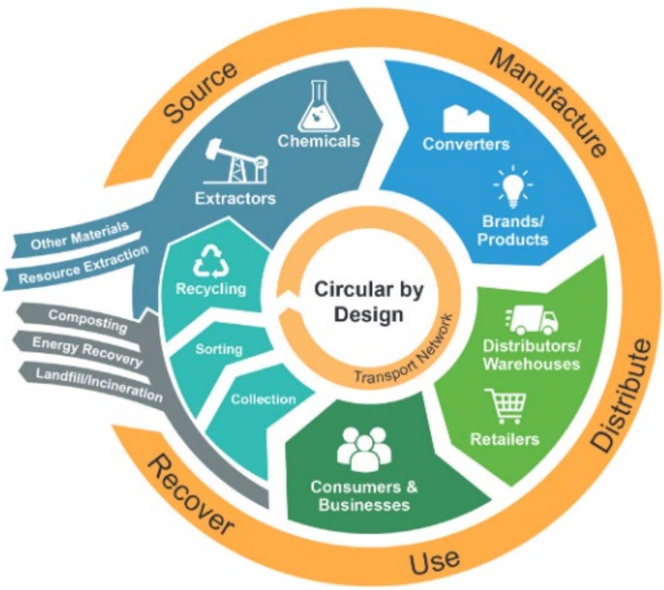


Figure 5.8
The Circular Economy for the packaging industry. (Provided courtesy of the World Packaging Organisation.)

The pillars of the Circular Economy are protecting the environment, reducing waste and GHG emissions, systematizing recycling and ending planned obsolescence. In addition, dependence decreases on imported resources such as raw materials, water and energy.

The packaging goals of the Circular Economy are to eliminate unnecessary packaging; develop innovative approaches in which all necessary packaging is designed to be safely reused, recycled or composted; and ensure that materials produced for packaging remain in the economy and avoid becoming waste or pollution. Companies at the leading edge of the Circular Economy are beginning to roll out ambitious plans to make every piece of their packaging reusable, recyclable or compostable. This area is evolving rapidly.

Beyond that, pioneering companies are developing alternative delivery or reuse models while examining action plans to minimize unrecyclable packaging or unnecessary packaging that does not add value to the product or its protection. One example is the exploration of alternatives to plastic straws. Efforts at making improvements where possible with existing materials and developing alternative sustainable materials and processes, among other initiatives, are evolving rapidly.

However, it also is important to consider that redesigning packaging for circularity can fall short of delivering the intended results if waste-management systems aren't in place to ensure the packaging is recycled, reused or composted in practice. Package design teams need to join all other stakeholders in this value chain and commit to not only designing appropriate packaging but also to helping build effective, efficient and inclusive systems for collection, reuse and recycling.

Here are four sources of inspiration and guidance:

- The Ellen MacArthur Foundation, a UK-based nonprofit promotes the Circular Economy and advocates for EPR for the packaging industry. (See www. https://ellenmacarthurfoundation.org/reuse-rethinking-packaging) A growing number of companies endorses the EPR approach to packaging.
- Sustainable Packaging Coalition: https://sustainablepackaging.org.
- The Recycling Partnership, https://recyclingpartnership.org/circularity/.
- Consortium for Waste Circularity, https://wastecircularity.org.

With this shifting paradigm, companies are making a Life Cycle Inventory (LCI) and conducting a Life Cycle Assessment or Analysis (LCA) on their products.

Life Cycle Assessment (LCA)

A life cycle is a plotting of the complete material, energy and process flow path from raw materials to the end of life for a particular product. The plot also details by-products and solid waste, liquid effluent and atmospheric releases. (See Figure 5.9) The quantities of each input and release are determined and added to this diagram to make an LCI. Using this complete picture, an LCA is conducted to identify opportunities for increasing the sustainability level. LCA is useful for focusing on the overall picture and as a means of eliminating oversights.

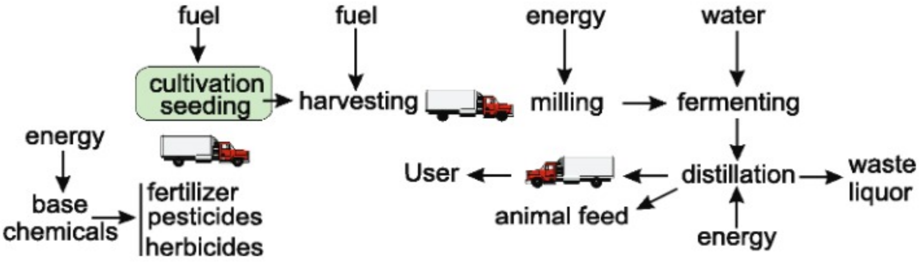


Figure 5.9
A simplified life cycle. Transportation fuel is part of the life cycle. The illustration approximates the life cycle for manufacturing ethanol from corn.

A not uncommon situation occurs when an apparently positive change in one part of the life cycle causes a more negative condition in another part. A good LCA circumvents this problem.

Many sustainability benefits are being claimed for various products that are marginal at best and deceptive at worst (so-called “greenwashing”). Downgauging or lightweighting a package certainly is laudable, but such work almost always has been done as part of a corporation’s continuous improvement program. It is not an innovative step forward into a new paradigm, it’s just doing what we’ve always done but giving it a different name. In terms of an LCA, it’s just one small bit in a complex flow of materials, energy, manufacturing practices and so on.

International concern led the International Organization for Standardization (ISO) to develop the ISO 14000 series of standards. These documents do not set recycling target levels or mandate package types. Rather, the ISO 14000 family provides guidance for suitable management policies, auditing methods, environmental labeling practices, corporate environmental performance evaluations and the LCA protocol guides, among other subjects. In summary, these are practical tools to help companies and organizations manage their environmental responsibilities.

A full, thorough LCA can be quite time-consuming and resource-intensive. So, it is necessary to understand everything that is involved before taking on this effort. Numerous resources can be leveraged including the ISO and Society of Environmental Toxicology & Chemistry (SETAC).

ISO 14044: 2006 — Life Cycle Assessment Requirements & Guidelines

“Specifies requirements and provides guidelines for LCA, including: definition of the goal and scope of the LCA, the life cycle inventory analysis phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, relationship between the LCA phases and conditions for use of value choices and optional elements.”

Society of Environmental Toxicology & Chemistry

In 2011, in conjunction with the UN Environment Program (UNEP), the SETAC Life Cycle Initiative published a free, downloadable 160-page document entitled *Global Guidance Principles for Life Cycle Assessment Databases: A Basis for Greener Processes and Products*. According to SETAC, one of the key objectives of the UNEP/SETAC Life Cycle Initiative is to foster a globally accepted LCA practice that builds on the concepts and methods in the ISO standards.

Armed with an LCI and an LCA, companies are better able to understand how their products’ manufacturing processes affect both upstream and downstream processes. With the growing interest in LCAs, sophisticated pieces of software such as GaBi and Sima Pro, as well as some user-friendly tools like COMPASS and PIQET, have made it a little easier for package designers to understand the impact their design choices make. These tools aim to quantitatively weigh and compare many different environmental impacts.

GaBi and Sima Pro, two leading full LCA tools, can accept all of the materials and processes for a package and its delivery and generate a list of its environmental impacts. The software can combine the various environmental impacts into a single score, which can be helpful for comparison.

- GaBi (from the University of Stuttgart, Institute of Polymer Testing and Polymer Science): high-quality LCA software (for all materials, not just plastic). (See http://www.gabi-software.com/)
- Sima Pro (from PRé Consultants): another leading LCA software (See http://www.simapro.com)

In addition, two newer user-friendly software tools allow the packaging designer to quickly assess the differences among multiple package designs.

- COMPASS (from the Sustainable Packaging Coalition): a comparative packaging assessment online software tool utilizing LCI data. (See www.sustainablepackaging.org/projects/compass)
- PIQET (from the Sustainable Packaging Alliance): a tool used for rapid packaging environmental impact assessments. (See http://www.sustainablepack.org/)

Energy considerations are an important part of an LCA. The cost of transport fuel is a large part of this cost, and exhaust gases are a major source of GHG. A large percentage of electricity is generated by coal-fired generating stations, and in the United States, these contribute more GHG to the atmosphere than transportation fuel.

Biodegradability

Biodegradation is the process by which a material is converted by microorganisms into basic elements and compounds such as carbon dioxide, water and mulch that can be safely absorbed into the ecosystem. Biodegradability is a positive sustainability attribute.

In the context of packaging materials, glass and metals are not biodegradable but, since they are easily recycled, this is not viewed as a problem. Paper is biodegradable and also not viewed as a problem.

Traditional plastic materials, however, are not biodegradable. Furthermore, although recyclable in principle, in practice there are many obstacles to be resolved, the most significant being sorting the collected plastics into their respective families and sometimes sub-groups within that family. Another problem concerns product residues that are absorbed into the plastic.

Recent developments have launched a group of biodegradable plastics; leading among these polymers is polylactide made from starch. (Polylactide frequently is referred to as polylactic acid or PLA.) Packaging made from corn starch is suitable for limited-use products such as takeaway food. Biodegradable plastics technology is a continually advancing area. The U.S. Environmental Protection Agency (EPA) is one source of current information at www.epa.gov/trash-free-waters/frequently-asked-questions-about-plastic-recycling-and-composting.

When selecting a plastic for an application, the package designer will determine the group of performance criteria (properties) required to contain and protect the product through production and distribution. (Stiffness, barrier qualities, machinability, coefficient of friction, printability, product compatibility, glass transition temperature and biodegradability are some of the properties likely to be considered.) The choice is based on which plastic will provide the greatest number of the required properties at the lowest cost. In many cases, no single plastic can fulfill all requirements. So, it is often necessary to specify multilayer structures that consist of several plastics. In making this choice, primacy is given to the safety and security of the product at an acceptable cost. Biodegradability is a secondary focus but pursued where possible.

Another factor to consider is how and where biodegradation will take place. Some biodegradable plastics biodegrade best in industrial composters that operate at elevated temperatures. Biodegradation at the ambient conditions of a backyard composter is marginal at best. This would suggest that a means of separating biodegradable plastics would have to be put in place. This is not a likely prospect for the immediate future. As a minority plastic, it would join the other minority plastics that are not recycled to any extent simply because quantities are too small to make recycling economically viable. The majority still will end up in a landfill. The sealed and capped environment inside a modern landfill is not conducive to aerobic biodegradation.

This is not to say that biodegradable plastics have no applications in packaging. There are many expanding niche markets where they are already in use, and others will be found. Further development will broaden their application window to make them more suitable for additional applications.

However, biodegradable plastics should not be viewed as the sole solution for all the problems of using and recycling plastic materials.

Compostability

Though the terms “biodegradable” and “compostable” share similarities, there are notable differences, according to the Biodegradable Products Institute (BPI). Everything that is compostable is biodegradable, but not everything that is biodegradable is compostable.

Biodegradable material will decompose by bacteria or other living organisms. There are no specifications on environments or timeframes for when the material will decompose. Technically, many things are biodegradable but the rate and success of decomposition depend on the environment and access to active bacteria or other organisms to break down the material.

When we say a material is compostable, the term refers to a specific timeframe and environment validated through standards set by organizations such as ASTM International. These standards provide scientific verification that a material can safely break down in a commercial compost facility and will not negatively impact compost quality.

"In this way," BPI says, "'biodegradable' is not an appropriate attribute for describing the end-of-life for products and packaging because it lacks specificity on timeframe and environment. This term is generic and misleading, which is why it is illegal to market products as 'biodegradable' in some states."

More detailed and current information on biodegradability and compostability is at www.bpiworld.org/BPI-Resources.

DEFINING AND PRODUCING SUSTAINABLE PACKAGING

Sustainable Packaging:

- Is beneficial, safe and healthy for individuals and communities throughout its life cycle.
- Meets market criteria for both performance and cost.
- Is sourced, manufactured, transported and recycled using renewable energy.
- Optimizes the use of renewable or recycled source materials.
- Is manufactured using clean production technologies and best practices.
- Is made from materials healthy throughout the life cycle.
- Is physically designed to optimize materials and energy.
- Is effectively recovered and utilized in biological and/or industrial closed-loop cycles.

While this is a widely accepted definition, it is a lofty goal. Anyone would be hard-pressed to find a package that meets all of these criteria. It is not meant to dissuade but rather inspire and constantly strive for improved sustainability in package design.

One way to start down the path of improving the sustainability and environmental impact of any package design is to follow a nine-step procedure described in Figure 5.10. The methodology may be used to establish an internal, corporate environmental policy or for specific packaging design projects. However, the methodology is not meant to be followed exactly; rather its purpose is to highlight different elements that should be considered at each step of the way. A worksheet at the end of this chapter will assist the packaging professional through the design procedure.

Packaging professionals can significantly influence the scale of environmental impacts associated with their product packaging. The decisions made at each step of the package design process should be considered on three levels: theoretical, technological and practical. For example, a package may be theoretically recyclable but might not actually be recycled at the end of its life if the technology is not present, the infrastructure is not available or use of the technology is not economical. Due to the complexity of environmental impacts, environmental design evaluations often are subjective; normally, there are no "right" or "wrong" answers. Answers depend on factors such as business requirements, corporate environmental goals and customer awareness of environmental issues. To be complete, the environmental packaging procedure should consider the package's total life cycle, including manufacturing, distribution, marketing, consumer use and disposal.

Figure 5.10
Environmental Packaging Design Flowchart

Note: Although a package's environmental impact is a significant concern in the package design process, the integrity of the package (and the product it contains) must take precedence over any actual or possible environmental impact. In addition, each aspect of the package design must be evaluated for economic viability. An ambitious program to design environmentally preferred packaging will not be beneficial to the company if the package fails due to a loss of protective capabilities or greatly increased cost.

Step 1: Identify Environmental Goals and Initiatives

The first step in package design should be to identify your company's goals and initiatives. It is important to understand what environmental impacts your company is most concerned with and design with those in mind. For example, is your company concerned about the amount or types of plastic they use? If so, then that should be taken into consideration when designing packages.

With all the continuing talk in the media about climate change, overflowing landfills and environmental impacts, much of the packaging industry is concerned with the idea of "product stewardship."

> *"Product stewardship means that whoever designs, makes, sells or uses a product takes responsibility for minimizing its environmental impact. This responsibility spans the product's life cycle—from selection of raw materials to design and production processes to its use and disposal."*
>
> (Source: Western Electric Product Stewardship Initiative.)

This concept is becoming the foundation for legislative action in the realm of EPR. The following are examples of initiatives that support product stewardship programs:

- **Design for the Environment (DfE):** DfE is a commitment to reduce a package's environmental impact through the inclusion of environmental considerations in the design phase of packaging and product development. (See https://www.epa.gov/saferchoice/safer-choice-related-programs)
- **Restrictions on Hazardous Substances (RoHS) Compliance:** Companies that ship to Europe or wish to improve their product stewardship should comply with the European Union's Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) Directive, which took effect on July 1, 2006. The RoHS Directive prohibits the sale of electronic equipment containing certain hazardous substances in the European Union. Other countries have implemented their version of RoHS, including China, India, Japan, Korea, Norway, Taiwan and Ukraine. (See https://www.epa.ie/our-services/monitoring--assessment/waste/chemicals/rohs/)
- **EPA's Product Stewardship/Extended Product Responsibility:** The EPA has a voluntary program to support product stewardship. (See https://archive.epa.gov/wastes/conserve/tools/stewardship/web/html/basic.html)
- **Product Stewardship Institute (PSI):** PSI is a national, nonprofit, membership-based organization. It works with state and local government agencies to partner with manufacturers, retailers, environmental groups, federal agencies and other key stakeholders to reduce the health and environmental impacts of consumer products. (See http://www.productstewardship.us)

Step 2: Identify the Destination of the Package

The second step in the design workflow is identifying the package destination. This knowledge helps the designer understand what end-of-life options (recycling, landfill and incineration) are available at the destination, which might impact package design. In addition, knowing the destination allows for the accounting of fees that may be charged for any environmental impacts associated with a package.

The regional destination of the package determines the available infrastructure for end-of-life choices (i.e., recycling). To minimize or eliminate costs faced by the end-user (or the producing company, in the case of take-back programs), end-of-life management should be considered early in the design phase.

The following are considerations when designing for end-of-life:

- **Cradle-to-Cradle design:** Design packaging that will be reused or recycled so the materials remain in the supply stream instead of ending up in a landfill.
- **Multiple end-of-life options:** Design packaging that gives the end recipient several options, such as reuse and recycling, not simply disposal.
- **Packaging that breaks down easily into recyclable components:** When a package contains multiple materials, design it so it separates easily for recycling. This step is especially important when use of a non-recyclable component is unavoidable.
- **Recycling standards and capabilities:** When designing recyclable packaging, keep in mind the recycling infrastructure at the package's destination.
- **Reuse:** Design packages for ease of reuse, either by the end-user or by the supplier through a take-back program.
- **Take-back programs:** Advocate take-back programs when the infrastructure for recycling is not readily available to the end-user.

Step 3: Identify Applicable Regulations

The third step in package design is to identify applicable regulations. Regulations should supersede all other considerations in package design and, therefore, need to be considered early in the process. It is important to understand if regulatory requirements are consistent for all destinations. If not, decide whether the package can be tailored to each destination or must be designed to meet regulations in all destinations.

Regulations vary from region to region, and it is usually the packaging professional's job to ensure that material choices, design and other aspects of the package do not violate local regulations at the package's destination. Most regulations will pertain to aspects of material recovery, source reduction, reuse and labeling. Finally, fees associated with applicable regulations should be considered in evaluating the cost of the package.

Step 4: Identify Mode(s) of Shipping

The fourth step is determining how a package will be shipped. In general, the most energy-efficient mode of shipping is preferable. However, the mode of shipping often is determined by business requirements (e.g., balancing cost challenges, reduced inventory/increased turnover, flexibility/customized features/delivery, suppliers'/customers' locations, etc.) Additionally, reduced lead-time requirements of customers sometimes necessitate more time-efficient choices, such as air transport. However, in areas connected by land, transport by rail and/or truck may be fast enough, and these methods are more energy-efficient (and cost-efficient) than air. Finally, for packages that can withstand long time delays, transport via ship or barge is the most energy-efficient option. It is important to design packages consistent with the mode of shipping selected and, when possible, to choose the most energy-efficient shipping option.

Step 5: Identify Company-Specific Requirements

The fifth step in package design is to identify internal requirements: marketing, regulatory affairs and/or other applicable internal departments that should be considered. Internal requirements could pertain to whether the environmentally responsible package is economically viable, whether it enhances the product's image and acceptability and/or whether the package protects the product from physical, biological or chemical harm, etc.

- **Economics:** The costs and benefits of any new design should be quantified and compared with traditional packaging before implementing the program. This also will provide an opportunity to revise the program to optimize benefits based on recognized factors for cost savings found in the analysis. For example, damage reduction, reduced labor costs, reduced warehousing/storage costs, extended package life cycle and other economic benefits may be noted and pursued.
- **Marketing:** The package design can add physical attractiveness to the product to support product differentiation and marketing techniques. Is there an opportunity for these characteristics to be part of a broader green-marketing effort?
- **Protection:** The design process should consider the integrity, quality and safety of the package throughout its life cycle. For example, the mode of shipping used to transport the package should be considered when determining the structural characteristics of the package. Additionally, the package should be designed to hinder tampering and pilferage.
- **Performance:** Failure to account for all processes relevant to the package will hinder its effectiveness. For example, the package should fit well on existing or new machinery lines. The package should be designed for efficient performance throughout its life cycle.
- **Consumer information:** Does the packaging program provide adequate and accurate environmental labels and declarations regarding the environmental impact of the package? All labels and declarations should meet ISO standards and company-specific regulations.

Step 6: Identify Applicable Customer Requirements

The sixth step is identifying and understanding any applicable customer requirements. It is much more common for customers (mainly retailers) to have specific packaging design guidelines that must be followed. These guidelines often include packaging materials they will not accept (such as PVC, for example), specific pallet requirements, etc. The best source in your company for finding this information is your sales teams or supply chain organization. In addition, you often can find information on the customer's website.

Step 7: Select Raw Materials

The seventh step is raw materials selection. There are many tradeoffs when choosing between raw materials. Choices made should consider the complete life cycle of the package. Some questions to answer before selecting raw materials are:

- Have material options been clearly identified? Are there new materials or improvements on old materials to consider?
- Are the materials renewable? If not, are there renewable alternatives that should be included in the options?
- Are the materials recycled? If not, are there recycled alternatives that should be considered?
- Can the packing materials be reduced, reused or recycled? What are the end-of-life options for the materials?
- What are the environmental impacts of the material options?
- Do the material options meet the company-specific requirements and applicable regulatory requirements?
- How will the combination of materials affect the package's end-of-life treatment?
- Are any toxic materials (i.e., inks and adhesives) being used or do the materials contain heavy metals? If so, how will they affect end-of-life treatment?

Raw materials selection should be made to facilitate movement toward a Cradle-to-Cradle design. Traditional design, such as Cradle-to-Grave, assumes a package will end up as unwanted waste that must be dealt with at some cost to the end-user, and often pits environmental concerns against profitability. (See Figure 5.11) However, Cradle-to-Cradle design allows the package to travel in a technically and/or biologically closed loop, meaning materials used in the package will be reused, recycled or will biodegrade and return to the environment.

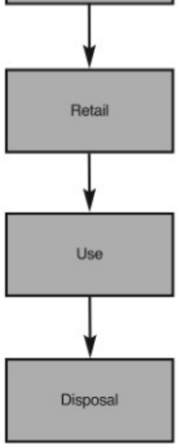
Step 8: Design the Package

The eighth step finally brings us to actually designing the package. If you followed Steps 1 through 7, you should be armed with all the information you need to minimize the environmental impact of a package. You should be able to identify your company's goals and initiatives, the destination of the package, specific business requirements, marketing goals, applicable regulations, customer-specific requirements, shipping modes and raw materials options and their environmental impacts. At this point, the package should be refined to minimize environmental impact and make it the most sustainable package possible, given all the factors. The following questions should be answered at this step:

Figure 5.11

Comparing Cradle-to-Grave and Cradle-to-Cradle Packaging Design

Cradle-to-Grave Design

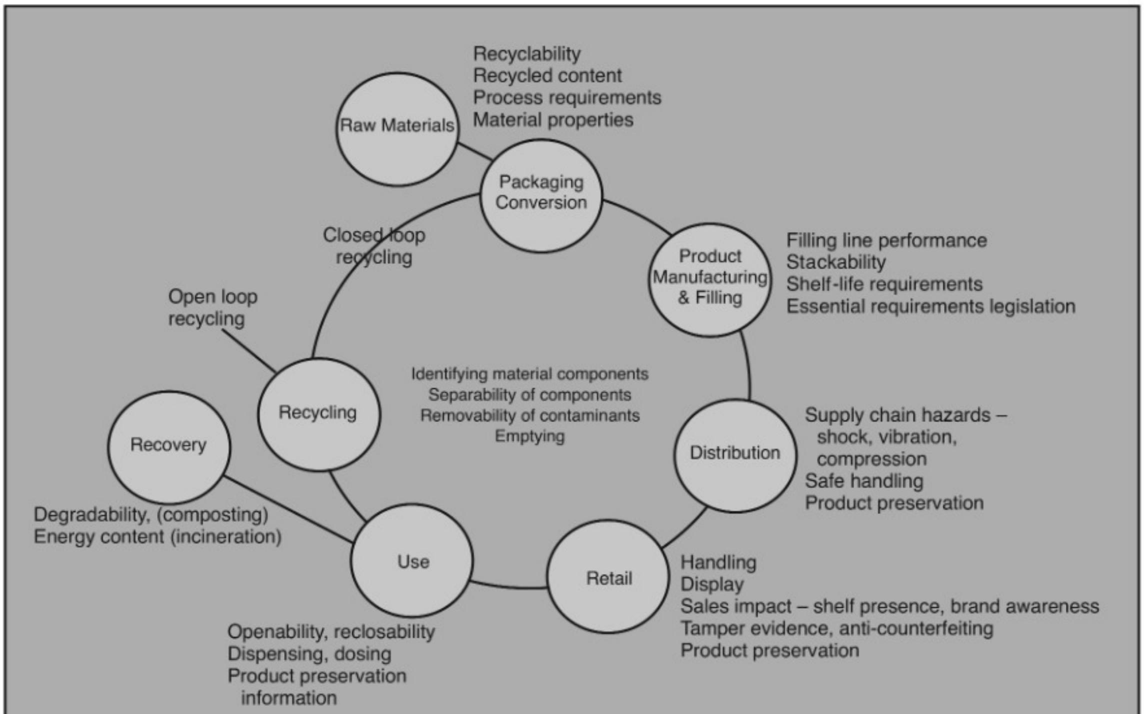


Traditional cradle-to-grave packaging design versus cradle-to-cradle packaging design:

<u>Cradle-to-Grave</u>
Linear production of packaging.
- Packaging is disposed of in a landfill at its end-of-life.
- The raw material entering the inventory pipeline is not recovered or used again after its intended use.

<u>Cradle-to-Cradle</u>
Operates in a closed loop.
- Packaging material does not end up in a landfill at its end-of-life.
- Technically closed loop.
  - Packaging is reused or recycled.
- Biologically closed loop.
  - Packaging material returns to nature.

Cradle-to-Cradle Design



Source: Pira International 2004

- Is the package designed to use a minimum of each raw material?
- Is the product over-packaged? Is it packaged to resist situations it will never encounter?
- Is the package easy to disassemble into its recyclable component parts (i.e., does the design avoid commingling materials)?
- What are the package's weight and dimensional characteristics?

During this step, it might be useful to utilize one of the tools previously discussed, such as COMPASS or PIQET. These programs can help quantify impacts and improve design choices.

Step 9: Communicate Environmental Characterization

The ninth and final step in the design process is communicating what the package hopes to accomplish, what has been done and why it is important. Educating the consumer and the retailer is essential to ensure their understanding of packaging, its purpose and impact.

The following questions should be answered at this step:

- What environmental impact characteristics make this package notable?
- How can these characteristics be accurately portrayed?
- What labels are required?
- Do labeling and marketing needs lead to a larger package than is necessary to protect the product? If so, is there a creative way to reduce package size while still satisfying labeling and marketing needs?
- Do consumers need to be educated about any environmental issues relating to the package?

The retailer and consumer may not know what the most environmentally-preferable option is, and since public awareness of environmental issues may impact purchasing decisions, effective communication is essential. By accurately portraying efforts to reduce the environmental impact of the package design and the materials being used, public awareness will improve and the product's market share may increase.

ENVIRONMENTAL LABELING AND DECLARATION

Environmental labeling and declarations are effective in informing consumers about companies' accomplishments through environmental initiatives. Let us examine the criteria the ISO and the U.S. Federal Trade Commission (FTC) have set for the appropriate use of environmental labeling.

The effective characterization of a package's environmental attributes can increase market share and reduce the environmental impact from that product category. According to the ISO, environmental labels provide potential purchasers with information about a product in terms of its overall environmental character, a specific environmental aspect or any number of factors. Assuming a competitive marketplace, other providers may respond by improving the environmental aspects of their own products to enable them to use environmental labels or make environmental declarations, resulting in reduced environmental impact from that product category.

The assessment of environmental performance should be based on scientific methodology that is sufficiently thorough and comprehensive to support the claim with results that are accurate and reproducible. (See ISO 14020: http://www.iso.org/iso/catalogue_detail?csnumber=38498) Specifically, assessment of environmental performance is based on environmental policy, environmental objectives and environmental targets (The Environmental Sphere).

The FTC and ISO have established voluntary guidelines for environmental performance characterization. ISO 14020 sets nine general principles on environmental labels and declarations. The following table lists the nine principles; however, it is useful to examine the first in more depth. The first principle states: "Environmental labels and declarations shall be accurate, verifiable, relevant and not misleading."

Cause-related marketing is not a new concept, but it has become so prevalent in environmental performance characterization that there are concerns of misleading or inaccurate information being disseminated by some companies. The term "greenwashing" refers to a provider trying to look more environmentally preferable than it really is. Another complication is that the extent of greenwashing is often subjective, due to the inherent uncertainty associated with scientific methods. In an attempt to discourage greenwashing, ISO 14020 requires that information concerning the procedure, methodology and any criteria used to support environmental labels and declarations shall be available and provided upon request to all interested bodies. This information must include any underlying principles, assumptions and boundary conditions.

Environmental Labeling Principles from ISO 14020

- Environmental labels and declarations shall be accurate, verifiable, relevant and not misleading.
- Procedures and requirements for environmental labels and declarations shall not be prepared, adopted or applied with a view to, or with the effect of, creating unnecessary obstacles to international trade.
- Environmental labels and declarations shall be based on scientific methodology that is sufficiently thorough and comprehensive to support the claim that produces results that are accurate and reproducible.
- Information concerning the procedure, methodology and any criteria used to support environmental labels and declarations shall be available and provided upon request.
- The development of environmental labels and declarations shall take into consideration all relevant aspects of the life cycle of the product.

- Environmental labels and declarations shall not inhibit innovation that maintains or has the potential to improve environmental performance.
- Any administrative requirements or information demands related to environmental labels and declarations shall be limited to those necessary to establish conformance with applicable criteria and standards of the labels and declarations.
- The process of developing environmental labels and declarations should include open, participatory consultation with interested parties. Reasonable efforts should be made to achieve consensus throughout the process.
- Information on the environmental aspects of products and services relevant to an environmental label or declaration shall be available to purchasers and potential purchasers from the party making the environmental label or declaration.

FTC *Green Guides*

Section 5 of the FTC Act "prohibits unfair or deceptive acts or practices in or affecting commerce." The *Green Guides* apply Section 5 of the FTC Act to environmental marketing claims. The following excerpts from the FTC *Green Guides* provide brief explanations and examples of how to avoid being deceptive or misleading about environmental claims.

Examples in italics come directly from the FTC *Green Guides*. To review more examples of appropriate and inappropriate environmental claims, see https://www.ftc.gov/news-events/topics/truth-advertising/green-guides.

Impact Reduction Strategies: Characterization of impact reduction strategies is an opportunity to explain programs and methods used to reduce environmental impacts throughout the life cycle of the package to potential purchasers. However, caution should be used to avoid over-generalization leading to misrepresentation; unqualified general environmental claims are difficult to interpret and may express a wide range of meanings to consumers. Every environmental claim about a quality, feature or attribute of a product or package should be substantiated. Avoid generalized claims of environmental benefit, such as "environmentally friendly," "green," "earth friendly," "environmentally safe" and the like, unless they can be substantiated.

- *Example 1:* A product wrapper is printed with the claim "Environmentally Friendly." Textual comments on the wrapper explain that the wrapper is "Environmentally Friendly because it was not chlorine bleached, a process that has been shown to create harmful substances." The wrapper was, in fact, not bleached with chlorine. However, the production of the wrapper now creates and releases significant quantities of other harmful substances to the environment. Since consumers are likely to interpret the "Environmentally Friendly" claim, in combination with the textual explanation, to mean that no significant harmful substances are currently released to the environment, the "Environmentally Friendly" claim would be deceptive.
- *Example 2:* A product is advertised as "environmentally preferable." This claim is likely to convey to consumers that this product is environmentally superior to other products. If the manufacturer cannot substantiate this broad claim, the claim would

be deceptive. The claim would not be deceptive if it were accompanied by clear and prominent qualifying language limiting the environmental superiority representation to the particular product attribute or attributes for which it could be substantiated, provided that no other deceptive implications were created by the context.

Biodegradability: Environmental performance characterization should not include unsubstantiated claims of biodegradable or degradable material. Any such claims should be substantiated with reliable and accurate scientific evidence that the package and all its constituent parts will completely biodegrade. Additionally, information should be provided on what conditions are required for the package to biodegrade (e.g., ambient) and whether these conditions are consistent with common forms of disposal.

- *Example 1:* A trash bag is marketed as "degradable," with no qualification or other disclosure. The marketer relies on soil burial tests to show that the product will decompose in the presence of water and oxygen. The trash bags are customarily disposed of in incineration facilities or at sanitary landfills that are managed in a way that inhibits degradation by minimizing moisture and oxygen. Degradation will be irrelevant for those trash bags that are incinerated and, for those disposed of in landfills, the marketer does not possess adequate substantiation that the bags will degrade in a reasonably short period in a landfill. The claim is therefore deceptive.

Recycled Content: A recycled-content claim should qualify the amount of recycled content, by weight, used in the package. Additionally, recycled content should only apply to material that has been recovered from the waste stream during the manufacturing process or after consumer use. If the entire package, except incidental parts, is made from recycled content, an unqualified claim of recycled content may be made.

- *Example 1:* A paperboard package with 20% recycled fiber by weight is labeled as containing "20% recycled fiber." Some of the recycled content was composed of material collected from consumers after use of the original paper product. The rest was composed of overrun newspaper stock never sold to customers. The claim is not deceptive.
- *Example 2:* A product in a multi-component package, such as a paperboard carton in a shrink-wrapped plastic cover, indicates that it has recycled packaging. The paperboard carton is made entirely of recycled material, but the plastic cover is not. The claim is deceptive since, without qualification, it suggests that both components have recycled content. A claim limited to the paperboard carton would not be deceptive.
- *Example 3:* A package is made from layers of foil, plastic and paper laminated together, although the layers are indistinguishable to consumers. The label claims that "one of the three layers of this package is made of recycled plastic." The plastic layer is made entirely of recycled plastic. The claim is not deceptive provided the recycled plastic layer constitutes a significant component of the entire package.

Recyclability: Recyclability claims should identify which components of the package are recyclable and which are not. Additionally, recyclability claims only apply to material that can be recycled with the available recycling infrastructure.

- *Example 1:* A packaged product is labeled with an unqualified claim, "recyclable." It is unclear from the type of product and other context whether the claim refers to the product or its package. The unqualified claim is likely to convey to reasonable consumers that all of both the product and its packaging that remain after normal use of the product, except for minor, incidental components, can be recycled. Unless each such message can be substantiated, the claim should be qualified to indicate what portions are recyclable.
- *Example 2:* A nationally marketed 8-oz. plastic cottage cheese container displays the resin identification code (which consists of a design of arrows in a triangular shape containing a number and abbreviation identifying the component plastic resin) on the front label of the container near the product name and logo. The manufacturer's conspicuous use of the code in this manner constitutes a recyclability claim. Unless recycling facilities for this container are available to a substantial majority of consumers or communities, the claim should be qualified to disclose the limited availability of recycling programs for the container. If the code, without more information, had been placed in an inconspicuous location on the container (e.g., embedded in the bottom of the container) it would not constitute a claim of recyclability.

Greenwashing: As previously mentioned, the term greenwashing refers to a provider trying to look more environmentally preferable than it really is. To heighten awareness about greenwashing, the company UL TerraChoice, together with an independent testing and certification organization, conducted a study on the "greenness" of green products. They found that a staggering 95% of green products were greenwashed. They identify what they call the Seven Sins of Greenwashing™, and these forms of deception are reflected in the FTC guidelines:

- Sin of the Hidden Trade-Off.
- Sin of No Proof.
- Sin of Vagueness.
- Sin of Worshiping False Labels.
- Sin of Irrelevance.
- Sin of Lesser of Two Evils.
- Sin of Fibbing.

ENVIRONMENTAL PACKAGING PROCEDURE TEMPLATE

This template is meant to help the packaging professional work through the design procedure presented earlier in this chapter. The purpose of this template is to help the packaging professional ask the right questions in the right order to incorporate environmental considerations with a minimal impact on design time. The questions should help highlight where the environmental impact of a package is coming from, so the professional can determine if it can be reduced.

Step 1: Identify Environmental Goals and Initiatives

1. What is the company's environmental policy?

   ____

2. What environmental issues have a high priority in your company?

   ____

   ____

3. What general processes are in place to meet environmental goals and initiatives?

   ____ Design for the environment

   ____ Take-back and recycling programs

   ____ Restriction of hazardous substances compliance

   ____ Supplier responsibility

   ____ Other: ____

4. Does the package meet the goals of applicable environmental stewardship programs (such as company environmental policies, action plans, etc.)?

   ____ Yes, the package meets all goals.

   ____ No, the package does not meet the goals but problem areas have been identified and are being mitigated.

   ____ No, the package does not meet the goals; other requirements (i.e., business considerations) do not allow the package to meet the goals.

5. What environmental goals and initiatives do the package fail to meet?

   ____

Step 2: Identify the Destination of the Package

1. To what regions is the package going?

   ____

2. What are the end-of-life options at the destination for each material?

Material 1:

____ Recycling
____ Reuse
____ Landfill
____ Incineration
____ Other: __________

Material 2:

____ Recycling
____ Reuse
____ Landfill
____ Incineration
____ Other: __________

Material 3:

____ Recycling
____ Reuse
____ Landfill
____ Incineration
____ Other: __________

Material 4:

____ Recycling
____ Reuse
____ Landfill
____ Incineration
____ Other: __________

Material 5:

____ Recycling
____ Reuse
____ Landfill
____ Incineration
____ Other: __________

3. How will the storage conditions for this region affect the protection requirements of the package?

____

Step 3: Identify Relevant Regulations

1. To what regulating entities will your package be subject (international, federal, state, etc.)?

____

2. With what regulations must your package comply?

____

3. Will existing or proposed legislation (e.g., package taxes, bans, deposits, solid waste bills, etc.) affect the package during its service life?

____ Yes, on the federal level: ______________________________

____ Yes, on the state level: ________________________________

____ Yes, on the local level: ________________________________

____ No

____ Don't know

4. a. Are regulatory requirements consistent for all destinations?

____ Yes

____ No. How? ____

____

b. If "no," can the package be tailored to each destination, or should it be designed to meet regulations in all destinations?

____

5. a. Does your company act in an advisory capacity to federal, state and/or local governments to ensure that they have access to accurate packaging data?

____ Yes. How? ____

____

____ No

b. If "yes," are the packaging structural design requirements fully considered by corporate lobbyists?

____ Yes

____ No

Step 4: Mode of Shipping Selection

1. **a.** What are the available shipping methods that meet the business requirements (time demands, cost, value of product, etc.)?

   ____

   b. How will each of these shipping methods affect the protection needs of the package?

   ____

   c. How will each of these shipping methods affect the environmental impact of the package?

   ____

   d. How is the shipping cost determined?

   ____ Truckload (volume)

   ____ Actual weight

   ____ Dimensional weight

   e. Will the package require additional packaging at any of these steps?

   ____ Yes: ____

   ____ No

   f. If "yes," how will the outer or inner packaging used for shipment and distribution of goods be treated at end-of-life?

   ____ Recycling

   ____ Reuse

   ____ Landfill

   ____ Incineration

   ____ Other:____

   g. Has a resource recovery and recycling system been established in cooperation with customers to collect and reuse distribution packaging waste that does not reach the ultimate consumer?

   ____ Yes

   ____ No

   ____ No, but a system is in development

2. Is there an opportunity to use a reusable, returnable container program to reduce waste?

   ____ Yes

   ____ No

3. Are programs in place to require reusable or recyclable secondary packaging from suppliers?

   ____ Yes

   ____ No

   ____ No, but a system is in active development

Step 5: Identify Company Specific Requirements

1. What are the protective requirements for the package?

   ____

   ____

2. Has marketing been consulted to determine their needs and the target market?

   ____ Yes

   ____ No

3. Is there a “green” marketing campaign that this product can support?

   ____ Yes: ____

   ____ No

4. What are the handling requirements of the distribution system?

   ____

5. How high are your pallets and are they going to be double/triple stacked?

   ____

Step 6: Identify Applicable Customer Requirements

1. Does the customer ban the use of any materials?

   ____

2. Does the customer require the use of certain materials over others, i.e., PET over PVC?

   ____

3. Does the customer require special pallets, i.e., CHEP?

   ____

4. Does the customer have pallet configuration requirements: stacking, TI-HI, etc.?

   ____

Step 7: Raw Material Selection

1. a. What materials were considered for the components of this package?

   Component 1: ____

   Component 2: ____

   Component 3: ____

   Component 4: ____

   Component 5: ____

b. What is the source of the selected materials?

Material 1:

____ Renewable
____ Nonrenewable
____ Virgin
____ Recycled

Material 2:

____ Renewable
____ Nonrenewable
____ Virgin
____ Recycled

Material 3:

____ Renewable
____ Nonrenewable
____ Virgin
____ Recycled

Material 4:

____ Renewable
____ Nonrenewable
____ Virgin
____ Recycled

Material 5:

____ Renewable
____ Nonrenewable
____ Virgin
____ Recycled

c. Are any materials going to be charged a fee or tax at their destination?

____ Yes. What? ____

____ No.

d. What are the primary environmental impacts of the selected materials?

Material 1: ____
Material 2: ____
Material 3: ____
Material 4: ____
Material 5: ____

2. a. Do these material options meet the company-specific requirements?

____ Yes
____ No. Why? ____

b. Do the material options meet applicable regulatory requirements?

____ Yes
____ No. Why? ____

3. a. Is the package mono-material or multi-material (e.g., laminated or coextrusion)?

____ Mono-material
____ Multi-material

b. If the package is multi-material, are current recycling systems capable of handling these multi-material packages?

____ Yes
____ No

c. If there is not a recycling system in place to process the multi-material package, is your company pursuing the development of such a system (either alone or in conjunction with industry, government or academia)?

____ Yes
____ No

4. Which materials were selected for this package and why?

____

5. Is this combination of materials the most environmentally sound design possible without compromising product integrity?

____ Yes

____ No. Why? ____

6. Do the materials need to be further separated to increase their recycling value or to avoid impeding the recycling process?

____ Yes. How? ____

____ No

7. a. Has the package and its components (e.g., inks, dyes, pigments, stabilizers, solders and adhesives) been made without the use of toxic cadmium, lead, mercury and hexavalent chromium?

____ Yes

____ No. Why? ____

b. If the package material currently uses toxic materials, can they be removed without compromising the package's functions?

____ Yes

____ No. Why? ____

c. If "no," does this violate any regulations at the destination of the package?

____ Yes

____ No

8. a. Can the package's materials be landfilled safely without leaching hazardous by-products or otherwise causing harm to the environment?

____ Yes

____ No. Why? ____

b. If "no," can the package be designed to avoid problems in landfill disposal?

____ Yes. How? ____

____ No

9. Can the package be incinerated safely to recover the energy value of the packaging materials without harmful ash residue or emissions?

____ Yes

____ No. Why? ____

10. Does the package contain sufficient combustible materials to be reprocessed for safe burning and energy recovery?

____ Yes

____ No

Step 8: Design the Package

1. Can any amount of packaging be reduced, with the package still meeting these requirements?
   ____ Yes, the package or one of its components can be eliminated.
   ____ No, all packaging or components that are not required have been eliminated.
2. Is the package easy to disassemble into its recyclable component parts?
   ____ Yes
   ____ No. Why? ____
3. Does the design of the package support the available end-of-life options?
   ____ Yes
   ____ No. Why? ____
4. Can the package be made smaller and/or designed to be compacted by consumers or waste-management companies so that it takes up less collection/landfill space?
   ____ Yes
   ____ No. Why? ____
5. Does the package fit well on existing or new machinery lines?
   ____ Yes
   ____ No. Why? ____
6. Does the package meet the handling requirements?
   ____ Yes
   ____ No. Why? ____
7. Does the package provide space for marketing needs?
   ____ Yes
   ____ No. Why? ____
8. Does the package provide space for environmental labels?
   ____ Yes
   ____ No. Why? ____
9. Is the package easy and safe to open while meeting security concerns?
   ____ Yes
   ____ No. Why? ____
10. **a.** Has the actual weight of the package been minimized?
   ____ Yes.
   ____ No
   Weight: ____

b. Has the dimensional weight of the package been minimized?

____ Yes

____ No

Weight: ____

11. Is the environmentally responsible packaging program economically viable?

____ Yes, the program has passed testing for viability.

____ No, the program adds significant cost to the product.

____ Don't know, no analysis has been performed.

Step 9: Environmental Characterization

1. What are the required labels for your package?

____

2. a. Are the notable environmental characteristics of the package effectively and appropriately portrayed on the package?

____ Yes

____ No. Why? ____________________________________

b. Could the environmental characterization be viewed as deceptive or misleading?

____ Yes. How? ____________________________________

____ No

3. a. Is labeling leading to a larger package than is necessary for the product?

____ Yes

____ No

b. If "yes," can the labeling be redesigned to fit on the amount of packaging required for protection?

____ Yes

____ No. Why? ____________________________________

REVIEW QUESTIONS

1. What is the most widely accepted definition of sustainability?
2. What prompted the paradigm shift that caused producers to change from a Cradle-to-Grave to a "Cradle-to-Cradle" responsibility?
3. The four Rs are the guiding principles for managing waste. What are the four Rs, in the correct order?
4. List examples that illustrate the "recovery" item in packaging waste management.
5. What are the advantages of the cascade model for plastic usage?
6. What are five conditions driving the need for sustainability?
7. What are the pillars of a circular economy?
8. How is packaging addressed in a circular economy?
9. What are the packaging goals of the circular economy?
10. A Life Cycle Assessment (LCA) is useful in the packaging industry for what purpose?
11. What is COMPASS used for?
12. What is a significant way to evaluate and improve the sustainability of a product?
13. Identify four initiatives that support product stewardship programs.
14. What considerations should be made when designing packaging for end-of-life?
15. The fifth step in package design is to identify internal requirements that include what considerations?
16. In which step among the nine steps in the Environmental Packaging Procedure Template does the actual package design occur?
17. Which regulation sets forth nine general principles on environmental labels and declarations?
18. To comply with the *Green Guides*, list the five claims that must be substantiated.
19. Define the term product stewardship.
20. What consideration should supersede all others when designing a package?
21. Define the term greenwashing.
22. Referencing Section 5 of the FTC Act, what do the *Green Guides* prohibit?

PAPER AND PAPERBOARD

6

CONTENTS

PAPER AND PAPERBOARD 6

SOURCES AND PREPARATION OF FIBER

Paper is defined as a matted or felted sheet usually composed of plant fiber. Paper has been made commercially from such fiber sources as rags (linen), bagasse (sugar cane), cotton and straw. North American paper is made almost exclusively from cellulose fiber derived from wood.

The paper industry has few definitive terms. For example, paperboard, boxboard, cardboard and cartonboard are used to describe heavier paper stock. "Paper" and "paperboard" are nonspecific terms that can be related to either material caliper (thickness) or grammage (basis weight).

The International Standards Organization (ISO) states that material weighing more than 250 grams per square meter (gsm) (51 lb. per 1,000 square feet) shall be known as paperboard. General U.S. practice describes material that is thicker than 300 micrometers (0.012 inch) as paperboard. The term micrometers is properly abbreviated as "µm," but the symbol is difficult to find on a keyboard, and is commonly written as "um.") In this text, materials measuring more than 300 µm will be referred to as paperboard. "Paper" will be used in a generic sense to include all thicknesses and also, more specifically, to those products less than 300 µm in thickness.

The properties of paper and paperboard are dependent on a large number of variables. To understand paper products, it is best to know the fiber source, how the fiber was extracted and prepared for papermaking, the machine on which the paper was made and treatments given the finished paper.

Fiber Source and Length

Cellulose fiber, suitable for making paper, can be obtained from many plants. Each forms cellulose into fiber bundles characteristic to the species. The most important characteristic for papermaking is fiber length—the longer the fiber, the better the fiber entanglement and the stronger the resulting paper. (See Table 6.1)

Table 6.1
Approximate fiber length of cellulose used in papermaking.

Fiber Source	Typical Fiber Length
Main Sources	
Hardwood (e.g., poplar, aspen, maple)	2 millimeters/0.08 inch
Softwood (e.g., pine, spruce, hemlock)	4 millimeters/0.16 inch
Other Sources	
Straw, bagasse	< 2 millimeters/0.08 inch
Bast (e.g., linen, cotton)	> 2 millimeters/0.5 inch
Recycled paper	varies depending on source

Longer fibers produce paper with proportionately higher tensile, tear, fold and puncture strengths. For example, newsprint made from short-fiber mechanical pulps will fail a standard fold endurance test in fewer than 15 folds. Typical office papers will last 20 or 30 folds, while kraft bag paper will last into the hundreds. Currency paper has a large percentage of bast fiber and will tolerate thousands of folds.

On the negative side, long, coarse fibers produce a rougher surface texture than short fibers. Also, individual fibers in long-fiber pulps tend to entangle and clump together when deposited on the screen of a papermaking machine. The density of the paper will vary across the sheet. Evenness of fiber distribution is referred to as “formation.” “Wild formation” refers to a very uneven distribution of fibers. Variations in density resulting from poor formation can lead to such problems as uneven ink absorption during printing or erratic adhesive bonding.

Shorter fibers produce paper with a smoother surface and a more consistent density. However, short-fiber papers possess significantly reduced physical properties. These relationships are illustrated in Figure 6.1.

Package designers occasionally must compromise between the requirement for good folding ability, high tensile strength or high burst strength (qualities requiring a long fiber but resulting in poor formation) and good printability (a quality requiring short fiber, but resulting in a loss of physical strength properties).

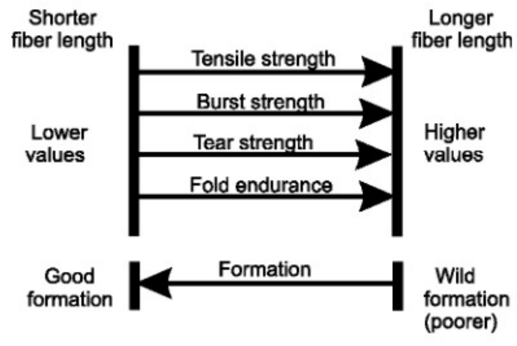


Figure 6.1
Paper qualities and fiber length.

Recovered or recycled fiber will have properties inherited from the original fiber source, but with the provision that every repulping process degrades and reduces fiber length. Recycled kraft (discussed next under Pulping Methods) will still have good strength, though not as much as virgin kraft, while recycled newsprint, already a short fiber, will be degraded further. Postconsumer waste may contain a variety of extraneous contaminants, many of which cannot be removed. The principal contaminants are water-insoluble adhesives, plastic debris and nonremovable printing inks. These appear in the finished sheet as tiny bits of color, "grease" spots and "shiners."

Pulping Methods

Wood, regardless of species, is about 50% cellulose. Carbohydrates and lignin, the other principal components, are unsuitable for papermaking because of their nonfibrous nature. Lignins, the natural adhesive that binds cellulose fiber together, is chemically not as stable as cellulose and discolors readily. Lignins are not water-soluble and so can't be easily removed by simple water washing. Water-soluble carbohydrates such as sugars and starches are dissolved and removed during pulping. Softwoods contain significant amounts of rosin-like substances that must be removed.

Cellulose fiber can be separated from the wood mass in several ways, and each method produces a different quality of pulp. The fastest and most economical method of extracting cellulose from wood is to mechanically abrade or cut the wood. (See Figure 6.2) However, the mechanical action breaks fibers and reduces their effective length. These groundwood, or mechanical, pulps are used for lower-quality papers such as newsprint, and for blending with other, more expensive pulps to reduce cost or to improve formation.

The least fiber damage occurs when chemicals are used to dissolve the natural lignin binders in wood, leaving the fiber bundles intact and undamaged. Several chemical processes can be used; the two most common are based on alkali sulfate and acid sulfites. The strongest chemical pulps are produced by alkali sulfate extraction, more commonly known as the kraft (German for strength) process. Sulfate extraction is preferred for softwoods because it can emulsify and remove resinous components.

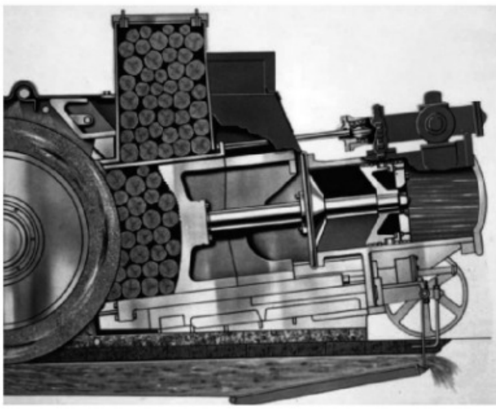


Figure 6.2
Early groundwood pulping simply forced logs against a large stone grinding wheel. Much groundwood pulp today is made from wood chips from the lumbering industry.

Table 6.2
Relative strength of pulps produced by different methods.

Pulp Type	Relative Strength
Stone groundwood hardwood	3
Stone groundwood softwood (newsprint)	5
Semichemical hardwood	5–6
Thermomechanical softwood	6–7
Semichemical softwood	7
Chemical: sulfite hardwood	7
Chemical: kraft hardwood	7–8
Chemical: sulfite softwood	9
Chemical: kraft softwood	10

Source: Smook G.A., Handbook for Pulp and Paper Technologists, TAPPI, Atlanta, GA

Kraft pulp costs substantially more than mechanical pulp and is used where maximum strength is required. Natural kraft is the mainstay of the corrugated box and multiwall shipping bag industries. Bleached kraft is used for many food and display packaging applications, particularly where the board may be exposed to wet conditions.

Mechanical pulping and chemical pulping represent the two extremes in both cost and resulting pulp quality. Intermediate in cost and properties are pulps made by semichemical processes (the wood mass is partly digested by chemicals before mechanical refining) and by thermomechanical processes, (the wood is softened by heating before mechanical refining). Table 6.2 lists the relative strength of pulps produced by these different processes.

Preparing Pulp for Papermaking

Cellulose fiber bundles separated from the wood mass are refined (beaten) to release small fiber strands, or fibrils. A small amount of refining produces paper with high tear strength (the paper's resistance to tearing) and high absorbency but lower burst strength (the paper's resistance to rupturing) and lower tensile strength (the strength of paper in tension). Increased refining decreases absorbency and tear strength, but increases burst and tensile strengths. High refining levels also reduce paper opacity.

Paper mills adjust the amount of refining to give an optimum property balance for a given application. Grease-resistant papers are made from highly refined pulps, and glassine is paper that has had the maximum fibril separation.

Natural pulps range from light to medium brown. Pulps are whitened by bleaching with chlorine-containing compounds or hydrogen peroxide. Chemical bleaching reduces the strength of the final paper and, in those applications where mechanical strength properties are at a premium, bleaching would be avoided if possible.

Internal Sizing, Additives and Wet-End Treatments

A variety of additives and sizings are added to the pulp in preparation for paper-making. The types of additives include:

Sizing Agents:	Untreated cellulose is essentially a highly absorbent blotting paper. Sizing consists of a group of additives that help control water and ink penetration. Papers with high sizing levels, or "hard-sized" paper, are very water-resistant, whereas "slack-sized" paper has little or no water hold-out capability.
Starches, gums:	Adding starches or gums improves burst and tensile strength, stiffness and pick resistance (the tendency for fibers to "pick" off the paper surface).
Wet-strength resins:	Resins are added to improve wet tensile strength retention under high humidity or damp conditions.

"Furnish" is the mixture of fiber, water and additives that is fed to the paper-making machine. About 98% of furnish is water. A furnish may be a single pulp type or a blend of different fibers selected to yield a balance of desired properties at the lowest possible cost. In addition to mixed-fiber furnishes, paper can be made of individual layers of different fibers matted together to form a multilayer sheet.

REPRESENTATIVE PAPER-MAKING MACHINES

There are many variations on paper-making machines, each imparting its own character to the resulting paper. Only three representative classes will be discussed here: Fourdrinier, cylinder and twin-wire.

Fourdrinier Machine

Fourdrinier machines pump furnish from a headbox directly onto a moving wire screen through which the water is continuously drained. (See Figure 6.3) Fourdrinier machines may have a second headbox situated downstream of the first headbox to add further quantities of furnish onto the partially dewatered initial lay-down.

However, it is impractical to add more headboxes to produce thick paperboard on a Fourdrinier machine, since the water from each successive addition must drain through fibers that have already been laid down. This limits the thickness of paper produced on a conventional Fourdrinier machine. Heavier caliper boards can be made by bringing together the wet pulp layers laid out by two or more completely separate Fourdrinier machines and pressing these together before the sheet is sent to the dryer.

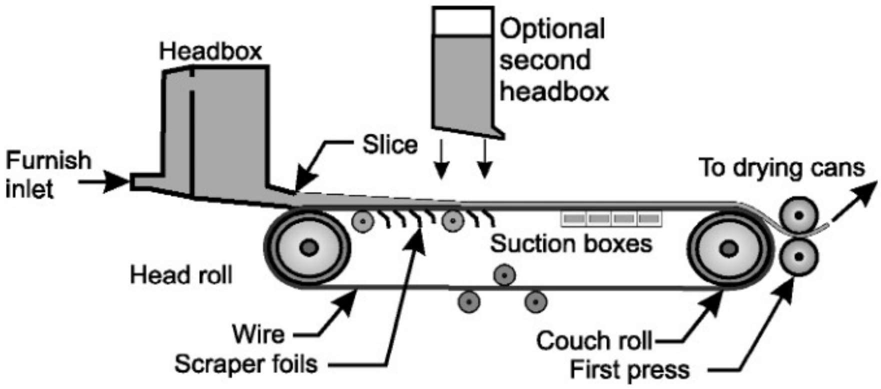


Figure 6.3
Furnish pours out of the headbox of a Fourdrinier machine and onto an endless wire or screen where excess water can be drained. The fibers remain trapped on the screen.

Most free water is removed at the "wet end" of a papermaking machine. At the couch (pronounced "kooch") roll, the wet paper has enough strength to be removed from the wire and passed around a series of heated drying drums where moisture content is brought down to finished-product specifications. The dried paper may go through some further treatments at the dry end of the papermaking process before being wound into a mill roll.

Cylinder Machines

A cylinder machine rotates a screen drum in a vat of furnish. (See Figure 6.4) (The paper is sometimes called vat lined paper.) As the water pours through the screen, fiber accumulates on the outside of the screen. This thin layer of matted fiber is transferred onto a moving felt belt that passes sequentially over further rotating cylinders, each of which deposits another fiber layer.

Cylinder machines dewater furnish at the cylinder and paste a thin layer of fiber against the felt. (See Figure 6.5) The fibers of subsequent layers do not intermingle, and therefore, the bond between the layers is weak. The dry end is similar to that of the Fourdrinier machine.

Cylinder machines commonly have six or seven stations. Higher-caliper boards for folding and setup cartons are usually cylinder boards. An advantage of cylinder machines is that low-quality fiber can be used to fill or bulk the middle of a board, which also can aid in lightweighting, while higher-quality bleached fibers can be used on one or both liners.

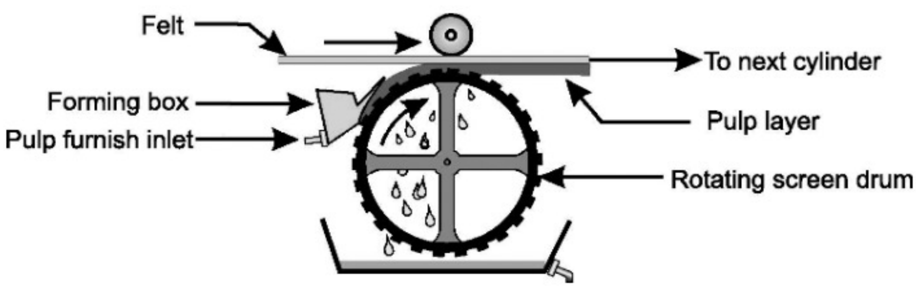


Figure 6.4
A single-cylinder station on a cylinder-type machine.

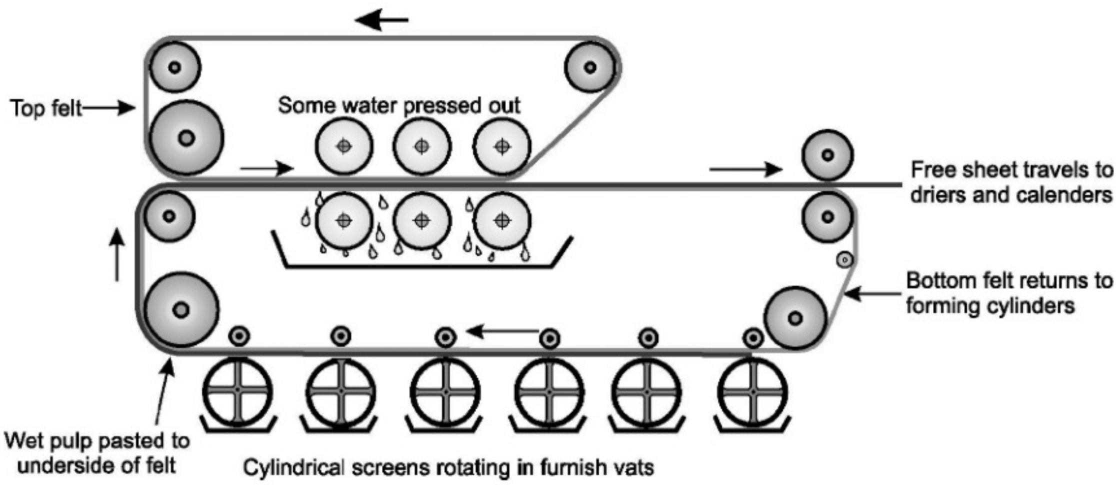


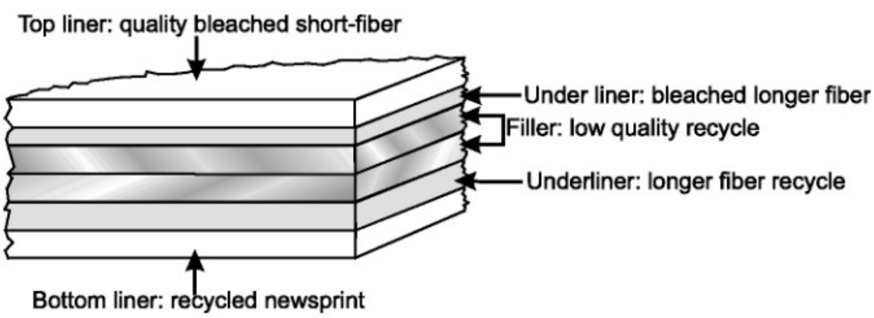
Figure 6.5
A cylinder machine with six cylinders at which paper layers can be formed.

Cylinder board has definite layers, or plies, and individual plies often can be easily separated. Poor inter-ply bonding can produce a variety of packaging problems related to ply delamination. Generally, papers are made on Fourdrinier or twin-wire formers, whereas heavier paperboard products are made on cylinder machines. Extremely heavy boards are made by laminating several thinner sheets.

A typical cylinder board construction may have a top liner composed of good-quality bleached pulp with some short fibers, possibly sized and clay-coated to produce a smooth, attractive printing surface. (See Figure 6.6) The underliner may be composed of a good-quality stock, possibly bleached to provide a smooth opaque base for the top liner.

Filler plies use the most economical recycled pulps since they have little impact on properties such as stiffness. The bottom liner is a better-quality pulp to add stiffness. If appearance is not a factor, the bottom liner may be better quality recycled pulp. If appearance is critical or if the paperboard will be printed on both sides, the bottom liner also would be bleached stock.

Figure 6.6
Cylinder boards are multi-ply boards. An advantage is that the plies can all be different.



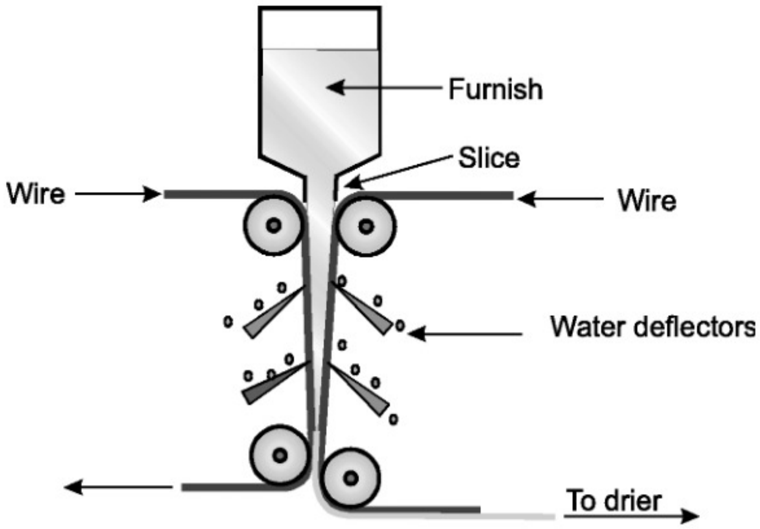


Figure 6.7
Water can be removed from both sides of the paper simultaneously on a twin-wire paper former.

Twin-Wire Machines

Vertiformers and twin-wire formers inject the furnish between two moving wire screens. (See Figure 6.7) The advantage is that dewatering takes place on both sides of the paper and is therefore fast. These machines can produce single and multi-ply sheets with identical formation at both faces.

Machine Direction and Cross Direction

Depositing a fiber-and-water slurry onto a moving wire belt tends to align fibers in the direction of travel, known as the machine direction (MD). The direction across the papermaking machine and the fiber alignment is the cross direction (CD). (See Figure 6.8) Because of this fiber alignment, paper is anisotropic material—measured properties differ depending on the direction in which the property is measured. Figure 6.9 shows the relationship of tear, stiffness and fold endurance to MD. Paper specification sheets normally show physical values measured in both directions. Package designers need to be aware of a paper's directionality. For example, it is much easier to create a tear strip along the MD rather than trying to force it in the CD.

Cylinder machines tend to align fibers more than Fourdrinier machines. Tensile strength ratios in MD and CD for a typical Fourdrinier board are about 2:1, compared to 4:1 or higher for a cylinder board, meaning that the MD tensile strength is four

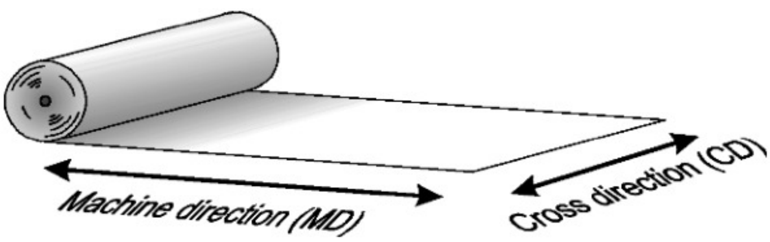


Figure 6.8
Fibers in a manufactured paper sheet tend to align in the machine direction.

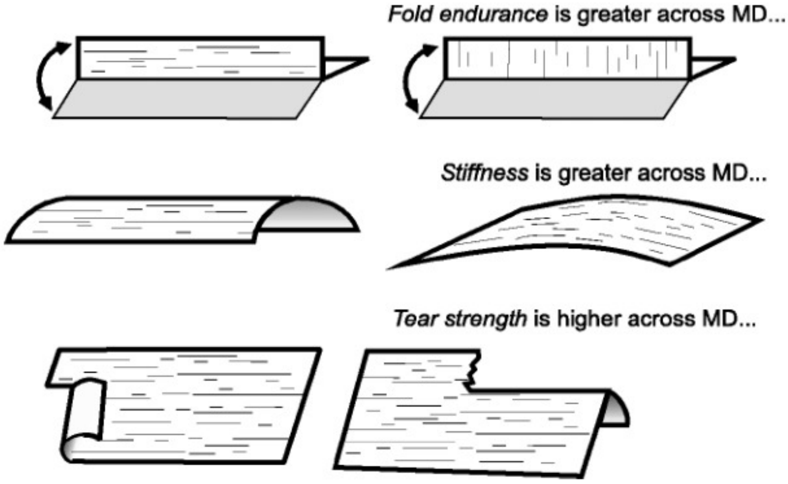


Figure 6.9
The relationship between MD (machine direction) and tear, stiffness and fold endurance properties.

times greater than the CD tensile strength. The greater the degree of fiber alignment, the greater the difference in a given property when measured in MD and CD. The ratio of a property in the two directions often is used as a gauge of fiber alignment.

Surface or Dry-End Treatments and Coatings

After the paper is formed and dried, it usually is passed between multiple sets of heavy rolls. (See Figure 6.10) This "calendering" operation has many variations, but the prime objective is to improve caliper consistency and iron and smooth out the surface of the paper stock to make it more suitable for printing. Calendering also compresses the paper sheet, producing a denser product and glossier surface.

Finished paper can have multiple surface sizings and/or coatings applied at the dry end to further improve surface characteristics. Starch is a typical surface sizing used to bind fibers together and reduce liquid penetration rate. Surface coatings made with pigments such as clay, calcium carbonate and titanium dioxide fill in irregularities between the fibers to produce an exceptionally smooth printing surface as well as to improve gloss and brightness. Coated papers usually are called "clay-

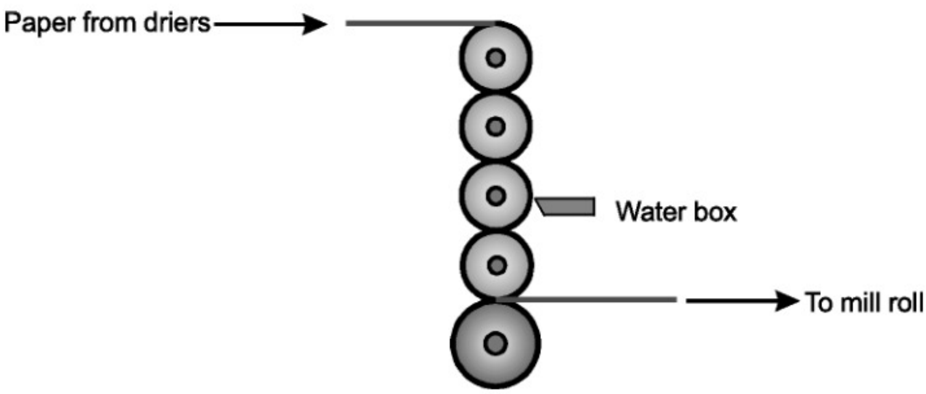


Figure 6.10
Calendering consists of passing the formed dried paper between sets of heavy rolls. The paper surface may be dampened to help smooth it.

coated" regardless of the actual formulation. Coated papers are calendered to maintain a high-quality smooth surface.

If clay-coated paper is passed under highly polished chrome drums that are rotating counter to the paper or faster than the paper speed, the clay coatings will be polished. These are referred to as machine-glazed or chrome cast-coated papers.

Poorly bonded clay coatings can cause printing and adhesive bonding problems. A common problem experienced in lithographic printing is when the extremely tacky lithographic ink picks off a small particle of clay. This particle adheres to the blanket cylinder resulting in a small spot, or "hickey," being printed with every subsequent impression. Clay lift describes a situation where an adhesive has bonded well to a clay surface coating but the bond has separated because the clay lifted away from the paper base. In addition, highly sized and clay-coated boards can be difficult to bond with water-based adhesive because of poor liquid penetration and the inability of the adhesive to bond to the underlying fibers. Adhesives need to be appropriate to the paper's properties. Where necessary, coated boards should have perforations in the bonding areas so the adhesive can penetrate to the body of the paper.

With such a large number of principal variables (and many lesser ones), it is easy to understand that no two paper mills in the world will produce an identical paper and that even a single mill might have difficulties producing within a tight tolerance level from day-to-day.

PAPER CHARACTERIZATION

Caliper and Weight

The prime specifying values for paper or paperboard include caliper, or thickness, and a value expressing a density. Both inch/pound and metric units are used, and different units may be used for different mill products. Care should be taken to know exactly what units are being quoted.

In inch/pound units:

- Caliper is expressed in thousandths of an inch or in "points." One-thousandth of an inch is 1 point. (For example, an 0.020-inch board would be 20 points).
- Containerboard for the corrugated board industry and most paperboards are specified by the weight in pounds per 1,000 square feet, the "basis weight."
- Fine papers may be specified by the weight in pounds per ream. A ream is 500 sheets, but the actual sheet size can vary depending on the product. In most instances, a ream is taken to be 3,000 square feet.

In metric:

- Caliper is expressed in micrometers. Sometimes, millimeters are used, but micrometers have the advantage of eliminating the decimal point.
- Paper mass/unit area relationship is reported as "grammage," defined as being the mass (weight) of paper in 1 square meter (m^2), regardless of the paper type.

The metric conversion factors are:

lb./1,000 sq. ft. × 4.88 = gsm
0.001 inch = 25.4 μm (usually rounded to 25 μm)
Therefore, 1 point (0.001 inch) = 25 μm
A 20-point paperboard would be 500 μm (20 × 25)

Brightness

Brightness is a measure of the total reflectance of white light. Values are expressed on a scale of 1 to 100, with 0 representing black (no light reflection) and 100 the reflection from magnesium oxide, the brightest material known at the time. The value is not a percentage. More recently, it was discovered that titanium dioxide pigments have an even higher brightness value. Hence, some photographic papers are 108 bright and higher.

Brightness should not be confused with "whiteness," which is a color description like red or yellow. Most packaging papers range between 78 and 84 bright. The cost of higher brightness papers becomes prohibitive. The brighter the board, the more brilliant the graphic possibilities. Paper stock brightness is a specification value for printing papers.

Paper and Moisture Content

Paper is hygroscopic and absorbs and loses moisture according to the ambient relative humidity (R.H.) and temperature. Paper at 20% R.H. contains about 4% moisture, while at 80% R.H., it will contain about 15% moisture. (Paper equilibrium moisture content will vary slightly, depending on whether equilibrium is reached from a lower or higher humidity. (This effect is known as hysteresis.) By convention, accurate moisture analysis is done by bringing paper to equilibrium from a lower humidity. Table 6.3 shows the equilibrium moisture content of paper and paperboard at different temperatures and humidity levels.

The physical properties of paper vary dramatically with moisture content, which is influenced by paper makeup, basis weight and R.H. In fact, in more sensitive applications, the moisture content of the paper must be controlled. Where strength is important, paperboard should be selected to perform at the highest anticipated R.H. To ensure optimum results, *all paper testing must be done at a precisely controlled temperature and humidity*. Internationally, the standard conditions are specified as 23°C and 50% R.H. In North America, paper mills target paper and board to be 40% R.H. at 72°F.

To ensure optimum performance, it is important that the printing and converting environments be close to the R.H. and temperature of the paper or board. First, incoming pallets of board should be allowed time for the material to acclimate to the temperature of the production department before unwrapping. Ideally, the R.H. of the plant needs to be within =/–10% the R.H. of the board. Otherwise, the board will deform, exhibiting tight edges in a drier environment or wavy edges in a more humid environment.

Table 6.3
Equilibrium moisture content for paper and paperboard.

Temperature °C	(°F)	Relative Humidity 10%	20%	30%	40%	50%	60%	70%	80%	90%
–1.1	(30)	2.5	4.3	6.0	7.3	8.3	9.6	12.3	15.5	22.5
4.4	(40)	2.4	4.3	5.9	7.3	8.1	9.4	12.1	15.4	22.0
10.0	(50)	2.4	4.2	5.8	7.2	8.0	9.2	11.9	15.3	21.5
15.6	(60)	2.3	4.2	5.8	7.1	7.9	9.1	11.7	15.2	21.0
21.1	(70)	2.2	4.0	5.8	7.0	7.8	9.0	11.4	15.0	20.5
26.7	(80)	2.1	4.0	5.7	6.9	7.7	8.8	11.2	14.8	20.0
32.2	(90)	2.0	4.0	5.5	6.7	7.5	8.6	11.0	14.4	19.8
37.8	(100)	1.9	3.8	5.3	6.5	7.3	8.4	10.7	14.0	19.5
43.3	(110)	1.9	3.7	5.1	6.2	7.0	8.2	10.4	13.7	19.1

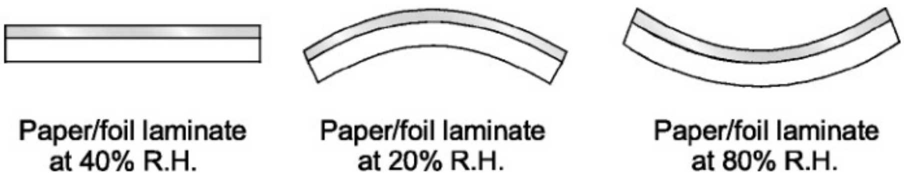


Figure 6.11
Paper's hygroexpansive nature can cause unwanted curling when paper is bonded to an environmentally stable surface.

Paper is hygroexpansive: When it absorbs moisture, it expands; when it dries; it shrinks. Between 0 and 90% R.H., dimensions can change 0.8% in the MD and 1.6% in CD. A 1% shrinkage over a 1-m (3-foot) carton blank is 10 millimeters (about 0.4 inch). Such a difference can play havoc with printing and die-cutting register.

Whenever a paper sheet is laminated to or coated with a material that is not affected by moisture (for example, plastic film, aluminum foil or heavy print or varnish), there is the potential for curling when the humidity changes. If the paper gains moisture and expands while the surfacing laminate or coating remains the same, the paper will curl toward the surfacing material. When the paper loses moisture, it will shrink and curl away from the surfacing material. (See Figure 6.11)

Viscoelasticity

Paper exhibits viscoelastic properties, meaning that certain strength values depend on the rate that a load is applied. Simply put, the faster a load is applied, the greater the apparent strength. Over long loading periods, paper fibers move and distort or "creep." Long-term static compressive strength is much less than dynamic compressive strength. For example, corrugated boxes tested at 500-kilogram (kg)-load compressive strength in the laboratory (a fast loading rate is dynamic) could be expected to fail in about a year when a 250-kg static load is applied in the warehouse.

The tendency for paper fibers to move or acquire a set also means that the longer a knocked-down folding carton blank is kept flat, the greater the permanent set developed at the score lines. This is because the deformation of the board along the score decreases with time, reducing its effectiveness. As a result, it takes more force for the cartoning machine to open the carton, and cartons can become difficult to erect.

PAPER TYPES

One result of the evolution of thousands of small papermaking craft shops into the giant industry of today is an almost complete lack of clarity and consistency in the naming of paper mill products. TAPPI, an association for the worldwide pulp, paper, packaging, tissue and converting industries, lists no fewer than 479 descriptors of paper mill products; there are 44 descriptors alone for what is called "paperboard" in this text.

Many of these descriptors are confusing or inconsistent. For example, papers made from chemical pulps are described as "wood free" and "boxboard" is described as a material used to make "cartons." Other descriptors are simply historically obsolete. For example, "bristol board" originally described a board produced in Bristol, England, and "manila paper" was made from scrapped manila and hemp rope. Names such as "railroad manila" and "cracker-shell" reflect an original customer or application. In addition, paper manufacturers have proprietary names for paper, and there is little uniformity in the names of the different types and grades.

The terminology in the following lists of paper and paperboard types has been selected to describe, as closely as possible, the actual fiber make-up and construction of the product or a significant current use. (See Table 6.4)

Most papers are made on Fourdrinier or twin-wire machines. Unlike multi-ply boards, papers usually are composed of a single pulp type or blend. In a few instances, additional layers are laid on from additional headboxes. Some papers are designed for particular printing processes, and it is important for the paper supplier to know which process will be used.

Newsprint and Related Grades. Newsprint is composed of up to 95% economical mechanical or groundwood pulps. Runnability is a prime requisite, and higher-quality pulps are sometimes added to improve strength qualities. Standard newsprint is about 49 gsm (10 lb. per 1,000 square feet). Newsprint has relatively low brightness, typically 55 to 65, and has low physical strength properties. Newspaper inks are primarily oil and carbon, and high oil absorbency is a desirable characteristic in newsprint.

Book Papers. Like newsprint, book and catalog papers are based primarily on mechanical pulp but are sized and clay-coated to varying degrees to improve surface appearance and printing qualities. Inexpensive pocket books are printed on heavier calipers of similar paper. The papers used in popular magazines are about 50% mechanical pulp and are coated and calendered to provide good white printing surfaces.

Table 6.4
Paperboard grades.

Grade	End Uses	Pulp
SBS – SBB Solid Bleached Sulfate	higher-end and general packaging, healthcare, cosmetics, greeting cards	Bleached chemical pulp
FBB Folding Box Board	higher-end and general packaging, healthcare, cosmetics, greeting cards	Chemical pulp with mechanical or (B)CTMP middle
SUS – SUB Solid Unbleached Sulfate	beverage carriers, frozen foods	Brown (unbleached) chemical pulp
CKB – CUB Coated Kraft Back	heavy consumer products, food	Coated unbleached chemical pulp (some mechanical)
LPB Liquid Packaging Board	milk, juices, etc.	Bleached chemical pulp (some CTMP)
WLC – CRB White Lined Chipboard	food, toys, hardware	One or more layers of recycled fiber

Source: Paperboard Packaging Council

Commercial Papers. Commercial papers cover a broad range of products, many of them specifically designed for particular applications. Generally based partly on groundwood and coated, such papers are used for higher-quality journals and books and general office purposes. Brightness usually ranges from 73 to 85. Papers used for photocopying are designed to withstand the heat of the copying process with a minimum of curl and distortion. They also must have controlled electrostatic surface resistance to provide uniform image transfer.

Greaseproof Papers. Greaseproof papers are made from chemical pulps that have been highly refined to break up the fiber bundles. The fine fibers pack densely, resulting in a structure that does not readily absorb fluids. Glassine papers are supercalendered, semitransparent greaseproof papers. Parchment papers are treated with silicone to increase water and grease barrier. Greaseproof papers are used for snack foods, cookies, butter and lard wraps, and other oily or greasy products. Occasionally, they will be used for their semi-transparent properties. Greaseproof paper may be treated with fluorochemicals or polyvinylidene chloride to further improve water and grease hold-out. Plastic films have replaced these grades in many applications.

Natural Kraft Paper. Natural kraft, the strongest of the common packaging papers, is used whenever maximum strength is needed. The light brown papers are used in industrial bags, carry-out grocery bags and as inner plies in multiwall bags. Impact strength is imparted to some kraft paper used for industrial bags by creping the paper. The slight extensibility gives the paper greater shock resistance (tensile energy absorption). Paper for carry-out bags can be machine-finished (calendered) to provide a pleasing surface gloss. The fibrous nature and color of natural kraft paper do not suit fine printing.

Bleached Krafts and Sulfites. Where appearance is important, kraft paper can be bleached. However, bleaching will reduce paper strength somewhat. For applications where the material will be printed, the kraft would be coated to smooth the surface. Flour and sugar bags are typical applications. Low-density bleached kraft and sulfite papers are used to produce "dry waxed" paper. Highly calendered bleached kraft and sulfites are used for "wet waxing," where the wax coats the surface and produces a high surface gloss.

Tissue Paper. "Tissue" is a generic term for any light paper. In packaging, tissue is used for protective wrapping and as a laminating component.

Label Paper. Label papers are similar to book papers. Generally, the printing quality required determines the grade chosen. For example, uncoated papers are used only for line copy and simple text. Machine-finished papers provide good results up to about a 110-line screen. Supercalendered paper is needed for higher line screens.

Most papers used for label printing are clay coated on one or both sides. Coated paper can be made in matte, dull, gloss and high-gloss finishes. Cast-coated paper is made by drying a clay coating in contact with a heated, highly polished chromed drum. The process results in a very smooth, extremely glossy surface.

Pouch Papers. Pouch papers are supercalendered virgin kraft papers that have been treated with a plasticizer to make them more pliable. The high-density material is very strong and has a smooth surface finish. Pouch papers treated to have alkali resistance are used for soap wrappers.

Containerboards (linerboard and medium). Containerboard specifically refers to linerboard and medium produced for use in the manufacture of corrugated board. Linerboard is a solid kraft board made specifically for the liners (facings) of corrugated fiberboard. Performance characteristics are governed by carrier specifications.

Most linerboard is natural kraft run on a machine with two headboxes. The inner face is somewhat rougher to promote good gluing to the medium. The outer liner is sometimes made of bleached kraft stock. The bleached liner is not heavy enough to hide the natural kraft underlayer, resulting in a somewhat mottled or off-white appearance.

Medium is the material used to produce the fluted core of corrugated fiberboard. The desired properties are glueability, stiffness, formability and runnability. Most medium is made to an industry specification of 127 gsm and 229-caliper (26 lb. per 1,000 square feet and 0.009 inch). Medium is made from semichemical hardwood pulps and recycled kraft containers. Medium board is the one paper product where lignin content is an asset; it imparts thermoformability properties.

CHAPTER 6

PAPERBOARD GRADES

Paperboard grades used in packaging are described below. Some of the more commonly used grades are identified in Table 6.4, which also shows end uses and fiber sources.

Chipboard, "Cardboard," Newsboard. Chipboard is made from 100% recycled fiber and is the lowest-cost paperboard. Colors range from light gray to brown. Chipboard is unsuitable for printing and has poor folding qualities due to its short fiber length. Chipboards often contain blemishes and impurities from the original paper application. They are used for set-up boxes, partitions, backings and other applications where appearance and foldability are not critical.

"Cardboard" is a depreciated term not commonly used among paper and packaging professionals, but consumers often use the word to generically describe chipboard-type products or corrugated. Newsboard is a low-grade board made mostly with recycled newspapers.

Bending Chipboard. Bending chipboard is a slightly better grade of chipboard. It is still primarily composed of recycled fiber, but with enough higher-quality fiber to allow scoring and folding. Usually a gray or light tan, it is the lowest-cost board used for folding cartons.

Lined Chipboard. Lined chipboard has had a white face-liner applied to improve appearance and print quality. Bending characteristics and filler and back liner colors will vary depending on ply composition. Lined chipboard may or may not be clay-coated. Single white-lined, double white-lined and clay-coated newsback are varieties of lined chipboard. (See below.)

Single White-Lined (SWL) Paperboard. The top liner of single white-lined paperboard is 100% new pulp or high-quality recycled pulp. The back is usually gray or brown. It is a smooth board with a typical brightness of 60 to 85. SWL is used for folding cartons where the appearance of the back is not critical. The board may or may not be clay-coated.

Clay-Coated Newsback (CCNB). This is a single white-lined paperboard in which the back and sometimes filler plies are made from recycled newsprint. The back liner has a neutral pale gray color that is judged to be more aesthetically acceptable for some applications than the mixed browns of other SWL boards.

Double White-Lined (DWL) Paperboard. Double white-lined paperboard is similar to SWL except that both front and back have been lined with a bleached white pulp. Usually, the back liner is somewhat less finished than the front. DWL is used when the internal appearance of the box is important or both sides will be printed. The primary face is usually clay-coated.

Solid Bleached Sulfate (SBS). SBS is a strong, premium paperboard composed of 100% bleached sulfate pulps. SBS boards are white throughout and used in applications where total board appearance is of primary importance and where maximum physical properties are required for the given weight of the board. Because

SBS boards are made from virgin pulps, properties vary less during a run than for a similar lined chipboard. Many high-speed packaging operations prefer SBS for its consistent line performance, even though from other considerations a lined chipboard may have been adequate.

Food Board. Highly sized SBS paperboards often are called food board. Uses include wet foods, frozen-food cartons and other applications where good performance under wet conditions is important.

Solid Unbleached Sulfate (SUS). SUS is a maximum strength unbleached kraft paperboard. Where surface appearance is important, the board will be heavily clay-coated, sometimes with a double coat to provide the opacity needed to hide the brown kraft body. Beverage baskets (six-packs) are a major application of clay-coated, solid-unbleached sulfate.

Folding Boxboard (FBB). Similar to SBS, except this is a multi-ply board. Normally, the middle layer (or layers) consists of some form of mechanical pulp, which is sandwiched between layers of chemical pulp.

PAPER CHARACTERIZATION METHODS

The majority of paper characterization methods are sponsored by ASTM International, formerly known as the American Society for Testing and Materials, or TAPPI. Common standard testing procedures for paper and paperboard are listed below.

Conditioning Paper and Paper Products (ASTM D685 / TAPPI T 402). All paper products must be tested under controlled temperature and humidity conditions. International conditions for paper testing are 23 °C and 50% R.H.

Grammage of Paper and Paperboard (ASTM D646 / TAPPI T 410). Procedure for determining the weight (mass) per unit area, otherwise known as the basis weight. ASTM D646 contains ream-weight conversion factor tables.

Thickness of Paper, Paperboard and Combined Board (TAPPI T 411). Since paper is compressible, the pressure of the micrometer foot must be accurately controlled. Several readings must be averaged to assign a paper caliper.

Moisture Content by Oven Drying (ASTM D644). Moisture content is expressed on an oven-dry basis.

Brightness (TAPPI T 452). Brightness measures the total spectral reflectance.

Gloss at 75 Degrees (TAPPI T 480). Glossiness quantifies surface shine.

Opacity (TAPPI T 425 / TAPPI T 519). Opacity is most important for thinner papers where it is essential that printing on the reverse face does not show through.

Petroleum Wax in Paper (ASTM D590 / TAPPI T 405). Used to determine the amount of paraffin in waxed papers.

Internal Tearing Resistance of Paper (TAPPI T 414). Used to assign a value to the force required to tear paper in the CD and MD. Commonly called the Elmendorf tear test.

Water Absorption (TAPPI T 441). Measures the amount of water absorbed by a given paper area in a specified time. The Cobb test is intended to be used with sized papers and paperboards.

Tensile Breaking Strength of Paper and Paperboard (ASTM D828 / TAPPI T 404). A measure of paper strength in tension.

Folding Endurance (ASTM D2176 / TAPPI T 423 / TAPPI T 511). ASTM's method is the M.I.T. test. TAPPI also has a standard for the Schopper fold endurance test.

Resistance of Nonporous Paper to Passage of Air (ASTM D726 / TAPPI T 460). Passage of air is governed by a paper's porosity. It is related to absorbency and has been used to indicate rotogravure ink absorption and to gauge filtering ability. Known as the Gurley porosity test.

Bursting Strength of Paper (ASTM D774 / TAPPI T 403). Measures the resistance to rupture. Also known as the Mullen burst test.

Moldability (TAPPI T 512). Quantifies crease retention or springback.

Wax Pick Test for Surface Strength of Paper (ASTM D2482 / TAPPI T 459). An arbitrary assessment of paper surface strength, the test uses a series of waxes having different adhesive values. Poor bonding of surface fibers or coatings can cause printing and gluing problems. Also known as the Dennison wax pick test.

Grease Resistance (TAPPI T 454). Important for applications in greasy products.

Water Vapor Transmission (ASTM E96 / TAPPI T 464). Usually done on barrier-coated or glassine-type papers.

Smoothness (TAPPI T 479). Surface smoothness relates to printability and other surface-influenced characteristics, such as coefficient of friction.

Stiffness (TAPPI T 451 / TAPPI T 489). Stiffness is measured in Taber stiffness units. The stiffness of a paperboard is important in maintaining a flat face on a carton's main display panel.

REVIEW QUESTIONS

1. What is the difference between softwood and hardwood as a source of wood pulp for papermaking?
2. Cellulose fiber can be separated from the wood mass by several means. Name the two main methods, and lists the advantages and disadvantages of each method.
3. What is the standard international test environment for all paper and paperboard testing? Why is it important to do paper characterization tests under these conditions?
4. Why is it difficult to print a natural kraft paper?
5. Paper is hygroscopic. What does this term mean?
6. What are MD and CD? Why it is important for a carton designer to know them?
7. Discuss the impact of fiber length on paper properties.
8. Paper is made with different machines, each machine imparting certain characteristics. In most discussions, paper is referred to as coming from two types of papermaking machines. What are these machines, and what is the principal characteristic that indicates what kind of machine it came from?
9. What is a 20-point board?
10. How is paper caliper (thickness) correctly specified in: (a) metric units and (b) inch/pound units?
11. Paper is often coated at the paper mill. What is the principal coating material, and what does it do?
12. What is the difference between a hard-sized and a slack-sized paper?
13. Discuss the benefits and problems of postconsumer waste paper as a fiber source for papermaking.
14. What is the strongest and what is the weakest papermaking pulp?
15. What kind of paperboard would you select for making a beverage basket (a six-pack holder)?
16. A paperboard specimen can be peeled apart into seven layers. What does this tell you?
17. Is there a difference between “whiteness” and “brightness” in describing paperboard? Define these terms.
18. What kind of pulp is kraft paper made from, and what are the distinguishing characteristics of kraft paper?
19. What is the difference between paper and paperboard?
20. What might give you a clue that a paperboard contained recycled materials?

21. Which paper would be stronger: mechanical softwood or mechanical hardwood?
22. What problem would be encountered if we tried to make a thick paperboard on a conventional Fourdrinier machine?
23. Explain why paper products are typically specified by both caliper and grammage (basis weight).
24. Paper is hygroexpansive. What does this term mean, and where might this property affect your packaging?
25. Name two typical softwoods and two typical hardwoods.
26. You want to design a box with a tear strip around the perimeter. How would you evaluate the characteristic in question?
27. What problem might be encountered if a highly sized board were used when making a folding carton?
28. What is the probable makeup of chipboard, and where might you use it?
29. The Cobb test measures the level of a particular paper treatment. What is that treatment?
30. What is the makeup of a glassine paper? Where might it be used?
31. What paper properties will calendering affect?
32. What paper properties does refinement affect? Name an application where low refinement is desirable and an application where high refinement is desirable.
33. Which of the following characteristics is highest in MD: tear, fold endurance or stiffness?
34. What is formation, and what qualities contribute to poor and good paper formation? What is the significance of formation to the paper user?
35. What is the moisture content of paper at standard test conditions?
36. A foil-laminated label stock is causing problems because the labels are curling. What is the cause of this behavior?

PAPERBOARD CARTONS

7

CONTENTS

Paperboard Package Classifications

Common paperboard constructions: folding cartons; rigid (set-up) boxes; tubs, trays and liquid-resistant boxes.

Folding Carton Design

Design considerations: single or repeated entry; weight; access prior to purchase; sift-proof, single- or double-glued; erection method; tamper-resistance; long-term storage; irregular shapes; loading method; machinery restrictions; consumer needs; retailing needs.

Selecting the Correct Paperboard

Physical strength, moisture and grease resistance, machinability, printing requirements, suggested board caliper.

The Carton Production Process

Concept development, hand samples, typical approval points, importance of sign-offs, cutting and creasing dies, crease formation and geometry, folding paperboard, bleed, single and double knifing, press approval and color standards, secondary and finishing operations, prebreaking of creases, paper set.

Basic Tube-Style Folding Cartons

Sealed-end cartons, tuck closure designs, other closure variations, external design features and internal partitions.

Basic Tray-Style Folding Cartons

Definition, Beers tray variations, tray grain direction, Brightwood tray variations, mechanical self-locking trays, frame-vue tray.

Beverage Baskets and Set-Up Boxes

Beverage basket material, partition selection, rigid box definition, advantages, limitations, applications, material selection, coverings, style examples.

PAPERBOARD CARTONS 7

PAPERBOARD PACKAGE CLASSIFICATIONS

Paperboard provides a versatile and economical material not readily matched by other packaging mediums. One significant advantage is the low tooling cost compared with that for materials such as plastics. Effective paperboard package design is based partly on knowledge of paper and product properties and partly on craftsmanship and art. Paperboard packaging falls into several categories:

Folding cartons. Folding cartons are by far the largest and most important group in paperboard packaging. Folding cartons are made as flat blanks or as preglued forms that can be flattened for shipping. They can be made economically on high-speed production machinery. The majority of folding carton designs can be classified as falling into either the tube-style or tray-style families.

There are many highly specialized variations within these carton families. The gabletop container is a tube-style carton that has found many applications, particularly for dairy products and fruit juices. The heavily sized and polyethylene-coated board is erected and heat-sealed at the point of fill. Combibloc and Tetra Pak are similar-appearing proprietary cartons made from complex paper/poly/foil/poly laminates. A principal application is aseptic beverage packaging such as juice boxes.

Not all folding cartons are box-like containers. Beverage baskets or carriers are typically designed to hold four or six beverage bottles.

Rigid (set-up) boxes. Rigid cartons are delivered erected and ready for filling. Because they are already "set up," they need as much storage space empty as they do when full. The rigidity of these boxes creates an upscale image for products. The sturdiness of set-up boxes also makes them desirable for applications where the container acts as a storage unit.

Tubs, trays and liquid-resistant boxes. Paperboard can be formed into round or square tubs with paper end seals. Such forms, constructed from food board, are used to contain such items as ice cream and frozen foods. Flat sheets with gusseted corners can be folded to form food trays for frozen entrees or other food products. In most wet-food applications, the board is coated with either polyethylene or wax. Dual-ovenable paperboard trays are coated or laminated with an oven-temperature-tolerant plastic such as polyethylene terephthalate.

FOLDING CARTON DESIGN

Good carton designs are not merely inspired creations. They are the product of careful analysis that considers product requirements, retailing factors, production requirements, consumer needs and other inputs essential for a successful package.

Carton design considerations always start with the product itself. Since the product's nature dictates how it will be filled, how it will be sold and how it will be used, product and carton design must be considered together. The first decision is to select the primary carton shape: for example, tube-style, tray-style or some other basic structural shape. After these decisions have been made, a great deal of carton design has to do with selection of the closure type and its location. For tube-style cartons, the following factors may influence the choice of closure:

- Will the carton hold a self-contained package? If the carton is to hold another package, such as a can or bottle, simple tuck flaps are adequate closures, since the designer need not be concerned with contamination, sifting or infestation. (See Figure 7.12) Tuck flaps have the advantage of not requiring a glue station at the fill point.
- Will there be one entry or repeated entries before discarding? If the tuck flap is a one-time-entry item, it should have a slit-lock feature that will provide a more positive and secure closure. (See Figure 7.15) This feature is particularly useful for heavier products or for when the board itself is springy. Well-designed slit locks will tear the carton tuck flap on opening. For repeated-entry cartons, a plain friction-lock tuck flap will provide a neater appearance over the carton's use life.
- Will the consumer wish to see the product before purchase? If the consumer wants to see the product, add an opening or window. However, in some instances, the consumer will want to touch the product. For such cases, the closure must allow entry without destroying the package. Plain tuck flaps are indicated.
- Is the product particularly heavy? Heavier products need greater security in the tuck flap. Locking tabs such as the tongue or edge lock provide a positive tuck-flap lock. (See Figure 7.17) Heavy products, like liquor and hair care, often are packed in automatic-bottom style cartons
- Does the product require sift-proof construction? If the product is not contained in a separate primary package, the carton requires double-glued end seals. Double gluing puts adhesive bonds on both minor and major flaps, providing a more effective block against sifting or entry of foreign agents. (See Figure 7.1)
- What is the nature of the packaging operation? Manual, semiautomatic and fully automatic operations are best complemented by different designs. (See Figure 7.2) Manual erection could call for preglued or automatic-erecting features such as a Himes lock or 1-2-3 lock for the bottom closure. (See Figure 7.16) Typically, the top closure would be a tuck flap.

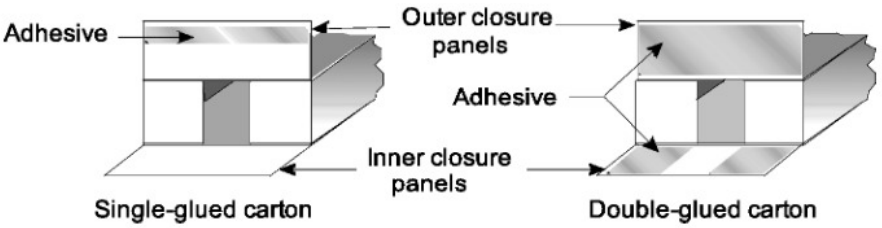


Figure 7.1
Single-glued cartons have adhesive on the outer closure panels. For a sift-proof or contamination-free carton, the flaps need to be double-glued.

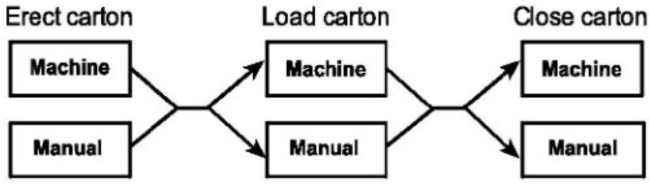


Figure 7.2
Each step in a carton-packing operation can be done by machine or manually. Carton design is influenced by the sequence being used.

- Does the carton need a seal to prevent casual entry? Single-glued flaps close the carton ends with adhesive applied along the major carton flaps. This provides security against casual entry.
- Will the consumer use the box as a storage container? A method of tidy entry, closure for storage and re-entry may be desired for boxes the consumer will use a long time. Set-up boxes with removable lids are useful, provided the added cost is acceptable.
- Is irregular shape an advantage? Rectangular shapes are the most convenient for shipping and displaying, but some products are effectively marketed in other shapes. While irregular shapes may provide a distinctive shelf appearance, they are more difficult to pack and ship. Obtaining machinery that will handle eye-catching shapes also can be a problem. Approach irregular shapes with caution.
- Will the product be loaded by dropping it vertically or by sliding it horizontally into the erected carton? (See Figure 7.3) Horizontal end-loading tube-style cartons are essentially the same as vertical end-loading tube styles, except that the filling orientation has changed. Some attention may have to be given to the direction in which the flaps open.

  Vertical end-loading is the preferred loading method since it is assisted by gravity. Granular or powdered products must be loaded through a vertically oriented end. Most multicomponent products, including primary packages with inserted instructions, are best loaded this way. Products such as convenience dinners, pizzas and cakes have definite horizontal orientations and cannot be dropped vertically. These must be handled gently and pushed horizontally into the carton.

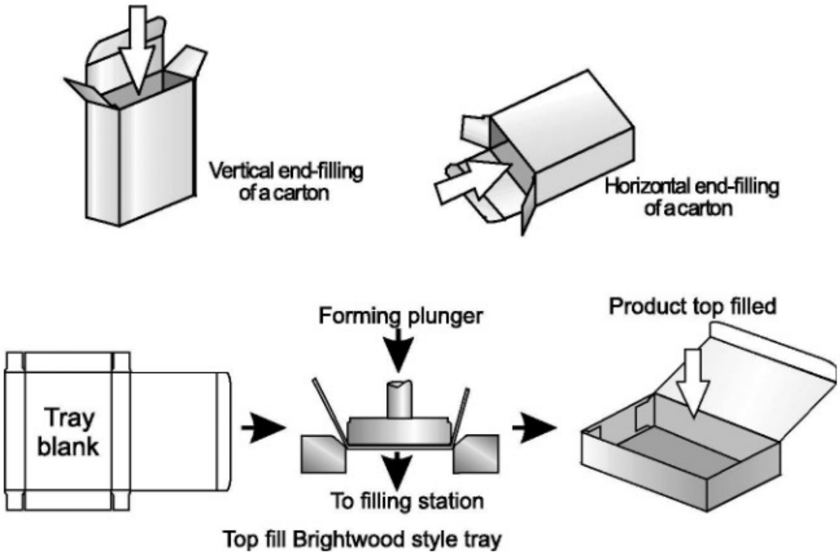


Figure 7.3
A vertical end-loading carton, a horizontal end-loading carton and a top-loading carton.

Cartoning machines designed for horizontal end-loading tend to be more complicated than those for vertical end-loading since a conveyor to transport the product parallel to the cartons and a mechanism to transfer the product into the carton are needed.

- Is the product best loaded through a large opening? Some products are best loaded through the largest possible opening, such as that found on a tray-style carton. However, a glued tray, in effect, becomes a rigid box that cannot be knocked down flat for shipping unless additional creases are put into the end panels to allow for the carton to fold flat. These extra creases affect the stiffness and rigidity of the finished tray. In some applications, this is undesirable.

  Where a stiff top-loading tray is required, flat, unglued tray blanks are sent to the filler. The packager uses a carton erector, a relatively simple machine that erects the carton with adhesive or locking tabs. The flat blanks of cartons, such as the Brightwood tray (see Figure 7.23), are pressed through a forming frame and glued to a stiff rigid-carton shape. (See Figure 7.3) Since top-loading cartons can be shipped as unglued blanks, they have the advantage of being palletized horizontally and flat.

  Dimensionally unstable products, such as apparel, are best packed in top loaders. Gift boxes that open at the top provide attractive display possibilities and frequently are used to create countertop displays for small items.

- Will machinery restrictions limit design options? A frequently overlooked point is that the carton must be manufactured on existing equipment. The type of erecting and filling machine to be used also will dictate certain design features. Clearances and setbacks are necessary to allow the machine to open cartons and move flaps and closure panels. Dust flaps are usually shorter than a closure panel so that machine "fingers" can pass over the dust flap and fold down the closure panel.

- How will the consumer use the product? Packages must fit conventional storage locations such as medicine cabinets or refrigerators. Convenient entry, carrying handles, pour spouts, tear tapes, dispensing aids and other devices easily incorporate into paperboard designs.

- How will the carton be retailed? Carton designs can help the retailer. The package should provide stable displays that attract buyers. Provision for easy unpacking, shelving and display are obvious features.

  If the carton is designed to be suspended from pegboard-type displays, make certain that the board is strong enough to hold the carton for long periods and through nominal abuse. Cartons that have a center of gravity far in front of the pegboard hole will hang at an angle facing away from the consumer and are particularly prone to tearing.

SELECTING THE CORRECT PAPERBOARD

The most important factors in paperboard selection concern structural requirements and printing and decorating needs. Structural considerations deal with the physical strength characteristics needed to hold the product successfully during shipping and display. Puncture resistance, stiffness, tensile strength, z-direction strength (i.e., the direction perpendicular to the cross direction and machine direction), directionality, glueability and other paperboard characteristics are also important.

Cartons for wet products or products that experience damp environments, such as freezer storage, need hard-sized, waxed or otherwise-treated paperboards. Oily or greasy products need grease-resistant boards or treatments. Kraft paper is used where maximum board tear or burst strength is needed.

The board's machinability affects how fast a carton can be selected from a magazine, pulled open and inserted into the flights of a cartoning machine. Coefficient of friction, also called "slip," and consistency of physical properties are key factors related to machinability. More costly solid-bleached-sulfate (SBS) boards sometimes are preferred over lined chipboards; SBS boards exhibit more consistent properties and run more trouble-free on high-speed equipment.

Many papers are designed for specific printing processes, and the suitability of the paper to the proposed printing method should be verified. Mechanical condition and uniformity all have a bearing on a paper's runnability.

Printing and decorating are concerned primarily with the characteristics of the paper surface finish:

color	brightness	opacity
smoothness	gloss	cleanliness
surface formation	ink compatibility	dimensional stability

Paperboard qualities vary widely and should be verified for every application. No two paper mills make identical papers even though the papers' generic names may be the same. The key properties required for an application should be determined and compared with boards from different suppliers. Table 7.1 provides convenient starting points for selecting board caliper based on the product weight.

Table 7.1
Product weight and suggested board caliper.

Approximate Weight	Board Stock Thickness
Up to 230 g (1/2 lb.)	380 to 450 micrometers (μm) (.015 to .018 in.)
450 g (1 lb.)	500 to 600 μm (.020 to .024 in.)
900 g (2 lb.)	700 to 800 μm (.028 to .032 in.)
Over 900 g (> 2 lb.)	900 μm (.036 in.) or consider E- or F-flute corrugated

THE CARTON PRODUCTION PROCESS

The carton design process starts with an in-depth review of the customer's needs and objectives. It is important at the initiation of any design project for the packager and marketer of the product to share all technical and marketing expectations. Since many carton makers do not keep paperboard stocks on hand for possible orders, it is equally important for the customer to contact the carton maker at an early stage so that paperboard orders can be placed. For more information about paperboard grades, see Chapter 6, Paper and Paperboard.

The carton designer develops one or several designs that meet the customer's stated objectives. A hand sample of each candidate design is cut, scored and manually assembled for the customer's approval. The customer's approval signature on the hand sample authorizes the carton maker to proceed to the next production steps. (The term "hand sample" is still commonly used although computer-aided-design, or CAD, technology has replaced hand cutting and scoring. Some prefer the more accurate term "CAD sample.") The customer inspects the hand sample and gives the approval, the first of many, to proceed to the next step.

The customer's approval, or sign-off of a sample, starts the carton production process summarized in Figure 7.4. During the production sequence, the customer will be asked for more sign-offs to indicate acceptance of work done to date and to authorize the next phase of the production process. It should be clearly understood that each sign-off constitutes a legally binding contract, and it is the customer's responsibility to ensure that every detail is correct at every stage of production. A missed spelling mistake discovered at the end of a production run is the responsibility of the customer, not the carton maker.

Digital dimensionally correct records of the approved design are forwarded to graphic arts and die-making departments. Carton layouts normally are shown looking at the outside or printed side.

To produce a folding carton, the flat carton blank must be cut from the press sheet, and the blank must have scores pressed into the board along the lines where the board will be folded to make the carton. Both functions are accomplished by pressing a steel-rule cutting and creasing die into the board. (The term *crease* and *score* often are used interchangeably, depending on the region or production plant).

Cutting and creasing dies often are made by laser-cutting slots into a heavy hardwood plywood base into which the appropriate steel rules are fitted. The blunt,

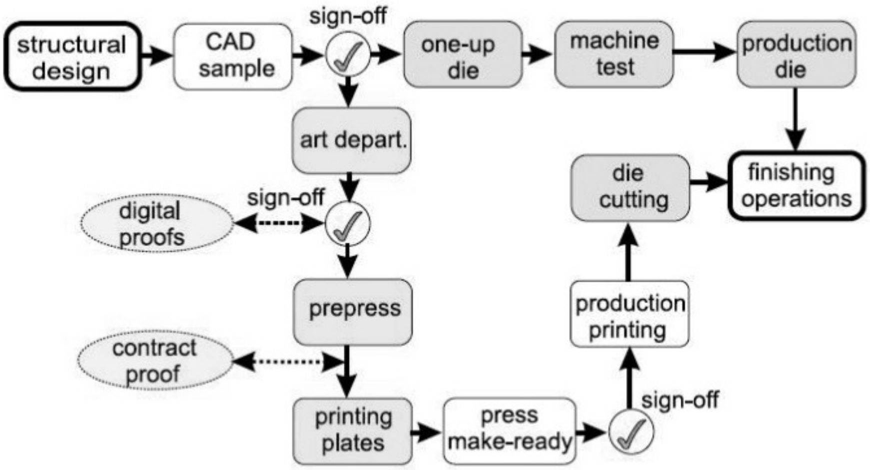


Figure 7.4
A typical carton production sequence, indicating the most usual sign-off points. Other sign-offs may be required, depending on the nature of the project.

rounded-edge creasing rules must be able to press a valley-like depression into the board. Resilient pads made of tympan must be placed under the creasing rules to raise the surrounding board and create the relief into which the rule will push the board. Newer technology includes matrix (a self-adhesive channel), and thin plates into which the channels are routed. (See Figure 7.5)

Cutting rules, on the other hand, need to cut through the paperboard and almost touch the plate. The final bit of paperboard is split apart by the wedging action of the steel rule, much as an axe splits wood. Ejection rubber is placed around the cutting rules to act like springs that push the cut board blank off the cutting rules after the cut is made.

Most folding cartons are cut with the print side up. A paperboard fold is made with the valley side of the score to the outside of the carton. (See Figure 7.6) As the board is bent, the outside "skin" flattens out, while fiber toward the inside of the fold breaks inward to take up the extra material on the inside radius.

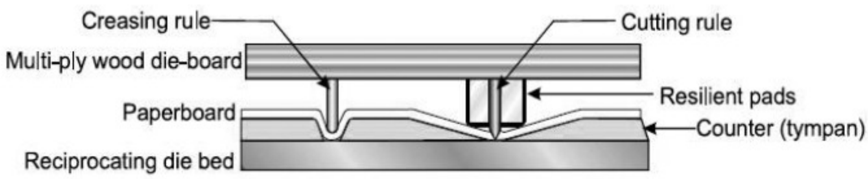


Figure 7.5
Scores are put into the paperboard with blunt-nosed rules. The creasing rule deforms and breaks the paper structure.

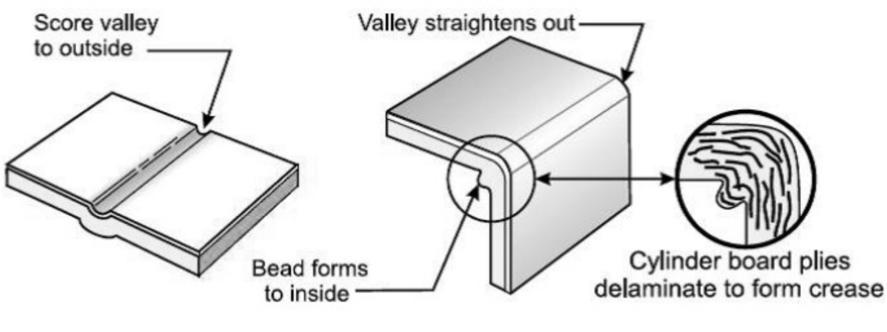


Figure 7.6
A paperboard is folded away from the valley side of the score. The distance around the outside of the folded board is greater than around the inside curve. The bead on the inside makes up for this difference.

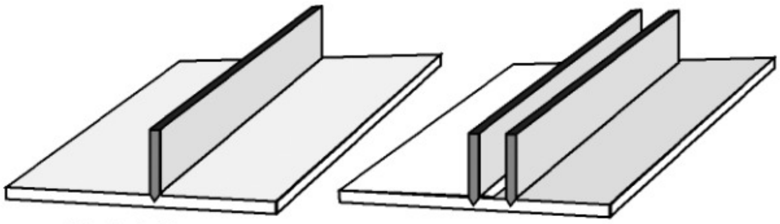


Figure 7.7
Single knifing can be used when colors are the same where two carton edges meet. Double knifing is necessary when colors are different or when bleed requires it.

As Figure 7.5 shows, the crease or score along which a carton will be folded can be formed only from one side of the board. Occasionally, a design requires the board to fold toward the die (valley) side rather than away. In these situations, a "cut score" (a series of short perforations cut completely through the board) is used.

Printing plates are designed to print slightly past the edges of a carton. This "bleed" compensates for the slight inaccuracies inherent in die-cutting and reduces the possibility of an unprinted white streak along a carton's edge. A pair of cutting rules is typically set 6 mm (1/4 inch) apart for separating two cartons out of the press sheet. However, if the two cartons are the same color along the entire adjacent edges, a single rule, also called single knife or common knife, can be used, reducing both die costs and paperboard requirements. (See Figure 7.7)

In a parallel workflow, while the dies are being made, the artwork for the carton graphics is created. When the proofs have been approved, printing plates are made and mounted in the press. The customer sometimes is called in to give final press approval. The customer and the printer will agree on color standards. Target, lightest acceptable and darkest acceptable carton samples may be filed for control purposes.

After the cartons are printed and secondary operations such as embossing or hot-stamping are completed, the cartons go to be diecut. Most diecutting is done on platen presses, but some cartons are cut on faster rotary diecutters. Other finishing operations may include additional carton features such as windows or handholds, or may simply involve folding, gluing and packing for shipment.

The force needed to erect a carton is a critical value for efficient running on high-speed packaging equipment. The carton manufacturer prefolds or prebreaks all scores so the carton can be easily pulled into the erected shape. (See Figure 7.8) The nature of paperboard is such that fibers will develop a permanent set over an extended period, often referred to as "memory." Freshly creased cartons have some springiness at the scores and are easily erected. With time, much of this spring is lost, and the cartons become harder to open. As a general rule, cartons are best run within 90 days of manufacture.

Improper storage (i.e., cartons that are not kept absolutely flat) will, over time, impart permanent curl or distortion that will interfere with proper carton operation.

BASIC TUBE-STYLE FOLDING CARTONS

The most common carton type is the tube-style folding carton, folded and glued by the carton manufacturer. An open-ended tube can be used as a product sleeve, but more often has some form of top and bottom closure. Cartons are flattened for shipping at the working scores, or working crease. (See Figure 7.9) The working scores are nor-

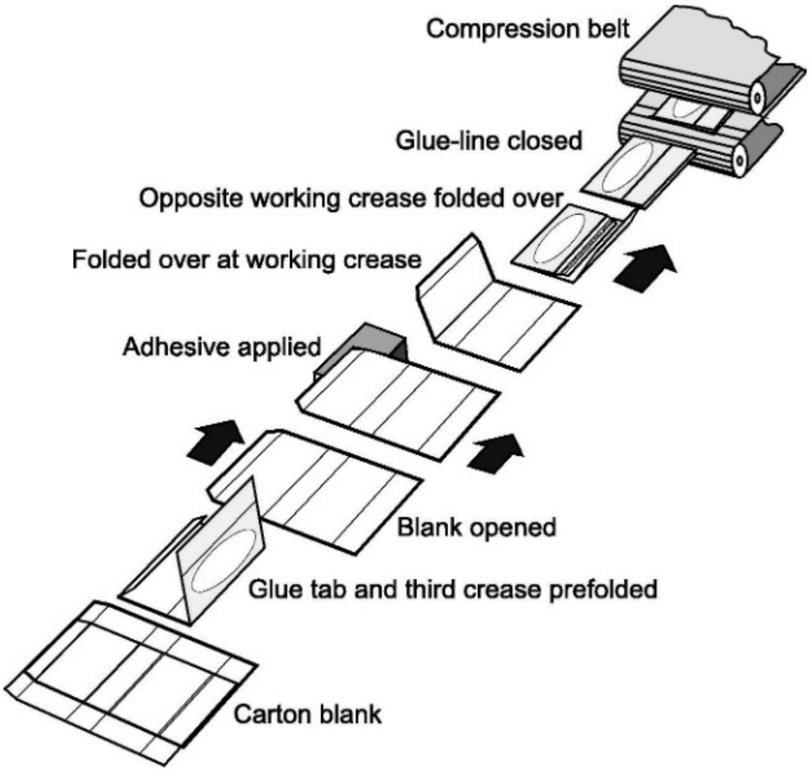


Figure 7.8
A carton's body scores are broken by folding and opening inline with the gluing operation. Prebreaking the scores makes it easier to open the carton on filling machines.

mally the pair not adjacent to the glue flap. Placing the working scores at the glue flap would make folding and flattening the carton more difficult. The tube is received "knocked down flat" (KDF) by the packager, who erects, fills and closes the carton.

Carton dimensions always are given in the order of length, width and depth, with length and width defined as the carton opening. Depth is perpendicular to the opening. The front, or "principal display panel" (PDP), is the panel situated between the two side panels on the carton blank (i.e., the main panel not adjacent to the glue flap). A normal carton has the glue seam, also called glue flap, at the right rear corner when viewed from the PDP. (See Figure 7.9)

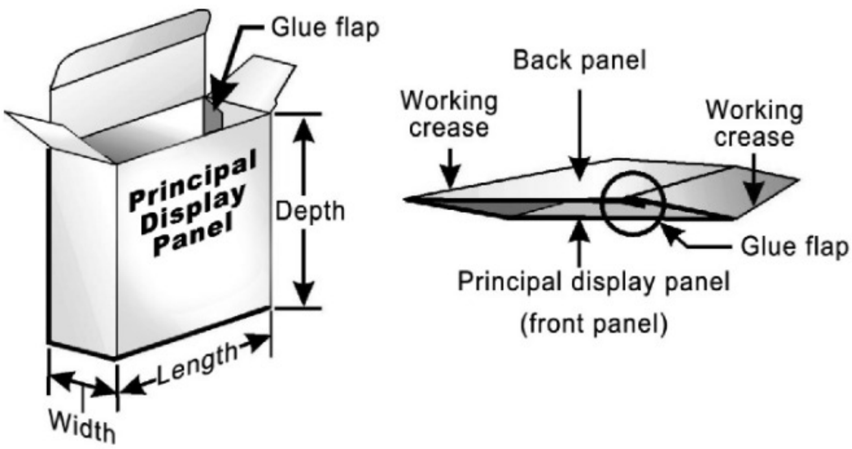


Figure 7.9
Carton terminology and placement of the working scores (creases) and manufacturer's joint.

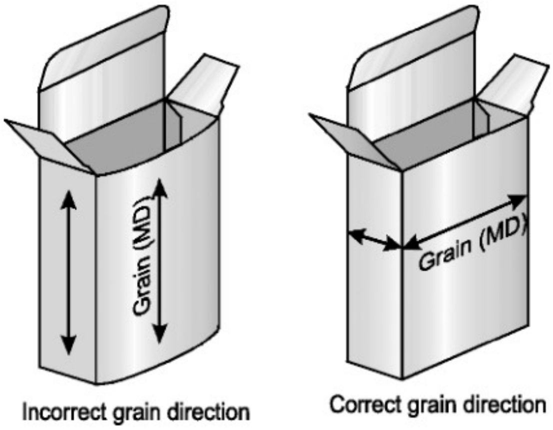


Figure 7.10
Carton grain should cross the corners (right) for maximum carton stiffness.

Grain must be correctly oriented. (See Figure 7.10) Most tube-style folding cartons have grain, or "paper machine direction," running around the carton perimeter (i.e., crossing the carton body scores). An end-to-end grain orientation would produce a carton more susceptible to bulging or rounding at the major display panels. Tear strips are more reliable if run in the grain direction.

For production purposes, multiple cartons are laid out on a sheet of paperboard (the press sheet) of the size used by the available printing and diecutting presses. Efficient utilization of the press sheet area is important since paper cost can represent at least half of the finished carton cost. Good designs minimize board and ink waste.

Sealed-End Cartons

The simplest tube-style folding carton is a full-overlap seal-end (FOSE) carton. The flat blank is essentially a rectangular sheet with appropriate cut-outs for the flaps. FOSE cartons for fine granular or powdered products have the inner and outer closure panels kept at the carton width and the dust flaps cut square. (See Figure 7.11, top closure) The full contact area between the closure panel and the dust flaps allows for full adhesive coverage as used in double gluing to provide a complete, sift-proof seal. (See Figure 7.1) Where sift-proofing or strength are not factors, the closure panels can be cut back to save paperboard.

Partial-overlap seal-end (POSE) cartons cut back closure panels to a point that there is just enough overlap of the two panels to provide for an adequate glue-line. (See Figure 7.11, bottom closure) POSE closure panels on cereal boxes are typically just slightly more than half the carton width. POSE closures are also known as "economy ends."

Carton dimensions frequently are set back on the order of 0.8 mm (1/32 inch) from the full dimension for aesthetic reasons or to provide a slight clearance to improve machinability. The most common setback is to the carton's right side panel. This improves appearance by moving the cut edge slightly back from the carton corner. Other setbacks on a FOSE carton may include narrowing the dust flap slightly so it does not interfere with the outer closure panel when the carton is sealed.

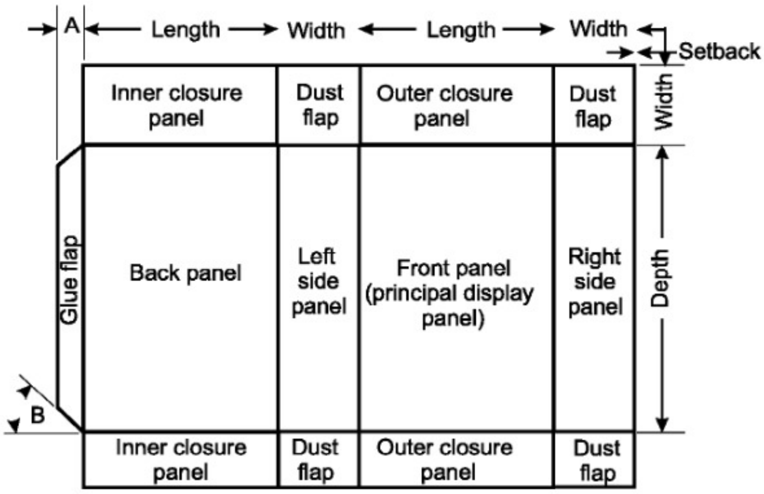


Figure 7.11
A seal-end carton blank. The top end shows a full-overlap seal-end (FOSE), and the bottom shows a partial-overlap seal-end (POSE.)

Tuck Closure Designs

Figure 7.12 shows the four tuck-flap combinations possible on a tuck-end carton. The two reverse-tuck designs are favored because the carton blanks can be better nested into each other on the press sheet for the best utilization of the board. (See Figure 7.13) The standard reverse-tuck has the top tuck panel tucking toward the carton front. The French reverse-tuck is used where a graphic design element continues from the front panel over to the top tuck flap. The French reverse-tuck also is favored for upscale products since it avoids a visible cut edge when viewed from the front. (See Figure 7.12)

A straight-tuck design eliminates a visible cut edge at both the top and bottom. In those designs calling for a window or cutout on the front panel, a standard reverse tuck could leave an easily damaged, narrow margin of board at the carton top or bottom. (See Figure 7.14) Straight-tuck designs avoid this problem by continuing the front panel into the tuck flaps. (See Figure 7.13) Straight tucks also may be preferred for some horizontal end-loading machines where it is necessary to keep both tuck panels clear of the carton openings. Airplane tucks are rarely used.

A carton tuck relying on friction alone to hold it in place does not create a positive closure. Slit-lock closures incorporate small slits between the tuck flap and the top closure panel. (See Figure 7.15) When the carton is closed, the slits engage shoulders cut into the dust flaps, securely locking the flap into place. For certain products where the customer wants to open the carton and see the product, a compromise is struck by making a slit lock at the bottom and a friction lock at the top. This is particularly applicable for products such as perfumes or colognes in glass bottles, where it is essential to have a secure bottom closure to ensure the heavy bottle doesn't fall out of the carton, while still allowing the customer to inspect the bottle.

Other Closure Variations

Where cartons will be manually erected, variations of snap-lock or Himes bottoms will be used for the bottom closure of the carton. The 1-2-3 snap-lock bottom, (See Figure 7.16, top), is the more economical option, but it requires slightly more time to erect than the Himes bottom lock. (See Figure 7.16, bottom) Himes locks, or crash locks and variations on them, are preglued, automatic bottoms. They are somewhat stronger than the 1-2-3 snap lock.

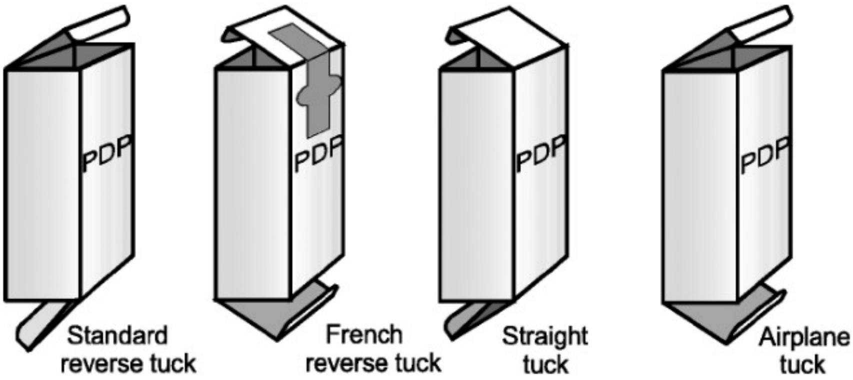


Figure 7.12
Tuck closures can be arranged in various directions relative to the principal display panel (PDP).

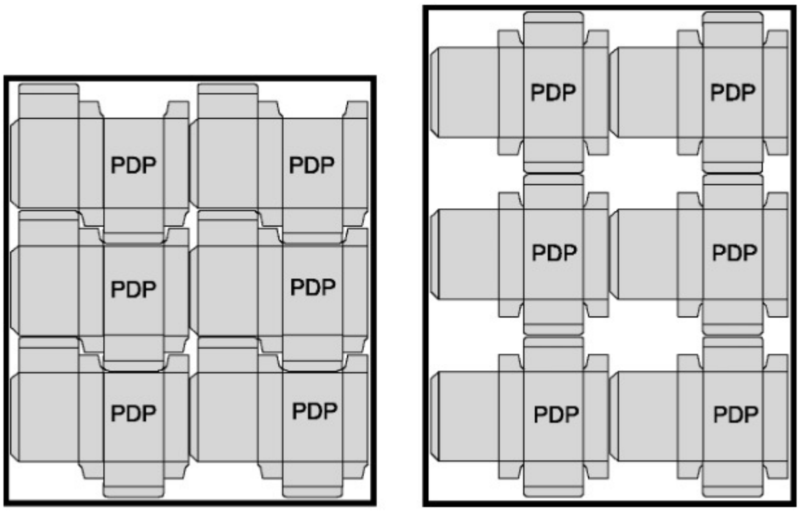


Figure 7.13
A reverse tuck and a straight tuck of identical body dimensions. The reverse-tuck carton (left) has the best board utilization when arranged on a press sheet. A straight-tuck design (right) is less efficient.

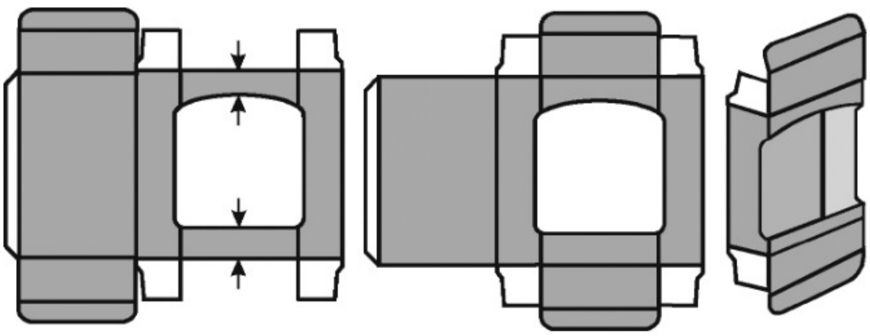


Figure 7.14
The straight-tuck carton on the right would provide supporting material to the front display panel in those designs that have windows or cutouts. The tuck-flap configuration on the left has less material to support the window, and windowing material glued to the carton interior can interfere with the tuck flap.

Tuck-and-tongue locks and edge locks add security to a tuck flap and allow it to tolerate considerable weight without opening. (See Figure 7.17) A tongue discourages opening while still making it possible. Doubled-edge locks provide added security for heavy products and are particularly useful for wide cartons.

The tuck end with an incorporated tear strip combines the convenience of a tuck end with the security of a glued carton seal. (See Figure 7.17) The inner closure panel has been designed with a tuck flap. The outer closure panel is glued over the inner one to provide a secure, tamper-evident carton. The tear strip must be used to open the box.

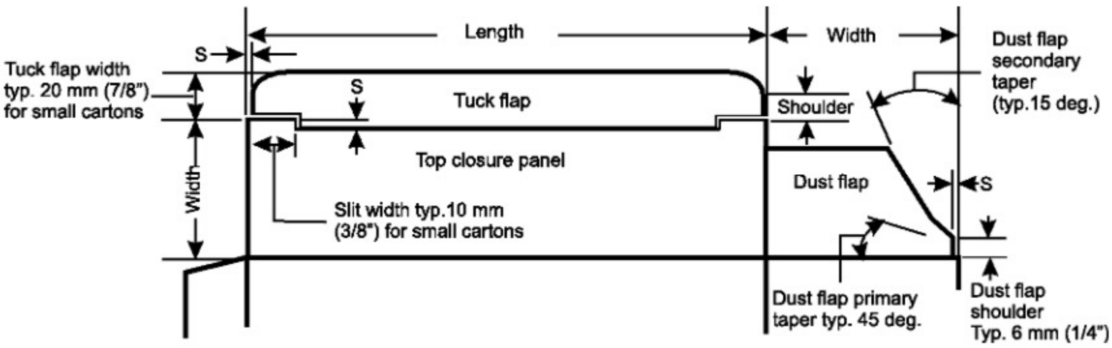


Figure 7.15
Slit-lock tuck closures have slits that engage against the dust flaps to form a more positive closure than a plain friction lock. Slit locks sometimes are called "pie locks." Setbacks (S) are about the board thickness.

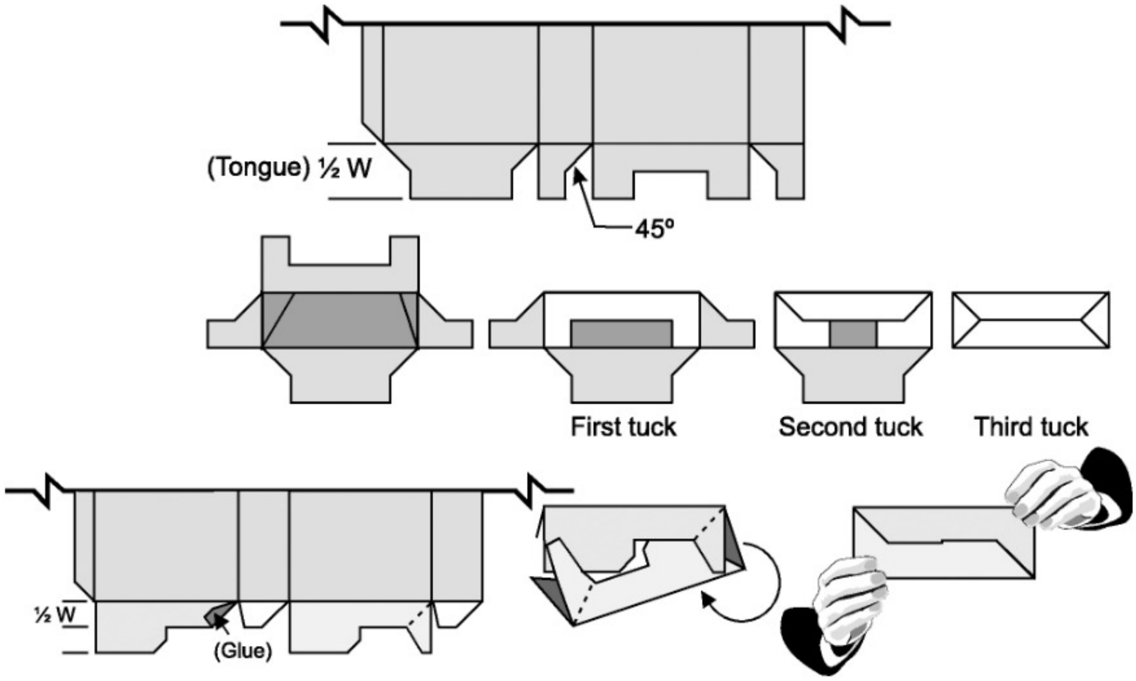


Figure 7.16
Automatic or self-erecting bottoms: a 1-2-3 snap-lock bottom (top) and a Himes lock (bottom).

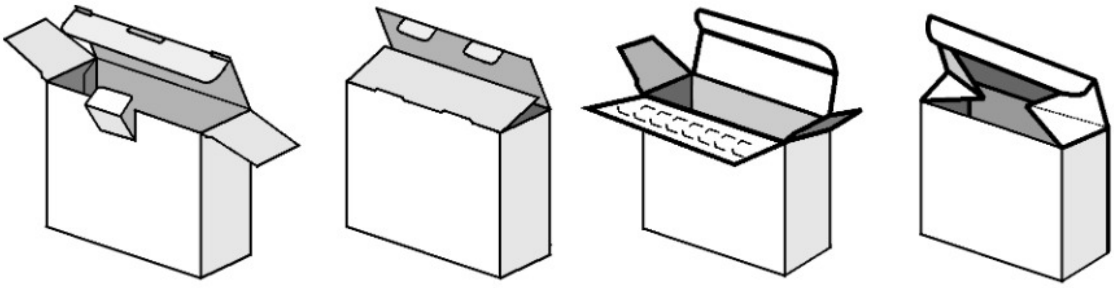


Figure 7.17
Examples of special end closures for tube-style folding cartons.

A gusseted (bellows) closure can be used to improve carton appearance by eliminating visible cut edges. (See Figure 7.17) With frozen food trays and other trays for wet product, gusseted corners rather than glued corners provide a higher level of water resistance.

Gabletop cartons, commonly used for dairy products and fruit juices, are a special application of the tube-style carton. (See Figure 7.18) Rather than having discrete top and bottom flap closures, all flaps are gusseted. The folded tube is sealed into its finished form by melting and fusing the polyethylene coatings present on both sides of the board. The board can be foil-laminated to improve barrier qualities.

The Combibloc carton is a proprietary design similar in many respects to the gabletop carton, except that the top seal is square rather than gabled. While similar in appearance to the Combibloc, the Tetra Pak, another proprietary design, is not a true folding carton because it is delivered as webstock to the user. The material is fed through a form-fill-seal machine, where it is folded into a carton shape, immediately filled and then sealed. The Tetra Pak design has the advantage over Combibloc and gabletop cartons of being able to create a package with no headspace.

External Design Features and Internal Partitions

A carton design often requires added elements that support the contents, add merchandising or marketing features and enhance customer appeal. Most of these designs are based on the tube or tray primary structural shapes, but with added material to provide the desired features. The added material can come from extending any cut edges of the primary shape. Designs that require the assembly of several board components are not favored since they require extra stock-keeping and are more labor-intensive.

Fifth panels can be used as pegboard hangers or to create additional surface area for graphics and information. (See Figure 7.19) Usually, they are created by extending one or both edges of board meeting at the manufacturer's joint. Doubled board thickness makes for a more tear-resistant location for the pegboard hole.

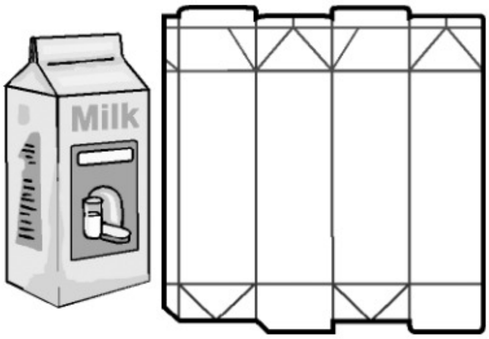


Figure 7.18
A gabletop carton blank and an erected gabletop carton.

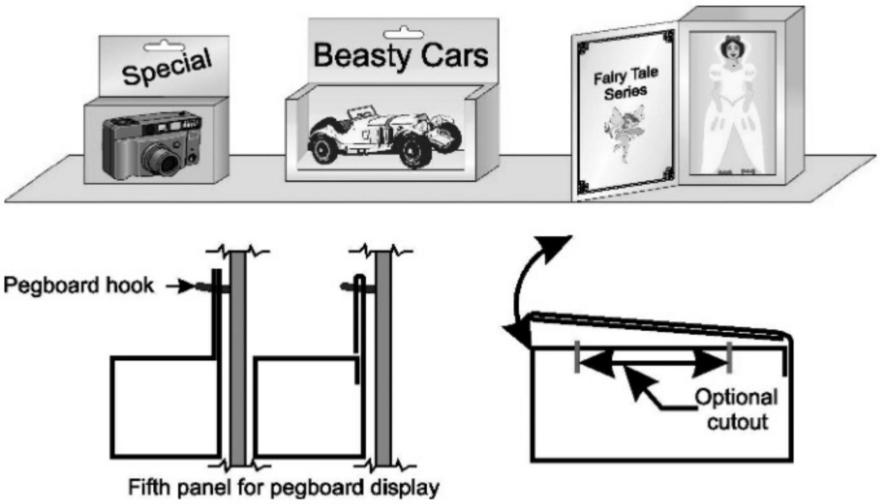


Figure 7.19
Examples of external extensions from the glue flap area to provide fifth panels for pegboard retailing (left) or a book-style display (right).

When the fifth panel is used as a book-style panel for added display area, the carton may have a window or cutout in its face. The fifth panel then acts as a cover for the opening.

Internal partitions provide security, divide cartons into cells and help display or support the product. Internal partitions also are used to fill space when the carton is holding a product that is significantly smaller than the carton. (Increasingly, this latter purpose is viewed negatively by consumers and sustainability activists.)

As with fifth panels, most of these internal arrangements are made by extending board from the manufacturer's joint, although some supports are made by extending dust flaps. Figure 7.20 shows three designs that provide support to a bottle or jar based on extending board to the inside of the carton. The design at the left extends the dust flaps to provide a jar base and neck support. The designs on the right extend material from the manufacturer's joint.

Figure 7.21 shows several ways of creating two partitions, or cells, in a carton. The cells can be the same or different dimensions and may be attached (left examples) or separated (right example.) The separated cells can be made to close like a book, providing an attractive presentation.

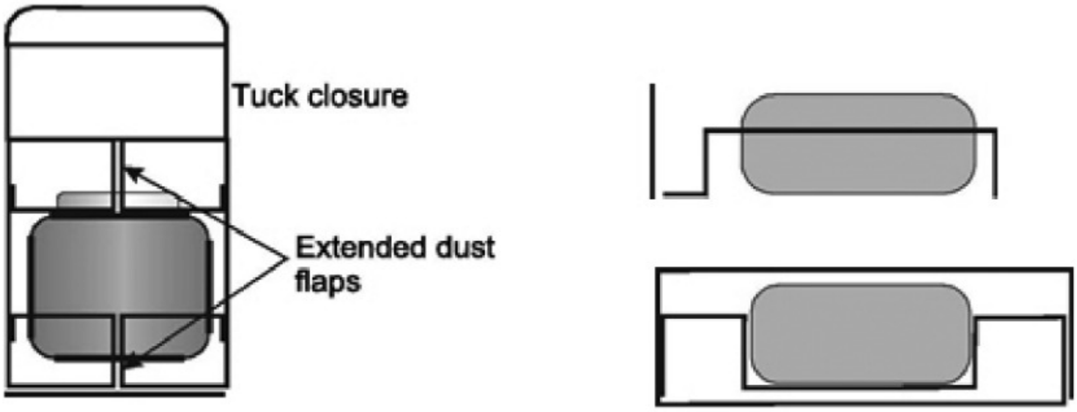
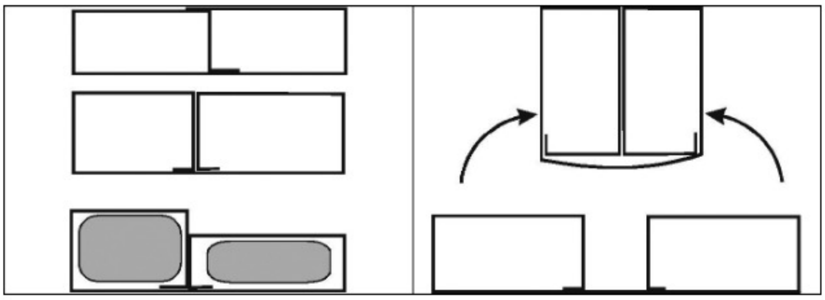


Figure 7.20
Examples of designs that provide internal support for the product.

Figure 7.21
Examples of designs creating partitions or cells (left). Another design (right) can be folded together in a book-like form.



BASIC TRAY-STYLE FOLDING CARTONS

Trays are top-loading cartons and form the second major structure in the folding carton family.

Four-corner Beers trays are knocked down flat (KDF) for shipping. (See Figure 7.22, top) Friction from the glue flaps against the tray's bottom panel holds up the erected carton. Angled flattening folds usually are found on the carton ends but also can be located on the side panels. Four-corner Beers trays often are made in pairs and commonly used in clothing and gift boutiques as a generic container.

The basic Beers tray can be provided with a tuck cover by extending one of the side panels. (See Figure 7.22, bottom) Dust flaps, which usually extend from the body end panels, increase box stiffness. Flaps can be placed on the cover ends (Charlotte flaps) instead, but the configuration does not permit flaps on both body and cover. Charlotte flaps stiffen and flatten the cover panel, and if dimensioned to the tray's depth, improve top-to-bottom compression strength.

The cover panel of a Beers tray also can be made with glue flaps and angled flattening folds to provide a six-cornered tray with a fully enclosing cover.

Most tray designs have grain running along the long dimension of the tray's bottom panel. Trays with doubled board in the side panels are the exception to this general rule.

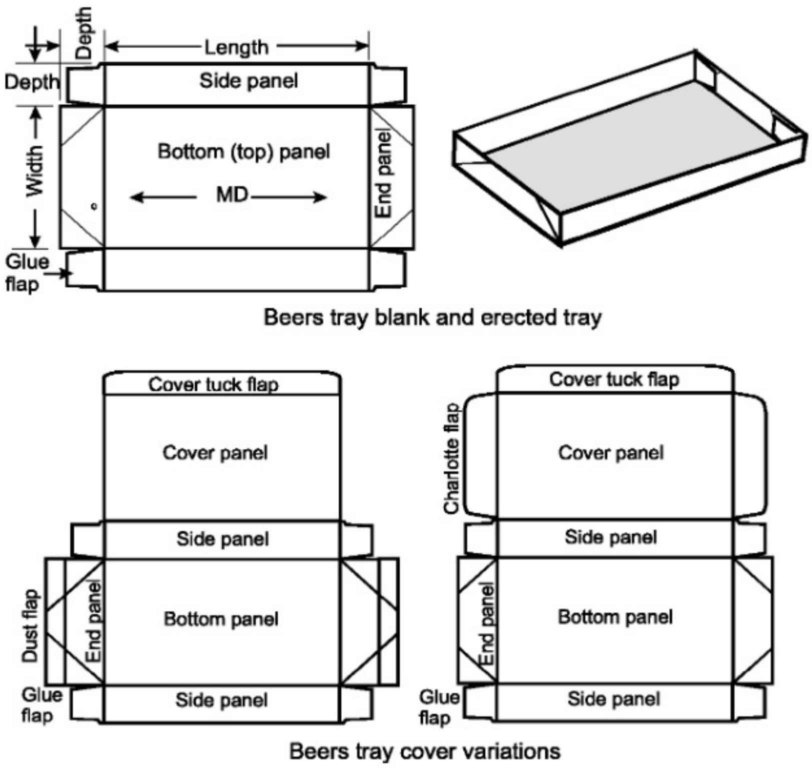


Figure 7.22
Beers tray variations.

Brightwood trays are similar to Beers trays, but are nonflattening once erected. Like Beers trays, there are four- and six-cornered variations. A second, slightly larger four-cornered tray of either type tray can be used as a slide-on cover.

Brightwood trays are machine assembled at the point of fill. A six-cornered Brightwood tray provides a fully enclosing cover. (See Figure 7.23) Because Brightwood trays do not have the diagonal slit scores that allow a Beers tray to be knocked down for shipment, they are much stiffer and hold their shape even when empty. Brightwood trays are used in the confection industry as a shipping unit, which retailers can convert quickly into a merchandising unit.

Many tray designs are intended for manual setup. The doubled end panels of the Walker-lock tray make a rigid tray. (See Figure 7.24, top) Pinch-lock trays have a small foot that locks the panel ends by friction and by engaging a locking slot. (See Figure 7.24, bottom) Pinch locks can be located on the two end panels or on both the end and side panels. Tray wall stiffness is increased if all four walls have an inner panel. Simplex trays double material in both end and side panels for greater rigidity. (See Figure 7.25)

Gusseted corners are useful for trays that must hold wet products such as frozen foods.

Shadow box refers to designs that have various walls built into the design that are intended to hold and display upscale products. The frame-vue tray is one example. (See Figure 7.26) Note that the grain direction for this tray is not along the length of the tray but across the width.

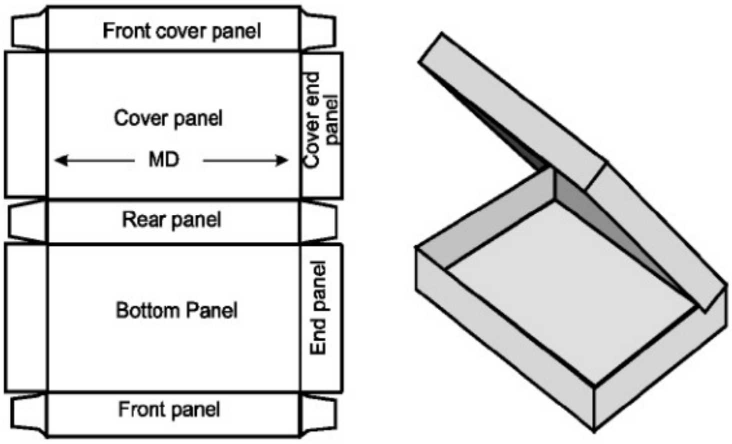


Figure 7.23
A six-cornered Brightwood tray, flat and assembled.

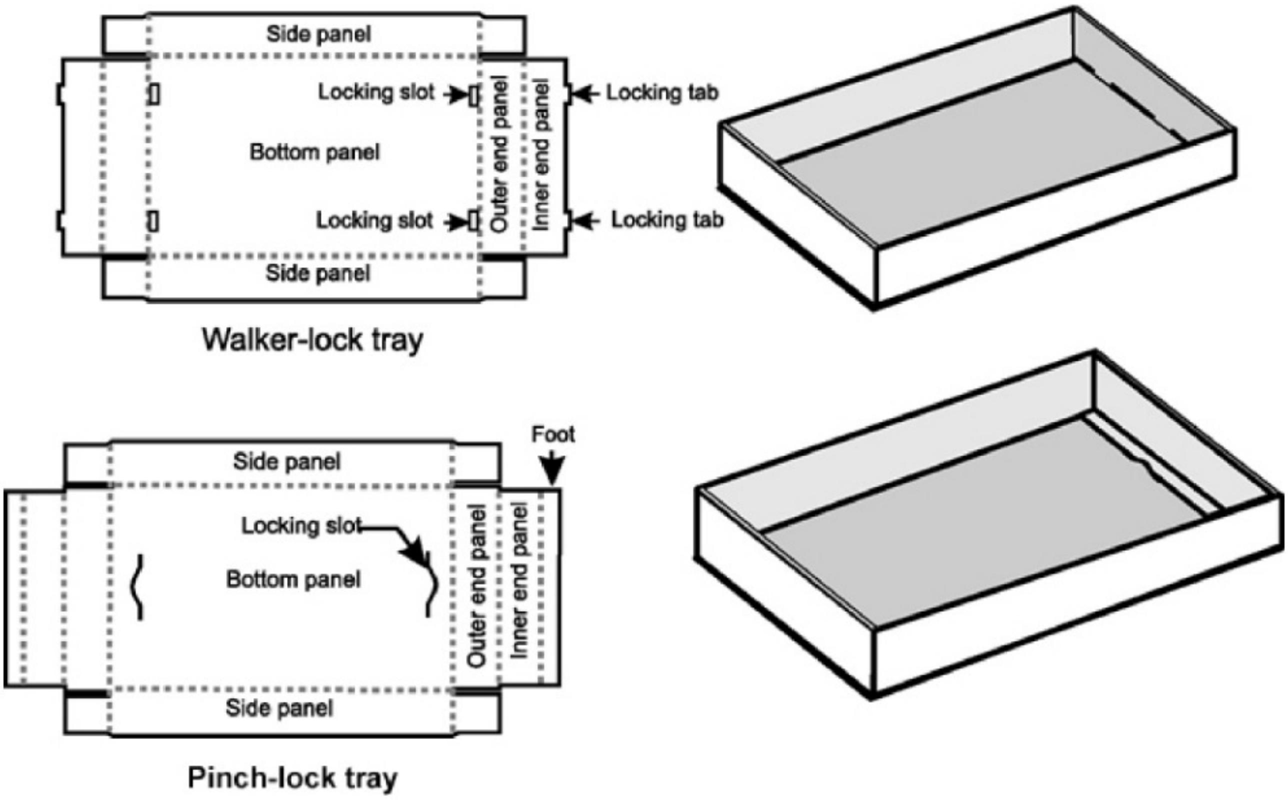


Figure 7.24
The Walker-lock and pinch-lock trays are the simplest manual set-up trays.

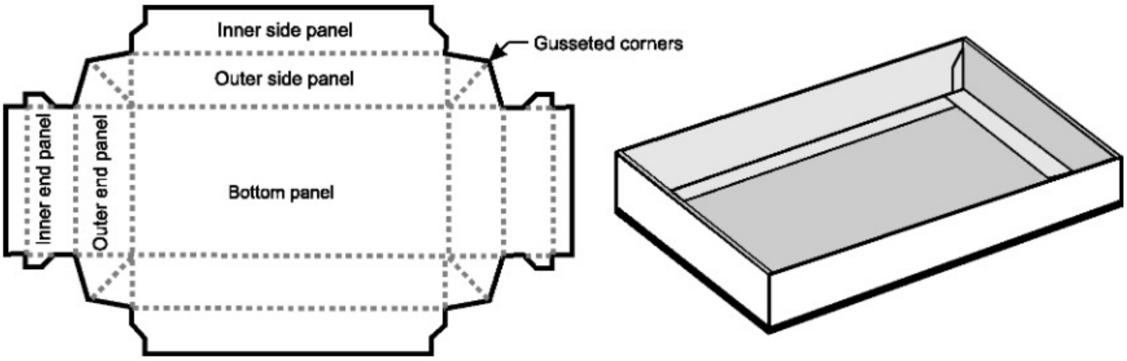


Figure 7.25
The Simplex tray is one of the most popular manually set-up trays. The double-wall thickness at the sides and ends makes it much stiffer than Walker-lock and pinch-lock styles.

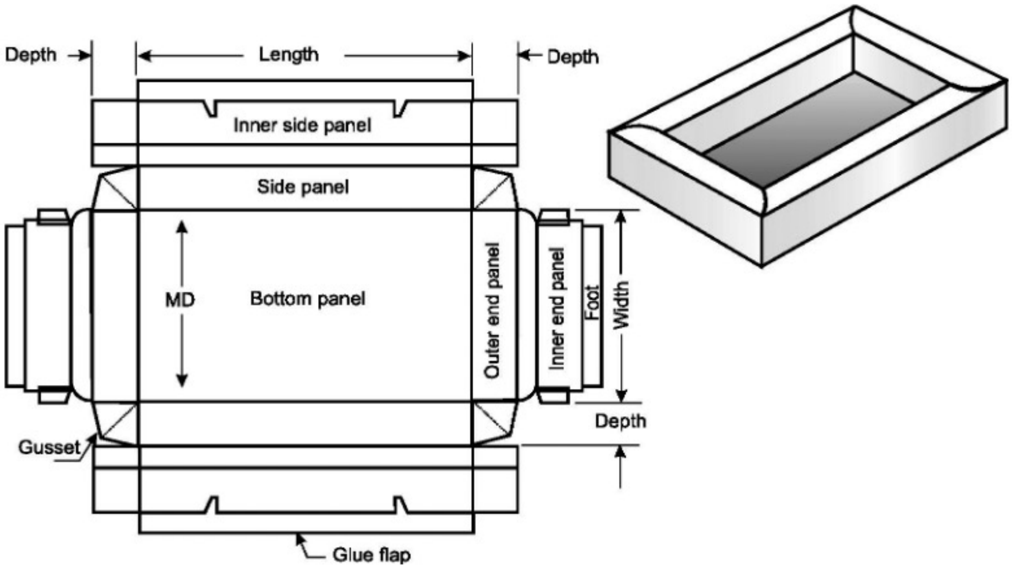


Figure 7.26
A frame-vue tray, flat and assembled.

BEVERAGE BASKETS AND SET-UP BOXES

Basket carriers or beverage baskets hold bottled beverages. The most common designs contain four or six plastic or glass bottles. The heavy product requires strong kraft-based paperboards, with bleached liners or heavy clay coatings to provide a smooth white printing surface. Where bottle-to-bottle contact must be avoided, partitions between bottle cells extend almost the full depth of the cell. Where bottle-to-bottle contact is not objectionable, as might be the case with plastic bottles, the partitions serve mostly to support the side panels and are relatively shallow. (See Figure 7.27)