Chapter 1

Basic Elements of Food Processing and Packaging

The Packaging Cycle

Packaging is a globally integrated discipline: It draws on nearly every aspect of science, technology, business, social science, and engineering. For that reason, the greatest difficulty in teaching a subject that encompasses so many fields is trying to pull them all together into a coherent map to follow as the discussion proceeds. Because most students have encountered some kind of cyclic model, whether a metabolic cycle in biology, a water or nitrogen cycle in earth sciences, or the flow of materials in engineering, a "Packaging Cycle" was devised in 1993 as a roadmap for new Package Engineering classes at the University of Illinois. This has served well and will serve as a basic roadmap for the materials in this book. This is simply a materials' life cycle, tracing the flow of materials from raw resources to finished packaging, but it helps pull together concepts from many different sources and disciplines to contribute to the final packaged product. The cycle completes or terminates as the materials are either discarded or, in a closed cycle, reused in recycling and refilling operations.

It is also necessary to include subjects that relate to several of the "steps" in the packaging cycle if one is to have a good grasp of the interrelationship between the packaging materials, machinery, and the actual food products and materials that are contained and preserved within the package. To this end, the next chapter outlines many of the basic engineering concepts used in the book, and there are segments addressing the basics of food processing and food shelf life. The linking of concepts from many distinct disciplines in the sciences and engineering that come together in many food processing operations and facilities is an important part of understanding the relationships in food and package engineering.

Elements of the Packaging Cycle

Although the subsequent chapters in the book deal with these in more detail, a short description of each of the steps in the packaging cycle will help show how the circular reduction of a global system can be mapped out.

Raw Materials

These include raw inputs into the packaging materials stream such as metal ores, wood fiber, oil, and energy.

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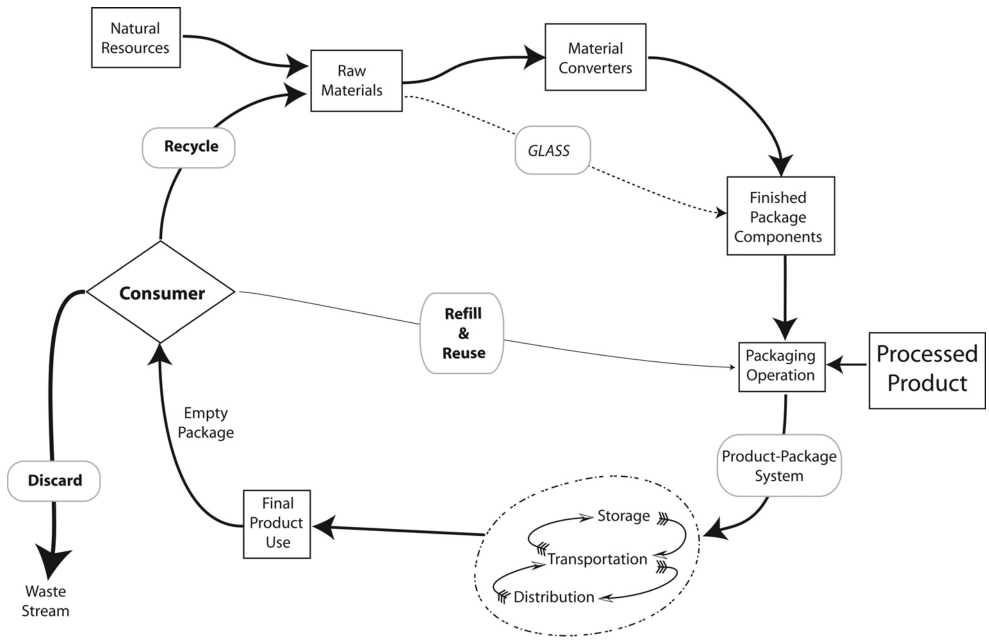

Figure 1.1. The Packaging Cycle

Primary and Secondary Materials Converters

Although the conversion processes are combined in the text, understanding the difference between primary and secondary converters can be useful in understanding materials' sourcing and production problems.

Primary Converters

These are the converters that will take raw materials and convert them into a recognizable single material such as plastic resin pellets, sheets of paper, or rolls of metal sheet.

Secondary Converters

Secondary converters are responsible for taking the materials produced by the primary converters and turning them into finished packages. At this point, the distinction blurs sometimes, because primary converters may be producing finished packages as part of their operation. The most visible example of this is glass manufacturing and molding that is done directly from raw materials to finished containers, primarily because of the enormous capital outlay for production systems and the energy-intensive nature of the material – once molten, it makes little sense to let it cool until fabrication is finished.

Processing, Filling, and Sealing Operations

These operations are where the product is processed, after which the processed product and the package come together to form an interactive system that must remain safe and saleable until used by the consumer. Unfortunately, many people (and more than a few companies) consider this to be the beginning and end of the involvement between packaging and food processing, and may not fully consider the environmental input that the package-product system must endure before it is finally used.

Distribution and Transportation

Distribution, inventory storage and management, and transportation modes and their related hazards are critical considerations in an industrial food production system. They will become even more so as the world's economy continues to integrate, with food, consumer items, and all manner of goods being shipped from one corner of the globe to the other. For the packaging cycle to be properly managed for a product, it is essential to be somewhat conversant with these issues, and particularly the economics and informatics that are involved in managing such huge, dynamic systems.

Final Product Use

Final use is where the package-product system is finally evaluated – the quality of the product and the package's utility may determine the physical and financial success of the product. An inconvenient, dangerous, or spoiled product (or one with insufficient information attached) has little chance of fulfilling the customers' needs and may be dangerous to the consumer, the environment, or both, whereas a splendid product that is economically unfeasible may satisfy the customer but leave the producer somewhat less pleased.

Recycle, Reuse, Refill, or Reduce

This decision, which is usually made by the consumer is also influenced by regulations and the existing market for recycled material, and by whether or not the infrastructure exists to return the empty package into use, either as a raw material or as a refillable container. In the absence of these choices, the package becomes part of the burden on landfills and incinerators that are scarce and expensive in some areas, due to public reaction, regulatory requirements, and the necessity of extensive environmental engineering. Because of the multiple economic incentives in materials use reduction, and better engineering practices, source-reduction strategies have become more common in the design of any number of packaged consumer items and have flattened the per-capita municipal solid waste production in many industrialized countries.

Food Processing

Although this text has a large packaging component, food processing plays an integral part in understanding the relationship of food production and packaging to the overall scope of operations typically seen in post-harvest food production. This text covers many of the engineering fundamentals necessary for the non-engineer, but also has some overviews of the product-processing requirements and shelf-life considerations that may be of interest.

Unlike the packaging material cycle, however, the processing segment is an incomplete cycle because much of it (e.g., the production, harvesting, and storage of agricultural commodities) is well beyond the scope of this book. What is hopefully more useful is the development of

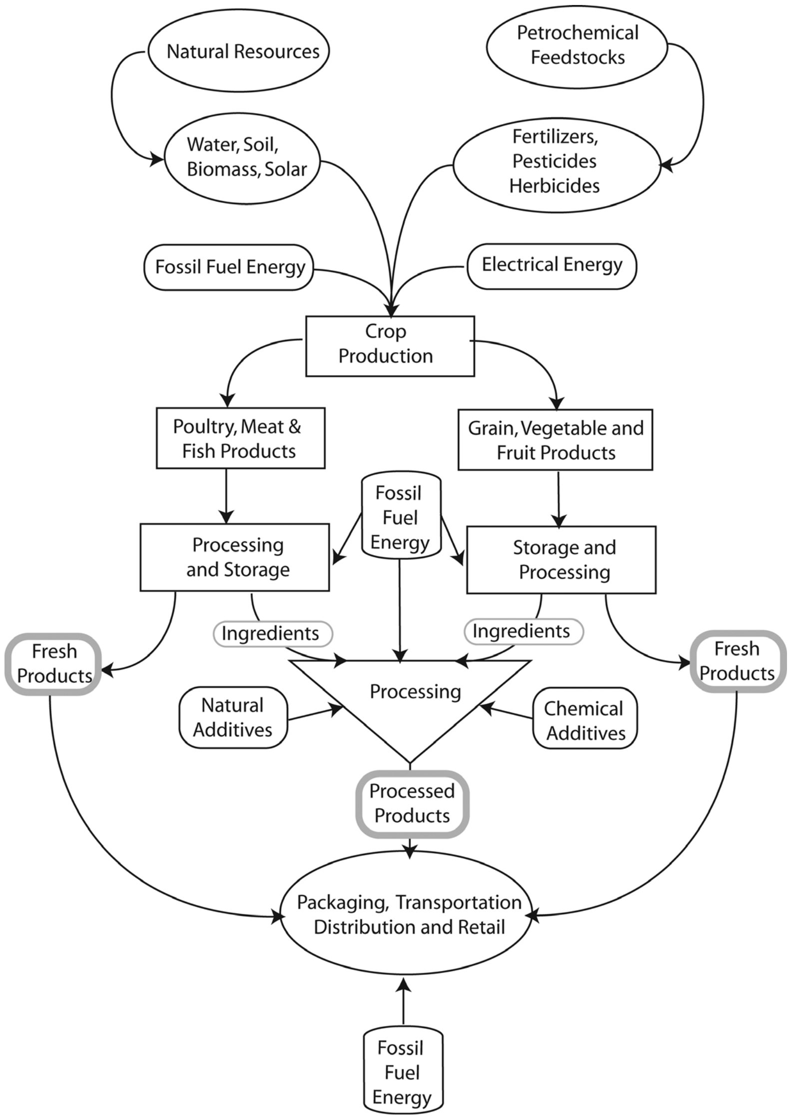

Figure 1.2. Agricultural Production Resource Flowchart

engineering concepts from first principles into basic, useful applications and methods that can provide either the starting point for more complex analysis and design, or the starting point for applied work in a production facility that operated on ingredient-level processes.

The Information Cycle

As materials feed forward from raw materials to manufacturers to consumers (and often recycle back into raw materials), there is a counterflow of information back to retailers, distributors,

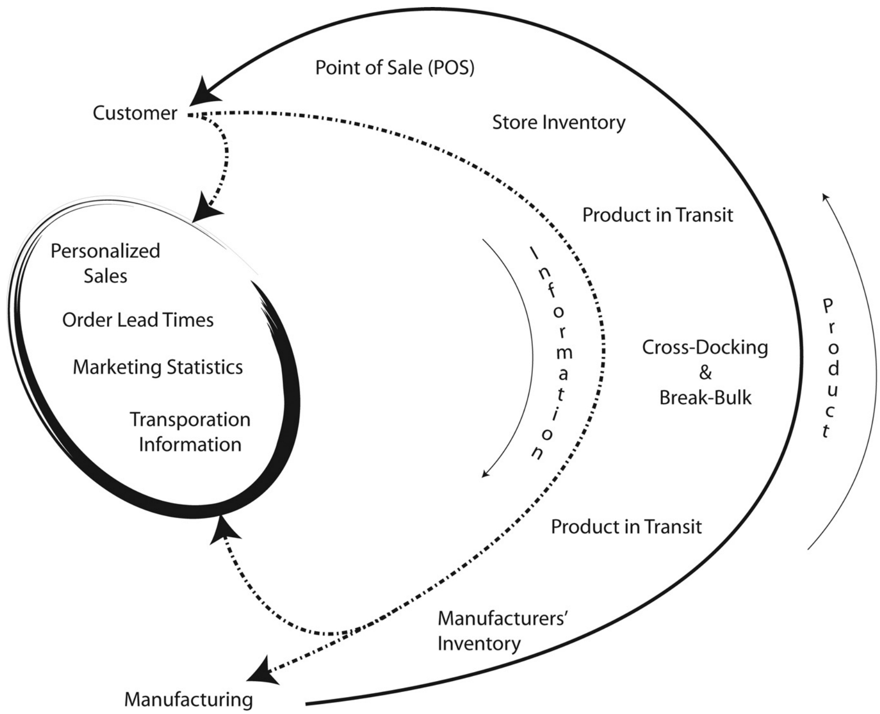

Figure 1.3. The Information Cycle

and manufacturers aided by the development of machine-readable codes that allow automatic tracking of items through the system. This information by itself gives a timely picture of inventory on hand, rates of sale, seasonality, local and regional consumption patterns, and a wealth of other distribution and economic data constantly used as feedback to fine-tune manufacturing, distribution, and retail systems. When integrated with engineering data, this information can also result in improved performance in processing systems and better product safety and shelf life.

In combination with other data taken from records associated with customers, a very accurate demographic picture can be created, which in turn affects marketing campaigns and promotional items advertised in particular markets, and will often directly affect the product mix that a consumer products company will field.

Economics, Marketing, and Packaging

The economics of the food industry may be unfamiliar to people entering the field and occasionally to those people working in the packaging industry that have an interest in entering the food industry. At its heart, the food industry is a marketing-driven, price-conscious converter of raw food materials into finished consumer products that are usually integrated with a large-scale marketing campaign. From this, it is important to remember that the marketing and salesmanship of the products may take precedence over many of the non-safety-related technical improvements in both food product technologies and in package design and manufacture. Much of the food packaging industry's "research" is the development of products to challenge a competitor in the marketplace, expand a successful existing product line, or adopt a process developed by a competing company; reverse-engineering (or "deformulation") of competitors' offerings is a common feature of product development. Thus, the industry has often been very reluctant to consider new production technologies and designs until they are proven, often by a competitor or by a different industry that processes similar materials – for instance, the pet food industry is a primary example of an industry that has been viewed as a prototype arena for the testing of new technologies for human food products.

The wait-and-see approach to investment and adoption of new technologies has led to the food industry – and, by extension, the food packaging industry – being very slow in adopting new technologies in spite of the fact that these may save enormous amounts of money in the long term and may provide more utility and better-quality products to the consumer. For example, retort pouches, which were originally developed in the late 1950s and early 1960s for military applications, are only now becoming available with a significant market presence in a few products after first being proven in pet food sales, in spite of the fact that they offer better product quality and require less energy to construct and process.

Unfortunately, this carries over into research institutions as well, where the nature of scientific publications in food- and packaging-related fields, although prolific in number, have remained remarkably static over the last 50 years, particularly when compared to other fields of life sciences and engineering. As a result, the packaging and food engineers searching for an advanced toolkit to achieve better results and analysis may find themselves frustrated by a lack of applicable research and tools unless they look to other fields first. One of the aims of this book is to introduce some of the advanced tools that have been used for many years in other fields of engineering and that can provide accurate, efficient analysis for design procedures and processes that for many years have been done on a "try it and see" basis.

In distinct contrast to technology developments, items that add marketing appeal have seen extraordinary involvement, from the adaptation of high-speed microembossing processes to produce surface holographic film for consumer food packages, to the test-marketing of implanted circuitry in packages to give voice messages to consumers. Given the extraordinarily competitive nature of food marketing, any feature that can be proven to make a consumer product stand out from a very similar crowd, and thus increase revenues, is likely to be embraced quickly and enthusiastically. In the best of circumstances, a combination of marketing appeal and technical improvement can be combined into product improvements or features that will increase customer satisfaction, expand product sales, and offset any additional cost.

Shortened Product Development Cycles

The increasing volatility of the food marketplace and the changeable and often contradictory nature of marketing-driven nutrition fads have caused the development times for companies to shrink, which has the secondary consequence of reduced time for product shelf-life testing that will be discussed in Chapter 7. Additionally, product development trends have shifted to "concurrent development" methods, where prototype product designers, suppliers, logistics, manufacturing, packaging, and marketing operations are involved early in the process to reduce the amount of repetition involved in refining and changing the system for the final products' production. In traditional, "linear" design models, new prototypes are fully developed and then passed off to manufacturing departments that then develop the means to mass-produce, package, and deliver the product. The "assembly line" nature of this development model means that any changes to the final product requires backtracking completely to the design stage and then downward again, and can lead to enormous delays and lost revenue and market share.

Ideally, a concurrent development model would allow all of these changes to occur simultaneously with product, production, supplier, and distribution input at all stages of the development process. If this goes well, the time wasted on internal procedural protocol can be reduced enormously, and bringing new faces to the table in the central creative process can allow new opportunities to be discovered as well as imparting a good degree of cross-functional understanding and cooperation. A difficulty may arise in that this kind of philosophical change may require a number of internal changes in corporate structure to reduce the "silo mentality" in a particular operation. Operations that are internally territorial and competitive may not be suited for the lateral integration of functions, but some degree of concurrence can usually be achieved.

In addition, ingredient suppliers, packaging materials and component suppliers, and contract packaging operations are increasingly providing ancillary functions that were once part of central research groups, and whole product lines are being assimilated wholesale from start-up companies in a manner similar to the computer software industry. This basic shift in the product development model allows an already risk-averse industry to pick and choose from products that have shown some degree of market success and adaptability, but brings with it the problems of scaling up production from a usually small single production facility to larger, multiple manufacturing operations. For this reason, concept-to-production times are much longer for large companies (as long as 36 months) than for small companies that typically market new concepts within 12 months of concept creation and are similarly responsive in terms of product line extensions and adapting to market changes. Therefore, the advantage of more flexible and responsive manufacturing capacity is the ability to adapt more fully to both rate and type of customer demand, which can allow an increase in market share and may begin to drive product trends if successful enough. To stay responsive to customer needs, methods to shorten concept-to-production times are constantly being sought both in terms of technical tools and in corporate management models.

Cost Analysis – The Bottom Line

Often the question comes down to "the bottom line," and without diverging into a general course on accounting, the bottom line that most people can relate to is simply:

Income − Expenditures = The Bottom Line.

More technically, the bottom line is literally that – the last line on the balance sheet – as simplistically illustrated in Table 1.1.

As can be seen, the Total Assets and the Total Liabilities and Equity must balance on the bottom line, thus increasing the bottom line implies a corresponding increase in the overall financial scale of the company, rather than a simple increase in profitability.

Packaging can affect the bottom line in several ways, and unfortunately the most common approach to increasing the bottom line is to look for costs reduction at the production level, where many of the packaging function decisions take place, without considering the effect on the entire package-product system and the larger product marketing scenario. This can have the final effect of producing substandard products or causing system failure at some point in the life cycle and sabotaging an otherwise successful product. What is often neglected is the consideration of the benefits that other plans of attack may have on the bottom line. This is often the result

Table 1.1. Example of a Corporate Balance Sheet

Morris Declining Assets Inc. Balance Sheet ($000)					
Current Assets			**Current Liabilities**		
Cash	300		Loans Payable	800	
Accounts Recievable	1850		Accounts Payable	1200	
Inventories	1500		Accrued Expenses	400	
			Dividends	600	
Total		**3650**			
			Total		**3000**
			Deferred Taxes		**500**
Investments		**800**	Long Term Debt		**3000**
Property Plant & Equipment			**Shareholder's Equity**		
Land	2000		Common Stock	1500	
Building	2000		Paid-In Capital	500	
Equipment	3000		Retained Earnings	2950	
Total		**7000**	**Total**		**4950**
Total Assets		**11450**	**Total Liabilities**		**11450**

of the "NOMLI" (Not On My Line Item) syndrome resulting from packaging operations being directly charged for the costs of their operations in corporate accounting methods, whereas any benefits that might accrue benefit other operations. The unsurprising results of this are that packaging operations seek to reduce costs as much as possible and may not consider the unintended consequences of customer dissatisfaction or market loss.

If the packaging function is considered at a sufficiently high decision-making level, there are a great number of things that can be done to increase the bottom line or otherwise free up resources within the existing financial structure, both in terms of increasing net income and reducing overall expenditures. Implementing these changes is usually a matter of collecting data about the actual consequences of actions, both good and bad, and understanding their effects on the overall financial well-being of a company.

Current Assets

Increasing sales and accounts receivable by increasing the sales income of a product can increase the assets side of the balance sheet. Achieving this may be as simple as using packaging innovation to promote increased overall market expansion, taking over an increased share of an existing market, or making inroads into an unconsidered market to which similar products have not been applied. Less obvious is the reduction of inventories on hand and their associated costs so that the liberated capital can be applied to other assets on the left side of the balance sheet, such as investments, machinery, or plant facilities – or payroll bonuses.

Inventory management has been lifted wholesale out of the dark ages by the advent of cheap computing and instant communication to the point where very little finished goods inventory is kept on hand in non-seasonal operations. Products are shipped almost immediately upon completion and are not accumulated for any significant period of time anywhere in the distribution chain. The net result of this has been to free the producers from both the "dead assets" of stored inventory and the carrying costs associated with them, thus allowing the emergence of flexible manufacturing as well. This will be considered from both the manufacturers' and the distributors' point of view in later chapters.

Property, Plant, and Equipment

As with inventory, reduced investment in property, plant, and equipment will result in an increased availability of resources elsewhere in the finances of the operation. Reducing the overall cost of an operation either by making the existing operation more efficient, producing more with existing facilities, producing the same product in fewer facilities by extending its shelf life (and therefore increasing its shipping radius, which may reduce the number of separate facilities needed) – and combining separated operations to reduce overall plant expenditures are several ways in which the resources tied up in these long-term asset investments may be extended.

Current Liabilities

Reducing liabilities in the form of reduced costs, investments, and other items that absorb resources is always an attractive strategy. This drives items that are seen as reducible costs such as ingredients, processing, and packaging to be managed as cost-efficiently as possible, consistent with product quality goals. Unfortunately, many of these decisions are made at the levels that leave the operations personnel struggling to maintain production, whether by substituting a cheaper ingredient or material or neglecting a small part of the item's quality, such as an "easy open" feature that becomes ineffective.

Stockholder Equity

Freeing capital from other sources, whether from more efficient production, reduction of liability, or higher sales, can result in an increase of stockholder equity – which ultimately benefits large companies and their shareholders either by providing an incentive for higher stock prices or paying out direct benefits.

Fundamental Packaging Functions

Once the necessary systems and technology are in hand, the basic considerations for package designs must be considered. Although it may be an oversimplification, a good representative list that describes the basic packaging functions is "Protection, Communication, Utilization, and Integration." There are many other considerations, but these four items can provide a good starting checklist for a new package design, or for the consideration of design changes.

Protection

Protection of a product from environmental influences is the most common function that people think of when they consider packaging. The most common type of protection is against contamination of a product by microbes, or protection against the loss of an important component (moisture, for instance) from the product. The other types of protection that a packaging system may provide are less often considered. For instance, protecting consumers from the dangerous contents of a package or protecting the public at large or the environment from the dangerous materials or devices in a package can be a crucial consideration.

A good example of packaging protecting consumers is the often-annoying child-resistant closure on household chemicals, particularly those that are stored under sinks and in areas easily accessible by relentlessly curious children. Although these devices are sometimes hard to open by adults, the number of fatal household poisonings of children from household chemicals and medicines dropped by an estimated 45% between 1974 and 1992 as a result of their use, with a similar drop in non-fatal medical emergencies [1], and from 1974 to 1981, the U.S. Consumer Product Safety Commission (CPSC) estimates of regulated products ingested by children under 5 years of age that prompted emergency room (ER) visits decreased from 48,000 (2.9/1,000 population under 5 years) to 34,000 (2.0/1,000) [2].

Finally, protection of the public and the environment from dangerous materials in a package is seldom considered, yet packaging plays an important role in getting everything from hair bleach and insecticide to nuclear fuel rods safely from manufacturer to its final users.

Communication

The communication role that packaging plays is also important and has become more so as packaging becomes more interactive and able to communicate with other devices using optical and electronic means, as well as communicating with people using printed words and images. Since packages are the "face" of the product that the consumer will see, usually while trying to decide which of several similar items to choose, the marketing impact of packaging has always been of the utmost importance, especially with consumer goods. Visiting a supermarket's cereal aisle will give a vivid impression of the competition among products, as the gaudy front panels of the boxes vie for attention. Packaging must perform many other communication functions as well simple display dominance. Most products marketed for consumer sales must give an accurate listing of the contents, and for products such as foods, pharmaceuticals, and household items such as cleaners, the packaging must communicate preparation methods, ingredients lists, and proper (or improper) usage of the product. For items intended for more specialized uses, such as surgical implements, emergency equipment, or munitions, the packaging may be critical in selecting the correct items under dangerous or stressful conditions.

The communication function has expanded with the spread and increased capability of computing equipment in all sectors of the retail and distribution networks. The Universal Price Code (UPC), which was originally adopted in the United States in the 1970s was initially developed to allow faster and more accurate checkouts of consumer goods, particularly groceries. The data that is gathered at the point of sale (POS, sometimes called Point of Purchase, or POP) was immediately useful in helping stores manage inventory. As items were scanned at checkout, the level of inventory was appropriately adjusted, and this would allow orders to be placed in time for replenishment. This inventory tracking quickly spread to automated ordering and tracking systems, often for the entire network of stores in a particular chain, with similar networks in place for the manufacturers of goods. Orders can be placed directly with manufacturers on a just-in-time basis, tracked through the entire distribution chain, and arrive on a schedule that allows stores to operate with only the stock on their shelves as inventory. This cascading rise in efficiency allows an extraordinary reduction in inventory held in most sectors (the exception being seasonally produced food items), reducing costs and essentially eliminating the need for warehouses. Those have been replaced by *crossdocking operations*, described more fully in Chapter 9, that take in truckloads of items from a single manufacturer and redistribute them to trucks waiting to go to individual stores or regions for redistribution.

This dynamic distribution scenario ensures that the inventory is constantly moving from the time it leaves the manufacturer until it arrives on the store shelf. In addition to the information transmitted by the package, information gathered at the point of purchase from discount cards, credit cards, and debit cards allows large amounts of very accurate market data to be collected about individual consumer's spending habits. Amusingly, this has led to the occasional embarrassment when manufacturers send inappropriate offers, coupons, and birthday greetings.

Information technology has also been expanded by the development of non-optical information devices such as Radio Frequency Identification (RFID) chips that can be read at a distance without having to uncover a tag or label. These have found limited use on single units of consumer goods because of technical and economic limitations, but are beginning to be included in credit cards, key tags for identification and gas purchases, luggage tags at several airports in the United States, and on large shipments (palletload or shipping container) of products. As these devices increase in memory capacity and utility, the ideal of store checkout by simply walking through a scanner becomes closer to reality, as does the less visible ideal of easier and more accurate product tracking and identification.

Utilization

Packaging is often blamed for a high level of consumer frustration in gaining access to products, but nearly all products require some form of package to be useful, at least in the sense that consumers have come to accept them; many gain some benefit of utility from the package, and there is a broad range of products that could not exist without packaging. The marketplace is full of products that gain their market niche solely from the utility given by the package, from hand-pumped spray cleaners to aerosol cheese spread; most of these items would be much less useful and would be certainly be much less profitable, if they existed at all, without effective packaging. It would be hard to imagine having to store ketchup in some kind of storage tank in the kitchen rather than getting it from a bottle, and more complex items such as aerosol spray paint or asthma inhalers would be very difficult to use without portable, relatively inexpensive packages that replace large-scale spray equipment and medical nebulizers.

Integration

Integration is seldom considered when package designs are proposed – designers are often attempting to convey a sense of style, a marketing message, or to provide a utility function, but there are several types of integration that must be considered. The first of these, and often the most annoying to designers, is the integration into manufacturing systems. A beautiful and useful package that cannot be produced quickly and cheaply will be unlikely to find its way to market for most large-volume consumer items. This often leads to protracted debate between designers and manufacturing engineers, but integrated designs where manufacturing concerns are included early in the design process can help alleviate this.

The second is integration into a product line and its associated media presence – does the package design fit in well with similar items produced by the same company? The electronics and cosmetics industries have made this a substantial priority in design of both packages and often of the products themselves – looking at a store display of shampoo, fingernail polish, or toys will give a good idea of this. Food and consumer products companies, which are often conglomerates of brand lines that are acquired and divested on a nearly continuous basis, may rely on a simple small brand to indicate that their product comes from a larger corporate entity.

This type of integration aids in brand recognition, as well as in repeat purchases by consumers who like the parent company's line of products. This in turn is often influenced by the customers' perception of the products in relation to their particular lifestyle, as well as their own personal preferences, with the designers continuing to come up with increasingly creative packaging to distinguish themselves among a plethora of similar products.

A third type of integration involves the product's physical life cycle – does the package fit in with available materials and production resources, as well as disposal or recycling regulations requirements? This has driven the design of some types of packages as well as a large component of materials selection in many packaging systems. As recycling issues continue to be a large concern in disposal of municipal waste, the design of packages to comply with a multiplicity of regulations and requirements limits the choices of materials and structures and provides a challenge to the technical implementation of package design.

Engineering Design versus Trial and Error

The packaging industry is unique among high-speed, high-volume industries in that there is often very little theoretical consideration of the factors involved in design, particularly as it applies to food package design. Standardized containers such as plastic and glass containers, as well as aluminum and steel cans, may have some stress analysis done on them during the basic design phase, but the vast majority of food packaging, which may be assembled of a variety of stock components, is designed to be appealing to the marketing scheme underway at the moment and often is only incidentally structurally capable of surviving the distribution environment.

This lack of design allows for a very fast introduction time if the design works well, but if complications arise, it then requires many cycles of the "build a prototype and see if it works" philosophy, which consumes a great deal of time and effort (Figure 1.4). Unfortunately, there is

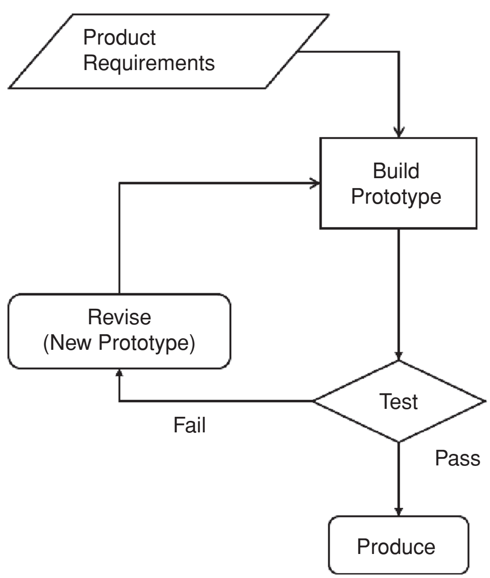

Figure 1.4. Trial-and-Error Design

a lack of specific design analysis tools for many parts of the industry, and there is also often a reluctance to use the ones that do exist for other industries, owing either to lack of experience with them, distrust of the results, or an aversion to investments that produce long-term savings. There is a severe need for both the use of analytical tools in the packaging industry and the understanding of their utility and results as a means of cost saving and efficiency improvement.

Most people, including those who actually work on a prototype-based design system, would hesitate to board an airliner that was developed by building a prototype, crashing it, examining the wreckage, making changes, and then building another prototype until the resulting guesswork finally flew. In fact, most people would not use many devices designed this way, from a car to a can opener, yet a lot of packaging development follows just this method. While shelf-life trials on food products are usually destructive, structural and physical development can be aided with the benefit of method developed (not surprisingly) for other industries.

Moore's Law, which roughly states that computing power doubles every year and a half, means that the cost and speed of computationally based modeling systems becomes ever cheaper. In fact, many of the limitations to the adaptation of these types of design systems are the result of poor software user interfaces that make them difficult and counterintuitive to use, and a poor managerial understanding of the results and benefits of the systems. If things go well with proper training and experience, product and package designers can do effective and even elegant predictive modeling as a design enhancement, as well as a means of shortcutting tedious preliminary trials.

As can be seen from Figure 1.5, the shortened feedback and model construction time in the design cycle system may offer an improvement over a prototype-based design scheme. Countering this is the reality that very often, packaging materials and structures are produced by secondary suppliers and are simply being comparatively evaluated. Even if produced "in house," the fabrication costs are so small and the tests so simple that it may be advantageous

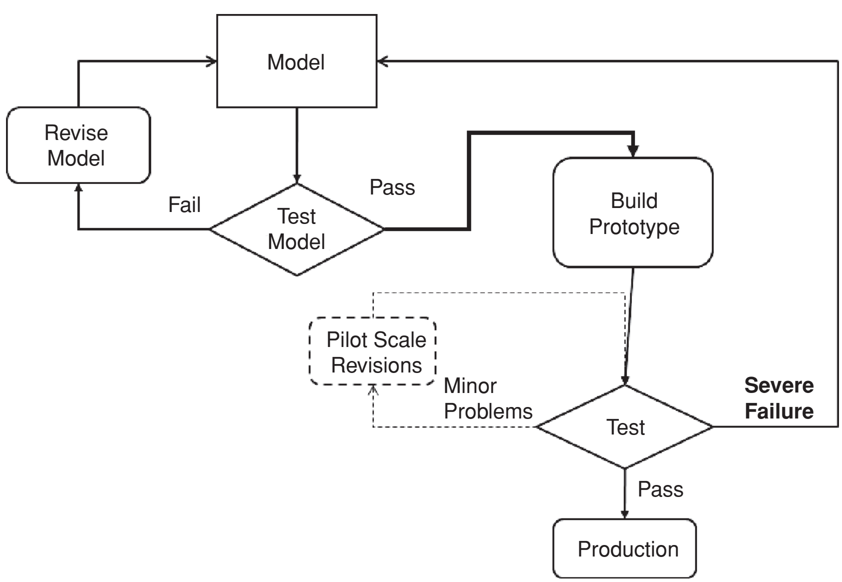

Figure 1.5. Modeling and Analysis Design

to simply continue with a prototype-based system. It may be difficult to find personnel trained in the tools and methods for evaluation and modeling, and the management of these types of operations may be very unfamiliar to an existing system.

The eventual consequences of not being adept in advanced design methods may eventually be that the operation will expand into products that require a higher degree of technical analysis, or that remaining competitive may demand these skills. The decision regarding the design method then is a matter of individual choice that depends on the product requirements, market size and complexity, and need for fast design turnaround. In addition, it may be possible to outsource many of the technical and design skills needed to create a good design cycle, though managing the flow and confidentiality of information can be challenging.

Finally, with a knowledge of the financial, marketing, scientific, and engineering processes that can be applied to better designs and implementation, whatever method and process is chosen, the design challenge is to be creative – developing a new product or package is an opportunity to learn from, rather than to copy, the accumulation of trial-and-error and guesswork of its predecessors and competition. Innovation requires managerial foresight and the dedication of necessary resources to take the risks implicit in change, and this may be the biggest challenge of all.

Additional Resources

1. National Academies Press, *Forging A Poison Prevention and Control System*, Washington, DC: The National Academies Press, 2004, p. 84. http://www.nap.edu/catalog.php?record_id=10971
2. Centers for Disease Control, "Perspectives in Disease Prevention and Health Promotion: Unintentional Poisoning Among Young Children – United States," *CDC Morbidity and Mortality Weekly* 32(9) (March 1983): 117–8. http://www.cdc.gov/mmwr/preview/mmwrhtml/00001263.htm