

*Design is a team effort, but how do marketing and engineering talk to each other?*

# The House of Quality

by JOHN R. HAUSER and DON CLAUSING

Digital Equipment, Hewlett-Packard, AT&T, and ITT are getting started with it. Ford and General Motors use it—at Ford alone there are more than 50 applications. The “house of quality,” the basic design tool of the management approach known as quality function deployment (QFD), originated in 1972 at Mitsubishi’s Kobe shipyard site. Toyota and its suppliers then developed it in numerous ways. The house of quality has been used successfully by Japanese manufacturers of consumer electronics, home appliances, clothing, integrated circuits, synthetic rubber, construction equipment, and agricultural engines. Japanese designers use it for services like swimming schools and retail outlets and even for planning apartment layouts.

A set of planning and communication routines, quality function deployment focuses and coordinates skills within an organization, first to design, then to manufacture and market goods that custom-

ers want to purchase and will continue to purchase. The foundation of the house of quality is the belief that products should be designed to reflect customers’ desires and tastes—so marketing people, design engineers, and manufacturing staff must work closely together from the time a product is first conceived.

The house of quality is a kind of conceptual map that provides the means for interfunctional planning and communications. People with different prob-

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lems and responsibilities can thrash out design priorities while referring to patterns of evidence on the house's grid.

### What's So Hard About Design

David Garvin points out that there are many dimensions to what a consumer means by quality and that it is a major challenge to design products that satisfy all of these at once.<sup>1</sup> Strategic quality management means more than avoiding repairs for consumers. It means that companies learn from customer experience and reconcile what they want with what engineers can reasonably build.

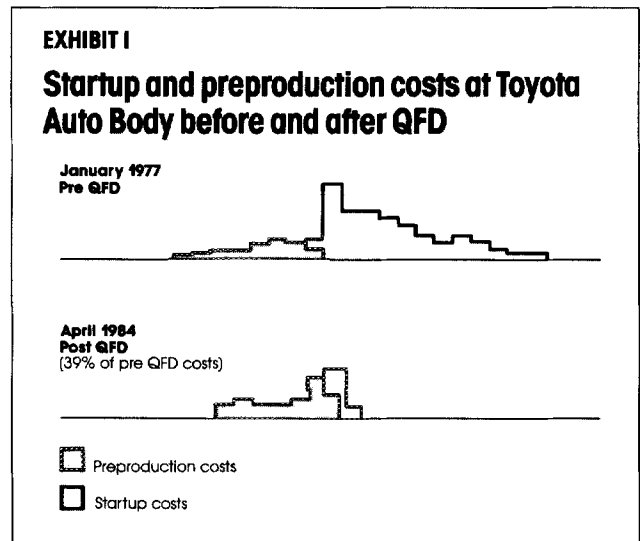
Before the industrial revolution, producers were close to their customers. Marketing, engineering, and manufacturing were integrated—in the same individual. If a knight wanted armor, he talked directly to the armorer, who translated the knight's desires into a product. The two might discuss the material—plate rather than chain armor—and details like fluted surfaces for greater bending strength. Then the armorer would design the production process. For strength—who knows why?—he cooled the steel plates in the urine of a black goat. As for a production plan, he arose with the cock's crow to light the forge fire so that it would be hot enough by midday.

Today's fiefdoms are mainly inside corporations. Marketing people have their domain, engineers theirs. Customer surveys will find their way onto designers' desks, and R&D plans reach manufactur-

ing engineers. But usually, managerial functions remain disconnected, producing a costly and demoralizing environment in which product quality and the quality of the production process itself suffer.

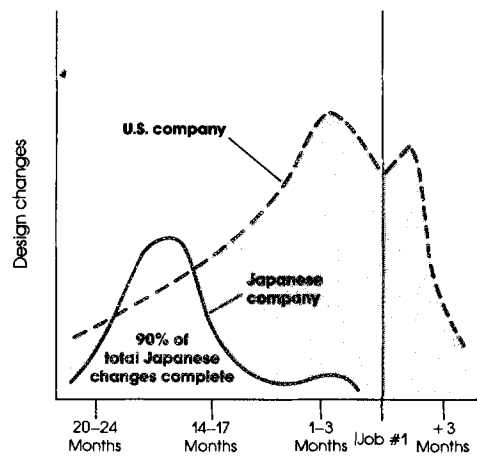
Top executives are learning that the use of inter-functional teams benefits design. But if top management *could* get marketing, designing, and manufacturing executives to sit down together, what should these people talk about? How could they get their meeting off the ground? This is where the house of quality comes in.

Consider the location of an emergency brake lever in one American sporty car. Placing it on the left between the seat and the door solved an engineering problem. But it also guaranteed that women in skirts



Source for Exhibits I and II: Lawrence P. Sullivan, "Quality Function Deployment," *Quality Progress*, June 1986, p. 39. © 1986 American Society for Quality Control. Reprinted by permission.

**EXHIBIT II**  
**Japanese automaker with QFD made fewer changes than U.S. company without QFD**



could not get in and out gracefully. Even if the system were to last a lifetime, would it satisfy customers?

In contrast, Toyota improved its rust prevention record from one of the worst in the world to one of the best by coordinating design and production decisions to focus on this customer concern. Using the house of quality, designers broke down "body durability" into 53 items covering everything from climate to modes of operation. They obtained customer evaluations and ran experiments on nearly every detail of production, from pump operation to temperature control and coating composition. Decisions on sheet metal details, coating materials, and baking temperatures were all focused on those aspects of rust prevention most important to customers.

1. David A. Garvin, "Competing on the Eight Dimensions of Quality," *HBR* November-December 1987, p. 101.

Today, with marketing techniques so much more sophisticated than ever before, companies can measure, track, and compare customers' perceptions of products with remarkable accuracy; all companies have opportunities to compete on quality. And costs certainly justify an emphasis on quality design. By looking first at customer needs, then designing across corporate functions, manufacturers can reduce prelaunch time and after-launch tinkering.

*Exhibit I* compares startup and preproduction costs at Toyota Auto Body in 1977, before QFD, to those costs in 1984, when QFD was well under way. House of quality meetings early on reduced costs by more than 60%. *Exhibit II* reinforces this evidence by comparing the number of design changes at a Japanese auto manufacturer using QFD with changes at a U.S. automaker. The Japanese design was essentially frozen before the first car came off the assembly line, while the U.S. company was still revamping months later.

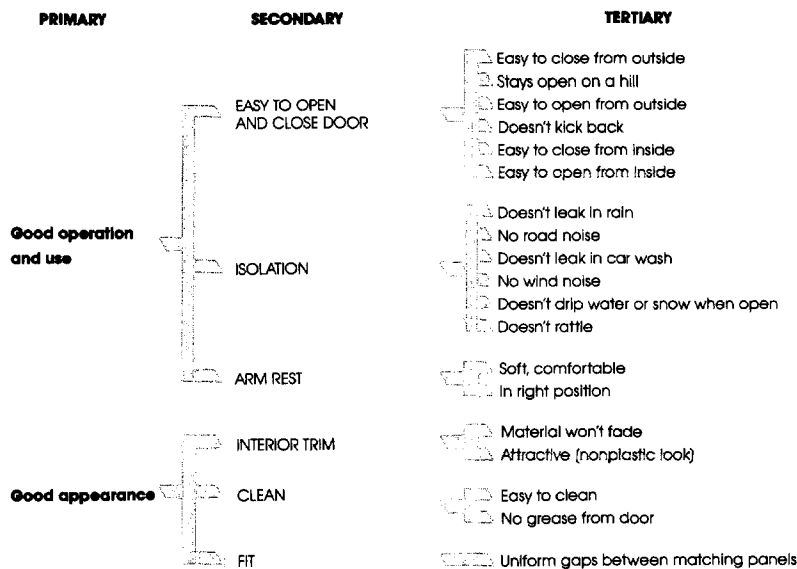
## Building the House

There is nothing mysterious about the house of quality. There is nothing particularly difficult about it either, but it does require some effort to get used to its conventions. Eventually one's eye can bounce knowingly around the house as it would over a road-map or a navigation chart. We have seen some applications that started with more than 100 customer requirements and more than 130 engineering considerations. A fraction of one subchart, in this case for the door of an automobile, illustrates the house's basic concept well. We've reproduced this subchart portion in the illustration "House of Quality," and we'll discuss each section step-by-step.

*What do customers want?* The house of quality begins with the customer, whose requirements are called customer attributes (CAs)—phrases customers use to describe products and product characteristics (see *Exhibit III*). We've listed a few here; a typical application would have 30 to 100 CAs. A car door is "easy to close" or "stays open on a hill"; "doesn't leak in rain" or allows "no (or little) road noise." Some

### EXHIBIT III

## Customer attributes and bundles of CAs for a car door



Japanese companies simply place their products in public areas and encourage potential customers to examine them, while design team members listen and note what people say. Usually, however, more formal market research is called for, via focus groups, in-depth qualitative interviews, and other techniques.

CAs are often grouped into bundles of attributes that represent an overall customer concern, like "open-close" or "isolation." The Toyota rust-prevention study used eight levels of bundles to get from the total car down to the car body. Usually the project team groups CAs by consensus, but some companies are experimenting with state-of-the-art research techniques that derive groupings directly from customers' responses (and thus avoid arguments in team meetings).

CAs are generally reproduced in the customers' own words. Experienced users of the house of quality try to preserve customers' phrases and even clichés—knowing that they will be translated simultaneously by product planners, design engineers, manufacturing engineers, and salespeople. Of course, this raises the problem of interpretation: What does a customer really mean by "quiet" or "easy"? Still, designers' words and inferences may correspond even less to customers' actual views and can therefore mislead teams into tackling problems customers consider unimportant.

Not all customers are end users, by the way. CAs can include the demands of regulators ("safe in a side collision"), the needs of retailers ("easy to display"),

## EXHIBIT IV

## Relative-importance weights of customer attributes

| BUNDLES                     | CUSTOMER ATTRIBUTES        | RELATIVE IMPORTANCE |
|-----------------------------|----------------------------|---------------------|
| EASY TO OPEN AND CLOSE DOOR | Easy to close from outside | 7                   |
|                             | Stays open on a hill       | 5                   |
| ISOLATION                   | Doesn't leak in rain       | 3                   |
|                             | No road noise              | 2                   |

A complete list totals 100%

the requirements of vendors ("satisfy assembly and service organizations"), and so forth.

*Are all preferences equally important?* Imagine a good door, one that is easy to close and has power windows that operate quickly. There is a problem, however. Rapid operation calls for a bigger motor, which makes the door heavier and, possibly, harder to close. Sometimes a creative solution can be found that satisfies all needs. Usually, however, designers have to trade off one benefit against another.

To bring the customer's voice to such deliberations, house of quality measures the relative importance to the customer of all CAs. Weightings are based on team members' direct experience with customers or on surveys. Some innovative businesses are using statistical techniques that allow customers to state their preferences with respect to existing and hypothetical products. Other companies use "revealed preference techniques," which judge consumer tastes by their actions as well as by their words—an approach that is more expensive and difficult to perform but yields more accurate answers. (Consumers say that avoiding sugar in cereals is important, but do their actions reflect their claims?)

Weightings are displayed in the house next to each CA—usually in terms of percentages, a complete list totaling 100% (see *Exhibit IV*).

*Will delivering perceived needs yield a competitive advantage?* Companies that want to match or exceed their competition must first know where they stand relative to it. So on the right side of the house, opposite the CAs, we list customer evaluations of competitive cars matched to "our own" (see *Exhibit V*).

Ideally, these evaluations are based on scientific surveys of customers. If various customer segments

evaluate products differently—luxury vs. economy car buyers, for example—product-planning team members get assessments for each segment.

Comparison with the competition, of course, can identify opportunities for improvement. Take our car door, for example. With respect to "stays open on a hill," every car is weak, so we could gain an advantage here. But if we looked at "no road noise" for the same automobiles, we would see that we already have an advantage, which is important to maintain.

Marketing professionals will recognize the right-hand side of *Exhibit V* as a "perceptual map." Perceptual maps based on bundles of CAs are often used to identify strategic positioning of a product or product line. This section of the house of quality provides a natural link from product concept to a company's strategic vision.

*How can we change the product?* The marketing domain tells us what to do, the engineering domain tells us how to do it. Now we need to describe the product in the language of the engineer. Along the top of the house of quality, the design team lists those engineering characteristics (ECs) that are likely to affect one or more of the customer attributes (see *Exhibit VI*). The negative sign on "energy to close door" means engineers hope to reduce the energy required. If a standard engineering characteristic affects no CA, it may be redundant to the EC list on the house, or the team may have missed a customer attribute. A CA unaffected by any EC, on the other hand, presents opportunities to expand a car's physical properties.

Any EC may affect more than one CA. The resistance of the door seal affects three of the four customer attributes shown in *Exhibit VI*—and others shown later.

Engineering characteristics should describe the product in measurable terms and should directly affect customer perceptions. The weight of the door will be *felt* by the customer and is therefore a relevant EC. By contrast, the thickness of the sheet metal is a part characteristic that the customer is unlikely to perceive directly. It affects customers only by influencing the weight of the door and other engineering characteristics, like "resistance to deformation in a crash."

In many Japanese projects, the interfunctional team begins with the CAs and generates measurable characteristics for each, like foot-pounds of energy required to close the door. Teams should avoid ambiguity in interpretation of ECs or hasty justification of current quality control measurement practices. This is a time for systematic, patient analysis of each characteristic, for brainstorming. Vagueness will eventu-

ally yield indifference to things customers need. Characteristics that are trivial will make the team lose sight of the overall design and stifle creativity.

*How much do engineers influence customer-perceived qualities?* The interfunctional team now fills in the body of the house, the "relationship matrix," indicating how much each engineering characteristic affects each customer attribute. The team seeks consensus on these evaluations, basing them on expert engineering experience, customer responses, and tabulated data from statistical studies or controlled experiments.

The team uses numbers or symbols to establish the strength of these relationships (see *Exhibit VII*). Any symbols will do; the idea is to choose those that work best. Some teams use red symbols for relationships based on experiments and statistics and pencil marks for relationships based on judgment or intuition. Others use numbers from statistical studies. In our house, we use check marks for positive and crosses for negative relationships.

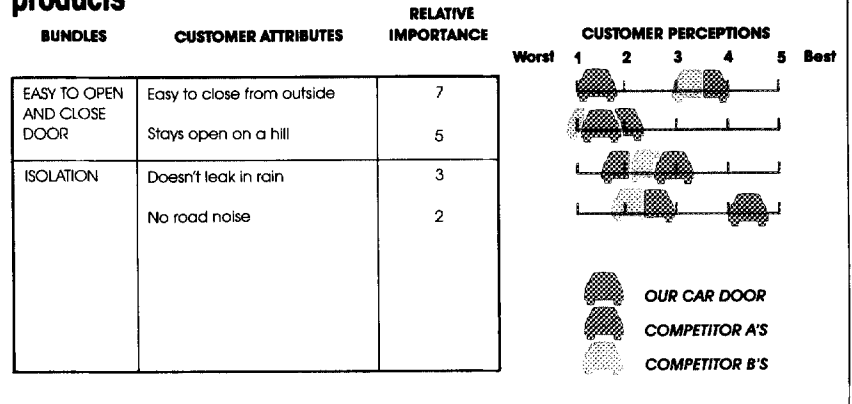
Once the team has identified the voice of the customer and linked it to engineering characteristics, it adds objective measures at the bottom of the house beneath the ECs to which they pertain (see *Exhibit VIII*). When objective measures are known, the team can eventually move to establish target values—ideal new measures for each EC in a redesigned product. If the team did its homework when it first identified the ECs, tests to measure benchmark values should be easy to complete. Engineers determine the relevant units of measurement—foot-pounds, decibels, etc.

Incidentally, if customer evaluations of CAs do not correspond to objective measures of related ECs—if, for example, the door requiring the least energy to open is perceived as "hardest to open"—then perhaps the measures are faulty or the car is suffering from an image problem that is skewing consumer perceptions.

*How does one engineering change affect other characteristics?* An engineer's change of the gear ratio on a car window may make the window motor smaller but the window go up more slowly. And if the engineer enlarges or strengthens the mechanism, the door probably will be heavier, harder to open, or may be less prone to remain open on a slope. Of course,

#### EXHIBIT V

### Customers' evaluations of competitive products



there might be an entirely new mechanism that improves all relevant CAs. Engineering is creative solutions and a balancing of objectives.

The house of quality's distinctive roof matrix helps engineers specify the various engineering features that have to be improved collaterally (see *Exhibit IX*). To improve the window motor, you may have to improve the hinges, weather stripping, and a range of other ECs.

Sometimes one targeted feature impairs so many others that the team decides to leave it alone. The roof matrix also facilitates necessary engineering trade-offs. The foot-pounds of energy needed to close the door, for example, are shown in negative relation to "door seal resistance" and "road noise reduction." In many ways, the roof contains the most critical information for engineers because they use it to balance the trade-offs when addressing customer benefits.

Incidentally, we have been talking so far about the basics, but design teams often want to ruminate on other information. In other words, they custom-build their houses. To the column of CAs, teams may add other columns for histories of customer complaints. To the ECs, a team may add the costs of servicing these complaints. Some applications add data from the sales force to the CA list to represent strategic marketing decisions. Or engineers may add a row that indicates the degree of technical difficulty, showing in their own terms how hard or easy it is to make a change.

Some users of the house impute relative weights to the engineering characteristics. They'll establish that the energy needed to close the door is roughly twice as important to consider as, say, "check force on 10° slope." By comparing weighted characteristics to actual component costs, creative design

teams set priorities for improving components. Such information is particularly important when cost cutting is a goal. (*Exhibit X* includes rows for technical difficulty, imputed importance of ECs, and estimated costs.)

There are no hard-and-fast rules. The symbols, lines, and configurations that work for the particular team are the ones it should use.

## Using the House

How does the house lead to the bottom line? There is no cookbook procedure, but the house helps the team to set targets, which are, in fact, entered on the

bottom line of the house. For engineers it is a way to summarize basic data in usable form. For marketing executives it represents the customer's voice. General managers use it to discover strategic opportunities. Indeed, the house encourages all of these groups to work together to understand one another's priorities and goals.

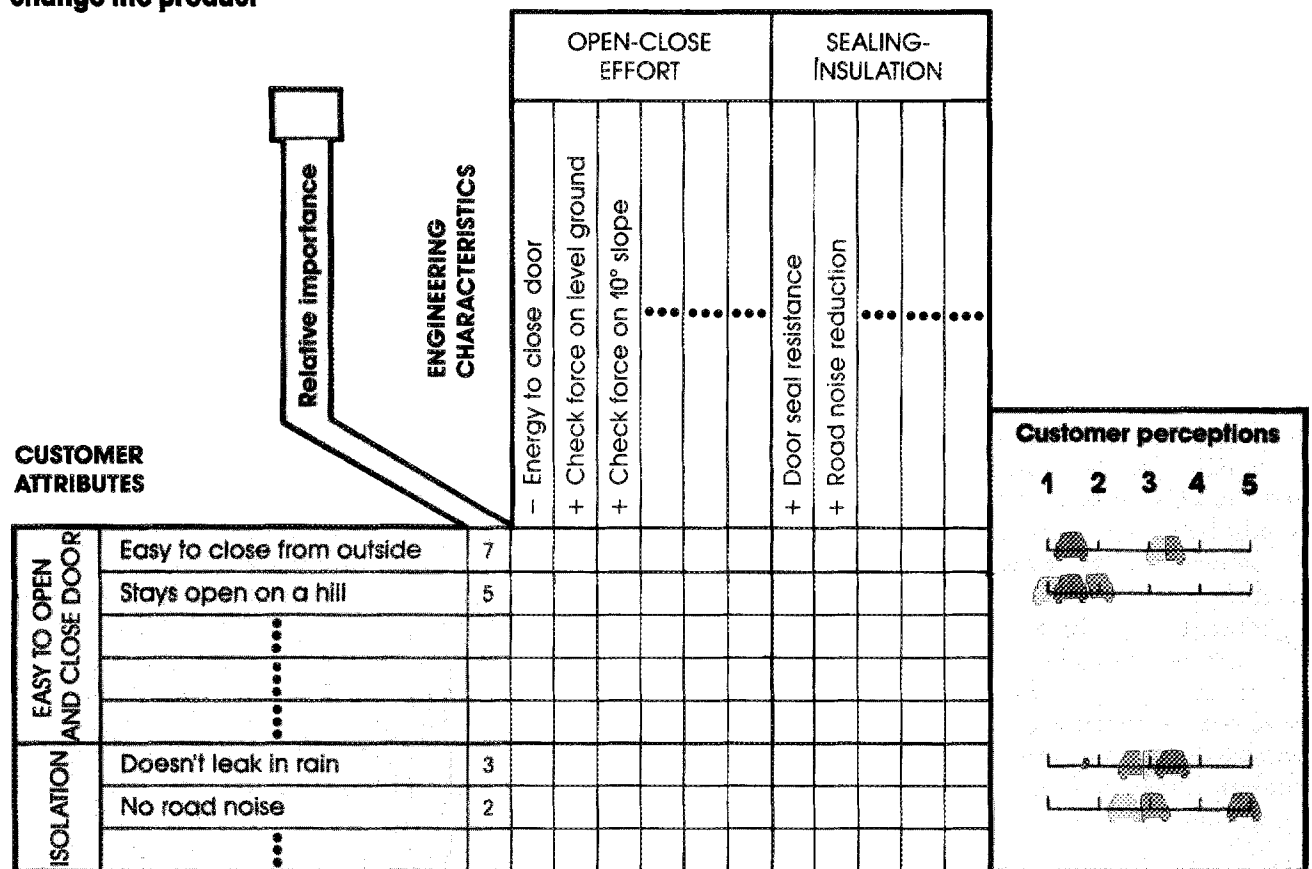
The house relieves no one of the responsibility of making tough decisions. It does provide the means for all participants to debate priorities.

Let's run through a couple of hypothetical situations to see how a design team uses the house.

Look at *Exhibit X*. Notice that our doors are much more difficult to close from the outside than those on competitors' cars. We decide to look further because our marketing data say this customer attribute is

### EXHIBIT VI

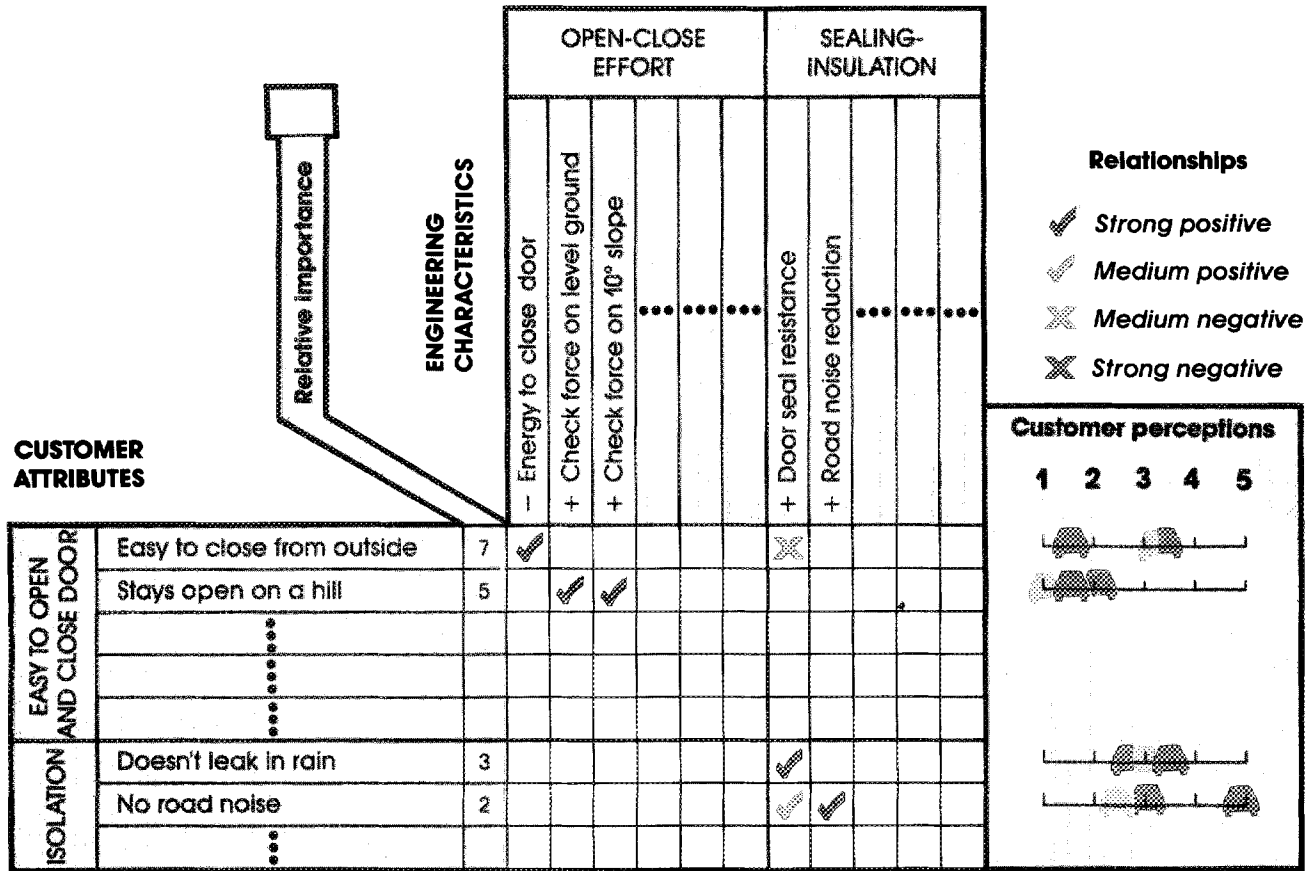
## Engineering characteristics tell how to change the product



— OUR CAR  
 — A'S CAR  
 — B'S CAR

EXHIBIT VII

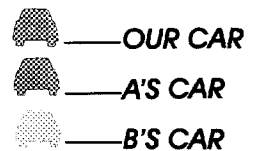
Relationship matrix shows how engineering decisions affect customer perceptions



important. From the central matrix, the body of the house, we identify the ECs that affect this customer attribute: energy to close door, peak closing force, and door seal resistance. Our engineers judge the energy to close the door and the peak closing force as good candidates for improvement together because they are strongly, positively related to the consumer's desire to close the door easily. They determine to consider all the engineering ramifications of door closing.

Next, in the roof of the house, we identify which other ECs might be affected by changing the door closing energy. Door opening energy and peak closing

force are positively related, but other ECs (check force on level ground, door seals, window acoustic transmission, road noise reduction) are bound to be changed in the process and are negatively related. It is not an easy decision. But with objective measures of competitors' doors, customer perceptions, and considering information on cost and technical difficulty, we—marketing people, engineers, and top managers—decide that the benefits outweigh the costs. A new door closing target is set for our door—7.5 foot-pounds of energy. This target, noted on the very bottom of the house directly below the relevant EC, establishes the goal to have the door “easiest to close.”



Look now at the customer attribute "no road noise" and its relationship to the acoustic transmission of the window. The "road noise" CA is only mildly important to customers, and its relationship to the specifications of the window is not strong. Window design will help only so much to keep things quiet. Decreasing the acoustic transmission usually makes the window heavier. Examining the roof of the house, we see that more weight would have a negative impact on ECs (open-close energy, check forces, etc.) that, in turn, are strongly related to CAs that are more important to the customer than quiet ("easy to close," "stays open on a hill"). Finally,

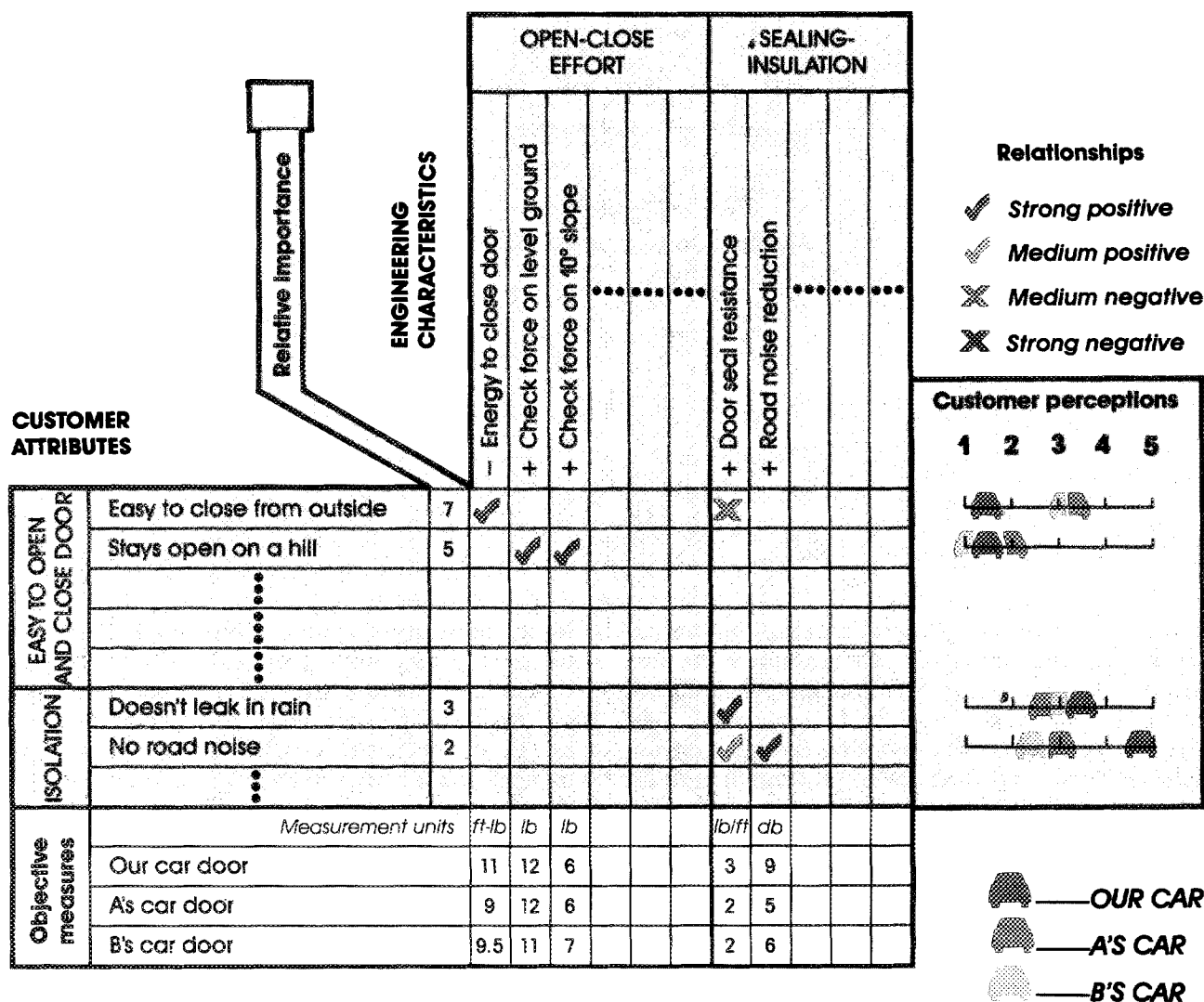
marketing data show that we already do well on road noise; customers perceive our car as better than competitors'.

In this case, the team decides not to tamper with the window's transmission of sound. Our target stays equal to our current acoustic values.

In setting targets, it is worth noting that the team should emphasize customer-satisfaction values and not emphasize tolerances. Do not specify "between 6 and 8 foot-pounds," but rather say, "7.5 foot-pounds." This may seem a small matter, but it is important. The rhetoric of tolerances encourages drift toward the least costly end of the specification limit and

EXHIBIT VIII

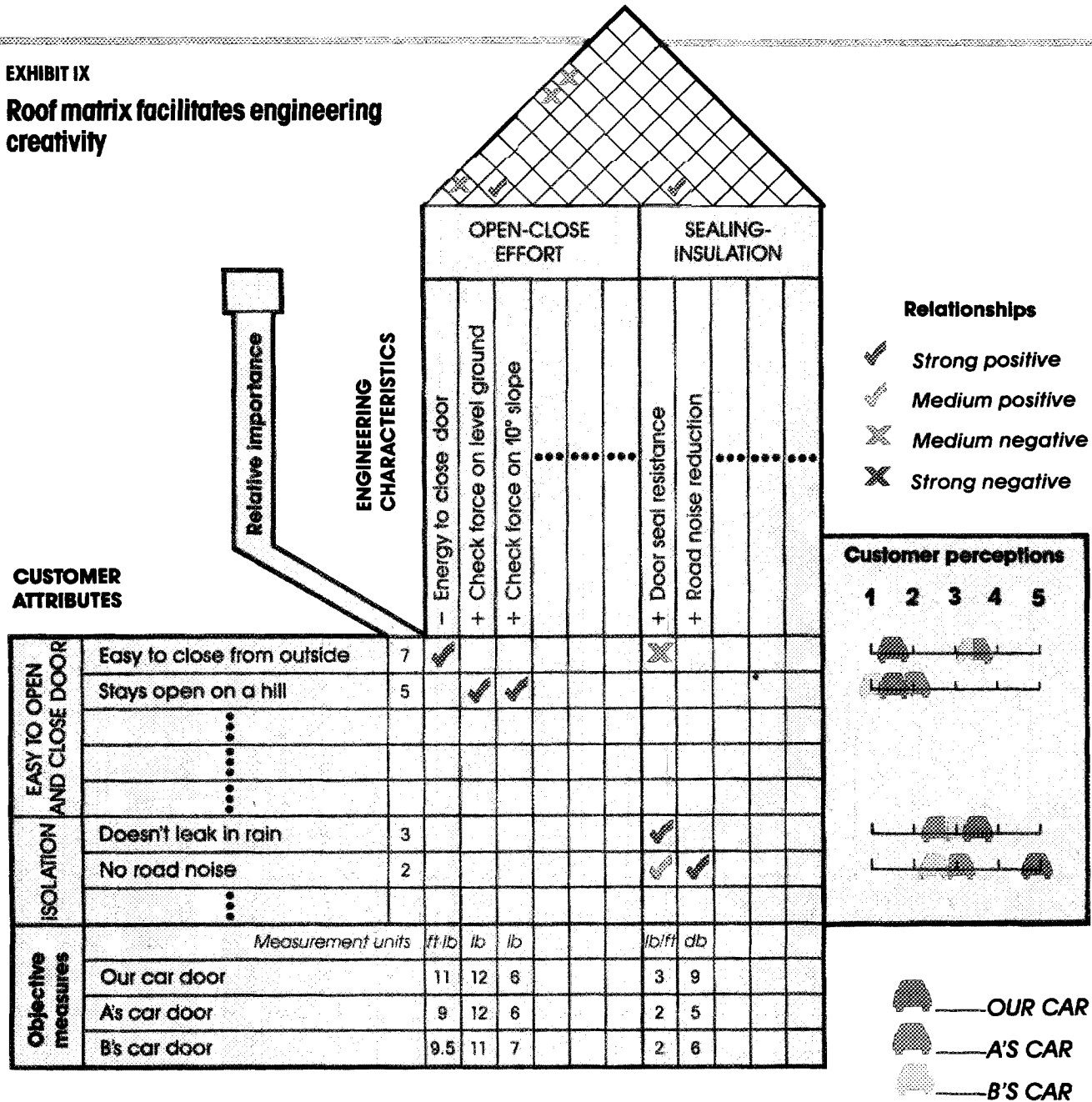
Objective measures evaluate competitive products





**EXHIBIT IX**

**Roof matrix facilitates engineering creativity**



does not reward designs and components whose engineering values closely attain a specific customer-satisfaction target.

**The Houses Beyond**

The principles underlying the house of quality apply to any effort to establish clear relations between manufacturing functions and customer satisfaction that are not easy to visualize. Suppose that our team

decides that doors closing easily is a critical attribute and that a relevant engineering characteristic is closing energy. Setting a target value for closing energy gives us a goal, but it does not give us a door. To get a door, we need the right parts (frame, sheet metal, weather stripping, hinges, etc.), the right processes to manufacture the parts and assemble the product, and the right production plan to get it built.

If our team is truly interfunctional, we can eventually take the "hows" from our house of quality and make them the "whats" of another house, one mainly concerned with detailed product design. En-

EXHIBIT X

House of quality

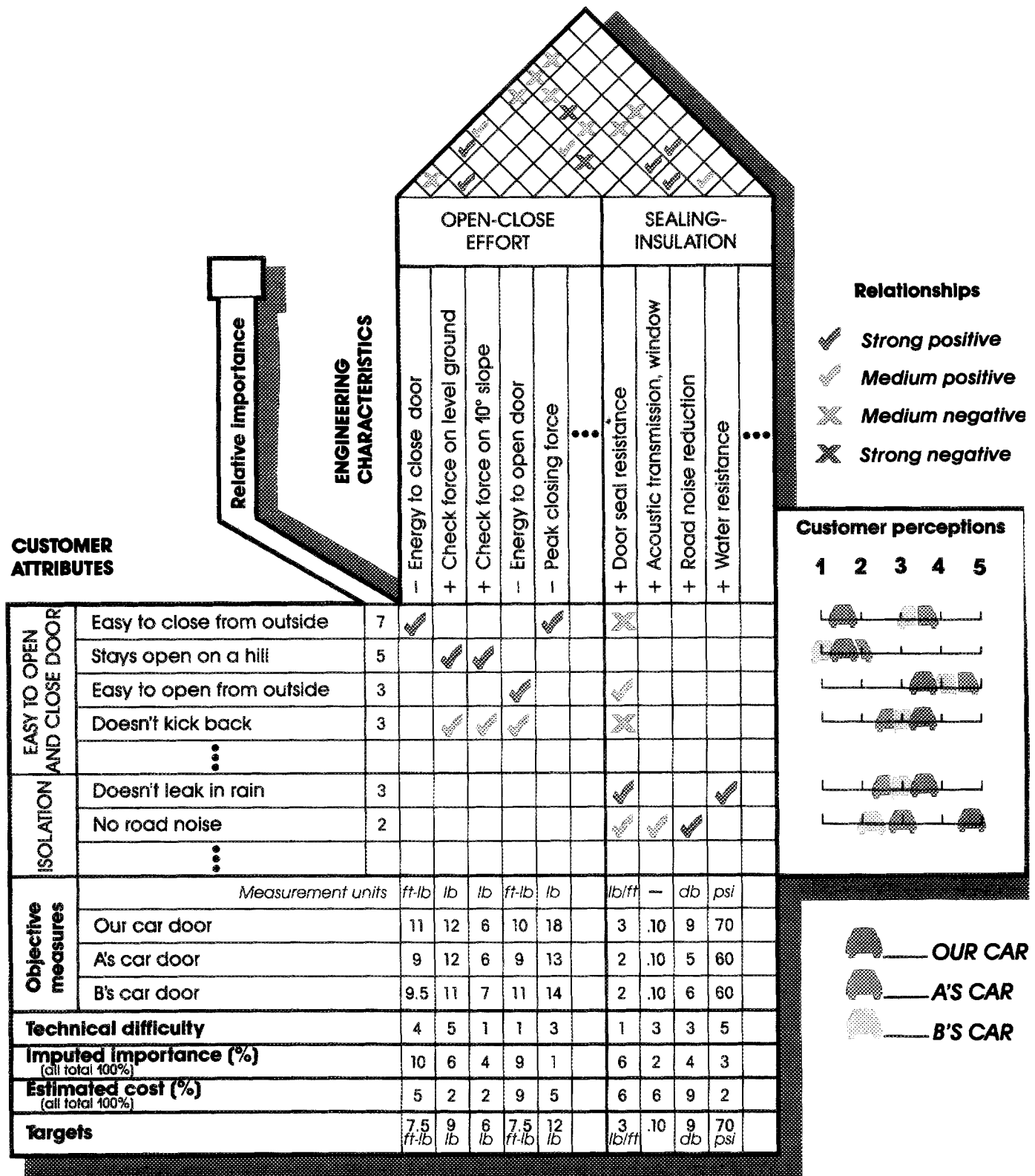
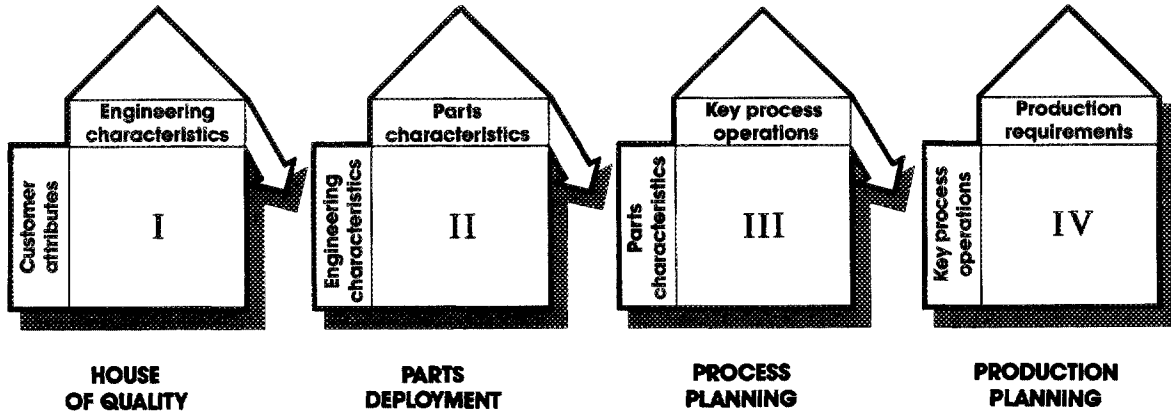


EXHIBIT XI

Linked houses convey the customer's voice through to manufacturing



Source: Modified from a figure supplied by the American Supplier Institute, Inc., Dearborn, Michigan.


gineering characteristics like foot-pounds of closing energy can become the rows in a parts deployment house, while parts characteristics—like hinge properties or the thickness of the weather stripping—become the columns (see *Exhibit XI*).

This process continues to a third and fourth phase as the "hows" of one stage become the "whats" of the next. Weather-stripping thickness—a "how" in the parts house—becomes a "what" in a process planning house. Important process operations, like "rpm of the extruder producing the weather stripping" become the "hows." In the last phase, production planning, the key process operations, like "rpm of the extruder," become the "whats," and production requirements—knob controls, operator training, maintenance—become the "hows."

These four linked houses implicitly convey the voice of the customer through to manufacturing. A control knob setting of 3.6 gives an extruder speed of

100 rpm; this helps give a reproducible diameter for the weather-stripping bulb, which gives good sealing without excessive door-closing force. This feature aims to satisfy the customer's need for a dry, quiet car with an easy-to-close door.

None of this is simple. An elegant idea ultimately decays into process, and processes will be confounding as long as human beings are involved. But that is no excuse to hold back. If a technique like house of quality can help break down functional barriers and encourage teamwork, serious efforts to implement it will be many times rewarded.

What is also not simple is developing an organization capable of absorbing elegant ideas. The principal benefit of the house of quality is quality in-house. It gets people thinking in the right directions and thinking together. For most U.S. companies, this alone amounts to a quiet revolution. 

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