Packaging Advisor™: An Expert System for Rigid Plastic Food Package Design

Alvin S. Topolski and Douglas K. Reece

E. I. du Pont de Nemours & Company (Inc.)
Wilmington, Delaware 19898

Abstract

In 1987, the Du Pont Company entered the market for barrier resins, which are used in the fabrication of plastic food containers. The company was experiencing difficulty establishing a position against incumbent competitors. A new and technically superior product was about to be introduced, and a way was needed to induce customers to invest in qualifying the new material. The solution was Packaging Advisor™, an expert system for rigid food container design. Deployed in February of 1988, Packaging Advisor automates the design process, providing our customer, the package designer, with information on alternative materials, the quantities of these materials needed to meet performance specifications, and estimates of material costs. Packaging Advisor was used in place of traditional marketing communications techniques to inform our customers and field sales staff about our new and existing products. Customer response, expressed in both words and orders, has been enthusiastic.

Introduction

Packaging Advisor is an expert system which designs rigid plastic food containers. It was developed at the Du Pont company to help both our customers and our own staff better understand the use and benefits of our barrier resin products in food containers. The barrier resins business was a new business for Du Pont, and we had new and unique products to introduce to the marketplace. Packaging Advisor was the keystone of the marketing communications strategy for these new products, and has been recognized by management for a substantial contribution to the success of the new business venture. In this paper we will describe the business and technical environment in which the system was constructed, review the system and its development process, and describe how the system was used successfully to achieve our business objectives.

The Business Environment

Rigid plastic food containers offer many advantages to the consumer. They are light in weight, dentproof, rustproof, shatter resistant, and can be molded with such convenience features as handles and pouring spouts. These advantages have lead to extremely rapid growth of plastic containers as replacements for metal and glass on supermarket shelves.

The size and growth rate of the plastic food packaging market was therefore an attractive market for the Du Pont company. Among our offerings to this market are several barrier resin products, introduced in 1987 and 1988. These plastic resins reduce the infiltration of oxygen, which can cause degradation or spoilage of package contents.

The products introduced in 1987 met with limited success for a number of reasons. We were competing with several established suppliers with similar products. The process which a package fabricator uses to qualify a new supplier is arduous: substantial design work must be followed by trial runs with the new material. Furthermore, as discussed below, the properties of barrier resins are complex, and many details of the application must be analyzed to predict performance.

Du Pont's business plan called for the 1988 introduction of new and technically superior materials which should be very competitive. However, means were needed to establish Du Pont as a credible and technically sophisticated supplier of barrier products and to communicate the value of the new products.

To address these needs the business team developed a concept for a computer system which would automate the process of designing a food package. The system would offer alternative designs using Du Pont and competitive resins and showing corresponding costs. The system would show clearly the value of the new products, and its ability to automate tedious design calculations should make it appealing to customers.

The Du Pont company has an aggressive program to implement artificial intelligence applications. Staff from the AI group agreed to provide the needed systems resources, and work was begun in May, 1987. The completed system was fielded nine months later in February, 1988.

The Food Package Design Problem

Food packages requiring an oxygen barrier are typically manufactured as multilayered structures. The bulk of the package will be composed of a structural material, selected for durability and low cost. One or more barrier layers will be used to achieve the required limits on oxygen infiltration, and layers of adhesive material will be used as necessary to prevent the package from delaminating. The design problem addressed by Packaging Advisor™ is to select appropriate barrier and structural materials for a given application, to determine how much of the (usually more costly) barrier material is required in order to achieve a specified limit on total oxygen permeation during the shelf life of the package, and to calculate the materials cost for the package. Selection of adhesive layers was left to a separate expert system.

The oxygen barrier properties of a material are measured by the rate at which oxygen infiltrates across a unit area and thickness of the material. This oxygen permeation parameter is a function of temperature and, for some materials, humidity. The humidity to which the material is exposed depends upon the humidity inside and outside the package and upon the water vapor transmission properties of other layers within the package. Some structural materials provide a significant amount of resistance to oxygen permeation. Thus, the requirements for the oxygen barrier material depend strongly on environmental factors and upon the other materials with which it is used.

Several other factors must also be considered. Packaging materials must be compatible with the intended fabrication process and must have whatever degree of optical clarity is required for the application. Since the layers of the package will be extruded together, they must all have similar processing temperature ranges. Federal regulations restrict or prohibit the use of some materials in food packages.

Another complication arises when packages are subjected to sterilization processes using steam. The steam will saturate the materials, altering the performance of humidity sensitive materials during the time the package is drying.

The package designer must choose among about 20 different structural resins and a similar number of barrier resins. The number of possible combinations is therefore in the hundreds -- too many to analyze manually.

The complexity of the package design problem makes it difficult to adequately describe a new barrier material through printed specifications. However, we found that a personal computer does have enough power to perform the necessary analysis.

The development process

Packaging Advisor was placed in full commercial operation nine months after it was begun. A rapid prototyping strategy was used to develop the system; we did not attempt to develop a full functional specification up front. The first prototype was demonstrated to potential users only three months after the start of the project, refinements were made over the next five months, and a final month was required for duplication of diskettes and related materials.

The prototyping approach to system development proved to have a number of advantages. At first, the complexity of the problem seemed a bit overwhelming. In addition to all of the considerations described earlier, we had discussed a number of other factors which could influence package design: type and location of handles, the need to stack some kinds of packages during transit and storage, etc. The decision to start with the simplest plausible prototype helped us to identify and focus on the truly important factors.

The prototypes helped the experts to identify areas in which the system's knowledge was inaccurate or incomplete. The first prototype, for example, recommended combinations of materials which seemed implausible to one of the experts. After reflecting, he realized that the materials had very different processing temperatures: one of the materials would vaporize before the other melted. The fact that we needed to include knowledge regarding processing temperatures became apparent in this way.

The prototyping strategy also made it possible for the process of fielding the system to begin before the development process was complete. Prototype systems were shown to both customers and field sales representatives early in the development process. Several customers offered strong expressions of interest based on the prototypes and enabled the system to earn a positive reputation with the field sales force before it was formally introduced. By the time the system was placed in production, there were customers waiting to license it and sales representatives ready to communicate success stories to their peers. The early positive feedback from customers made it easier to maintain management's support for the project and helped build the developers' morale.

We estimate that a system such as Packaging Advisor would, at current prices, cost approximately $50,000 to develop and field. This estimate includes costs for system development, documentation, and duplication services but does not include a charge for services of domain experts.

Annual maintenance costs should also be considered. Since substantial enhancements to Packaging Advisor are planned, annual maintenance costs may approach development costs. In the case of Packaging Advisor, these costs are more than offset by license fees charged to customers and by expenses for other marketing communications activities which have been displaced by the Packaging Advisor system.

The System

Packaging Advisor is a stand-alone system which runs on the IBM PC and compatibles. It consists of two components. The expert system front end, written in the Level 5 shell from Information Builders, Inc., is responsible for interacting with the user to obtain a specification of the package to be designed. This subsystem will query the user for the dimensions of the package, fabrication process to be used, desired shelf life, maximum allowable oxygen infiltration, desired optical properties, and a number of similar parameters. A typical question is shown in Figure 1.

The front end is designed to minimize the number of questions routinely asked. Inferencing is done in order to determine typical values for a number of secondary parameters. The parameters specified by the user and inferred by the system are then presented in the display shown in Figure 2. In the example shown the system has inferred that scrap will be recycled and that the scrap rate will be about 50%. The user may make any needed changes at this point in the interaction.

After the user accepts the package specification, the other system component, written in the dBase III programming language and compiled with CLIPPER, is activated. This subsystem is responsible for performing the necessary design calculations, retrievals from resin property databases, and package cost calculations.

The output of the system is shown in Figure 3. Alternative designs are ranked with the least costly first, as long as the user's shelf life requirement is satisfied. If no available materials have adequate oxygen barrier properties to meet the user's shelf life requirement, the package with the longest shelf life is shown first. The display in Figure 3 has been abbreviated; the actual system will present about 50 designs for the case shown.

Most of the barrier materials in the example are Du Pont products, but the system does not treat Du Pont materials preferentially. There are cases where competitive materials are more cost effective, and the system will present those materials first. The decisions to include competitive materials and to avoid preferential treatment of our own products reflect both faith in our product line and the desire to maximize the usefulness of the system to the customer. To further enhance the benefit of the system, it was designed to allow the customer to modify the databases to reflect his own resin costs and process economics.

The notes at the bottom of the screen in Figure 3 provide additional information which could not be handled easily elsewhere in the system. We found, for example, that FDA regulations were very complex. Some materials cannot be used with certain foods; others may be used with any food but only at certain temperatures, etc. We added this type of information to footnotes rather than ask all of the questions and code all of the rules that would be necessary to cover these cases.

After the user has analyzed a case, he may elect to return to the Package Requirements Summary screen shown in Figure 2 and make whatever changes he desires for a "what if" analysis. In this way he can gain a better understanding of the interrelationship between design criteria and package materials cost. For example, he may find that the cost difference between clear and translucent containers is greater than threefold.

How the system was used

The system was deployed on laptop computers and used by field sales personnel, with assistance from headquarters staff, to introduce the new products to potential customers. The system was also made available for license to customers for their own use. A videotaped demonstration of the system was prepared so that field sales personnel who did not yet have laptops or were not comfortable using them could still demonstrate the system.

To our knowledge, Packaging Advisor™ is the first artificial intelligence system designed to be the keystone of the marketing communications strategy for a new product line. Packaging Advisor is also a product in its own right -- one which offers substantial benefits to customers. Since designers typically limit their analyses to a few favored materials, Packaging Advisor will often suggest lower cost alternatives than they would otherwise have considered. Often, the designer is lead also to examine process changes involving variables such as scrap rate, package wall thickness, etc. In fact, a number of customers have used the system to justify investments in process improvements. Clearly, the system is much more broadly useful than printed product literature.

The results

Goals for the system were threefold: to establish Du Pont as a technology leader in the eyes of barrier resin purchasers, to provide a means of demonstrating the value of Du Pont products, and to increase resin sales. We judge the system a success by all three criteria. The system received favorable reviews in the trade press, and was well received by customers. The simultaneous introduction of technically advanced materials and Packaging Advisor established our position as leading-edge supplier. Moreover, we are now selling enough resin to justify an expansion in production capacity.

It is, of course, hard to estimate what sales of the new materials would have been without Packaging Advisor. However, management believes that about 30% of resin sales are attributable to accounts with whom we made contact via Packaging Advisor. Without the system, we might never have been able to open the door at these accounts.

The system enhanced the confidence of our sales representatives, enabled them to make more contacts, and improved the quality of their interactions with the customer.

Package designers often become deeply engrossed in their interactions with the system. On a number of occasions we have seen them skip lunch or ask that a demonstration be extended so that they could complete their analysis. Few other marketing communications vehicles have been as successful at holding the attention of their target audience.

Conclusions

The Packaging Advisor™ case illustrates how expert systems technology may be used to codify technical knowledge and deliver it to the field to obtain a competitive advantage. The expert system provided the vehicle for transforming our knowledge from a possession to a high-yielding asset.

```
                    Packaging Advisor
                Maximum Use Temperature

We need to know the maximum temperature the package will experience for a
sustained period (over 2 minutes) during normal use.  This maximum temperature
will normally be attained either during package filling/sterilization or
during heating of packages in microwave or conventional ovens.

{We will rule out materials which cannot tolerate the indicated maximum
 temperature. You may enter your temperature requirements directly if you
 wish.}

     Room temperature or lower

     Pasteurization (71°C)

     Hot fill (85°C)

===> Retort sterilization and/or microwave oven heating (121°C)

     Heating in conventional ovens (230°C)

     Enter maximum usage temperature directly
```

Figure 1. Package Parameter Specification

```
                         Packaging Advisor
                    Package Requirements Summary
                    ============================
Max. usage temp:    121 deg. C.          Humidity inside package:  100%
Storage temp:        23 deg. C.          Humidity outside package:  60%
Package area:      54.0 sq. inches       Retort sterilization: Yes
Package thickness:  30.0 mils
Shelf life:    365 days                  Scrap recycled: Yes
Oxygen infiltration:    2.0 cc           Scrap rate:  50.0 %
Processing method: Thermoforming
Optical properties required: Opaque, translucent, or clear materials
Location of barrier layer: centered   7.5 mils from Outside
Must be covered by FDA food contact regulations:
    Structural resin: Yes
    Barrier resin: Yes
Maximum thickness of barrier layer:   8.0 mils
Minimum thickness of barrier layer:   0.4 mils

Do you wish to make any changes in these parameters?

===> Accept these parameter values

     Change a parameter value
```

Figure 2. The Package Requirements Summary

Packages for Consideration

Structural Resin (Thickness, mils)	Barrier Resin (Thickness, mils)	Need BYNEL TIE	Mat'l Cost $U.S./M	Shelf Life (Days)	Notes
PP (29.0)	SELAR OH (30%) (1.0)	Y	34.129	365.0	B6
PP (27.3)	SELAR OH (44%) (2.7)	Y	50.210	365.0	B7
CPET (29.3)	SELAR OH (30%) (0.7)	Y	60.536	365.0	G3 S2 B6
PP talc filled (29.0)	SELAR OH (30%) (1.0)	Y	65.536	365.0	B6
PP (26.9)	PVDC (3.1)	Y	67.804	365.0	B5
CPET (28.0)	SELAR OH (44%) (2.0)	Y	70.175	365.0	G3 S2 B7
PP talc filled (27.3)	SELAR OH (44%) (2.7)	Y	77.804	365.0	B7
SELAR PT (29.1)	SELAR OH (30%) (0.9)	Y	79.068	365.0	G3 S20 B6

NOTES AND CAUTIONS

G2 Structure does not meet your shelf life requirement.
G3 Resin processing temperatures may not be compatible.

Structural Resin Notes

S2 CPET: not suitable for >50% alcoholic beverages; other limitations apply
S18 Polysulfone: FDA regs specify only frozen/refrigerated storage.
S20 SELAR PT: cannot withstand significant internal pressure at retort temps.

Barrier Resin Notes

B4 NYLON MXD6: FDA restrictions apply; Check regulations.
B5 PVDC: Requires special fabrication eqpt; Barrier degrades at high temps.
B6 SELAR OH (30%): FDA regs specify max. 7 mil thickness & 100 Deg. C. Storage
B7 SELAR OH (44%): FDA regs specify max. 7 mil thickness & 100 Deg. C. Storage
B10 SELAR PA: FDA limited ; not retortable in all cases.
B11 SELAR PT: cannot withstand significant internal pressure at retort temps.

Figure 3. System Output