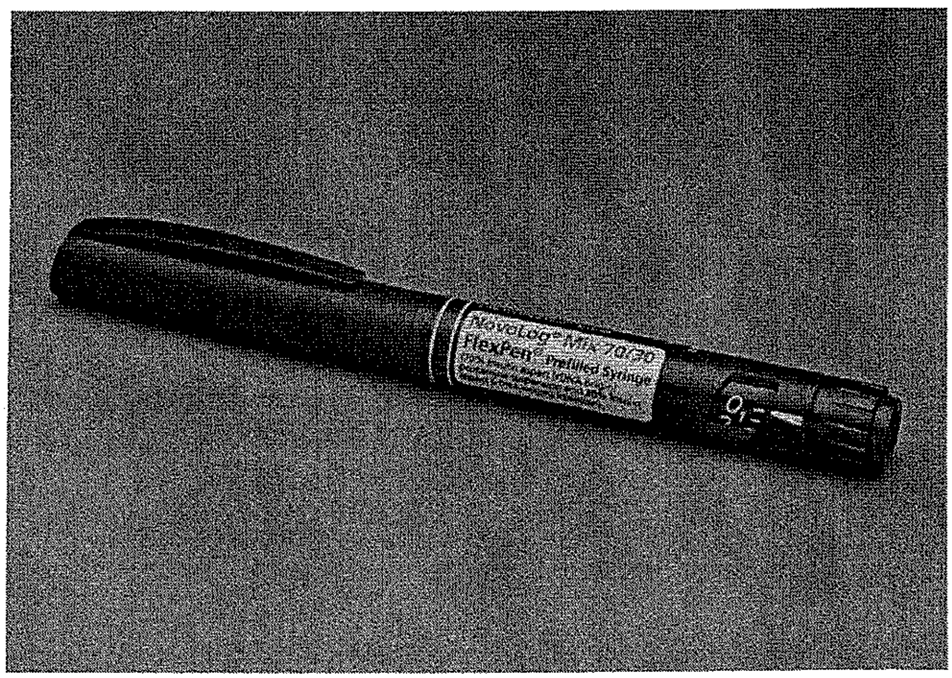
CHAPTER SEVEN

Concept Selection



Courtesy of Novo Nordisk Pharmaceuticals, Inc.

EXHIBIT 7-1
One of the existing outpatient syringes.

A medical supply company retained a product design firm to develop a reusable syringe with precise dosage control for outpatient use. One of the products sold by a competitor is shown in Exhibit 7-1. To focus the development effort, the medical supply company identified two major problems with its current product: cost (the existing model was made of stainless steel) and accuracy of dose metering. The company also requested that the product be tailored to the physical capabilities of the elderly, an important segment of the target market. To summarize the needs of its client and of the intended end users, the team established seven criteria on which the choice of a product concept would be based:

- Ease of handling.
- Ease of use.
- Readability of dose settings.
- Dose metering accuracy.
- Durability.
- Ease of manufacture.
- Portability.

The team described the concepts under consideration with the sketches shown in Exhibit 7-3. Although each concept nominally satisfied the key customer needs, the team was faced with choosing the best concept for further design, refinement, and production. The need to select one syringe concept from many raises several questions:

- How can the team choose the best concept, given that the designs are still quite abstract?
- How can a decision be made that is embraced by the whole team?
- How can desirable attributes of otherwise weak concepts be identified and used?
- How can the decision-making process be documented?

This chapter uses the syringe example to present a concept selection methodology addressing these and other issues.

Concept Selection Is an Integral Part of the Product Development Process

Early in the development process the product development team identifies a set of customer needs. By using a variety of methods, the team then generates alternative solution concepts in response to these needs. (See Chapter 4, Identifying Customer Needs, and Chapter 6, Concept Generation, for more detail on these activities.) *Concept selection* is the process of evaluating concepts with respect to customer needs and other criteria, comparing the relative strengths and weaknesses of the concepts, and selecting one or more concepts for further investigation, testing, or development. Exhibit 7-2 illustrates how the concept selection activity is related to the other activities that make up the concept development phase of the product development process. Although this chapter focuses on the selection of an overall product concept at the beginning of the development process, the method we present is also useful later in the development process when the team must select subsystem concepts, components, and production processes.

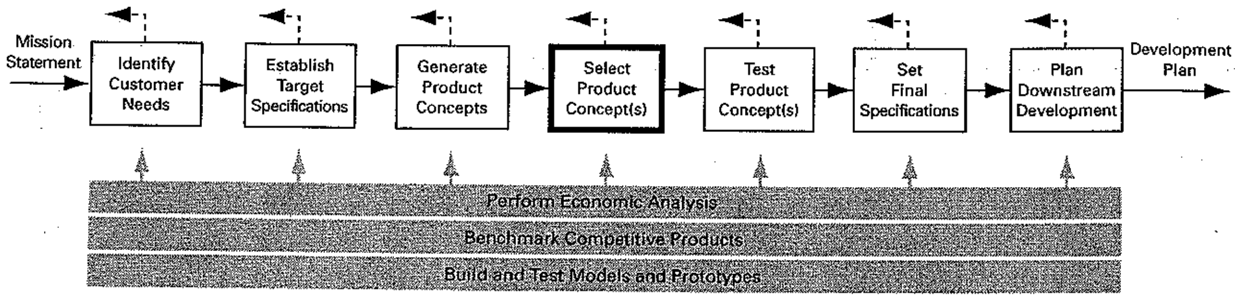


EXHIBIT 7-2 Concept selection is part of the overall concept development phase.

While many stages of the development process benefit from unbounded creativity and divergent thinking, concept selection is the process of narrowing the set of concept alternatives under consideration. Although concept selection is a convergent process, it is frequently iterative and may not produce a dominant concept immediately. A large set of concepts is initially winnowed down to a smaller set, but these concepts may subsequently be combined and improved to temporarily enlarge the set of concepts under consideration. Through several iterations a dominant concept is finally chosen. Exhibit 7-4 illustrates the successive narrowing and temporary widening of the set of options under consideration during the concept selection activity.

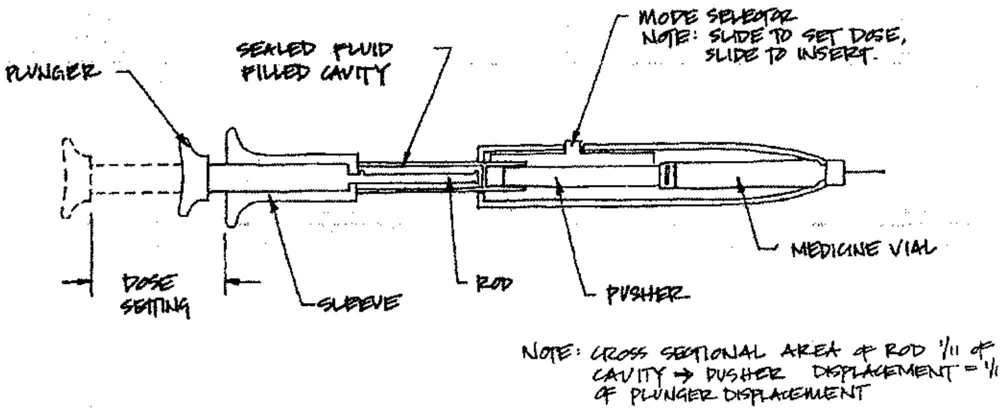
All Teams Use Some Method for Choosing a Concept

Whether or not the concept selection process is explicit, all teams use some method to choose among concepts. (Even those teams generating only one concept are using a method: choosing the first concept they think of.) The methods vary in their effectiveness and include the following:

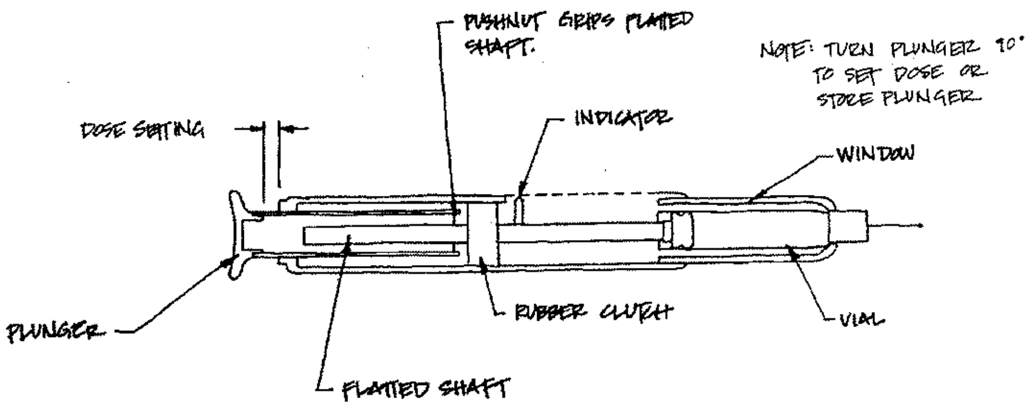
- ***External decision:*** Concepts are turned over to the customer, client, or some other external entity for selection.
- ***Product champion:*** An influential member of the product development team chooses a concept based on personal preference.
- ***Intuition:*** The concept is chosen by its feel. Explicit criteria or trade-offs are not used. The concept just *seems* better.
- ***Multivoting:*** Each member of the team votes for several concepts. The concept with the most votes is selected.
- ***Pros and cons:*** The team lists the strengths and weaknesses of each concept and makes a choice based upon group opinion.
- ***Prototype and test:*** The organization builds and tests prototypes of each concept, making a selection based upon test data.
- ***Decision matrices:*** The team rates each concept against prespecified selection criteria, which may be weighted.

The concept selection method in this chapter is built around the use of decision matrices for evaluating each concept with respect to a set of selection criteria.

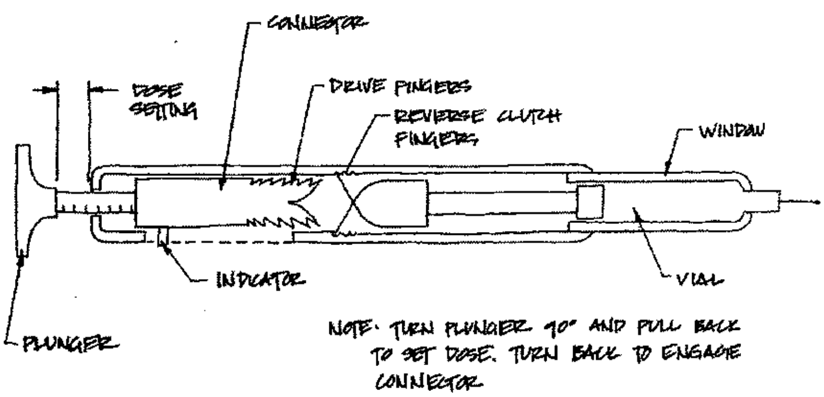
Concept A:
Master Cylinder



Concept B:
Rubber Brake



Concept C:
Ratchet



Concept D:
Plunge Stop

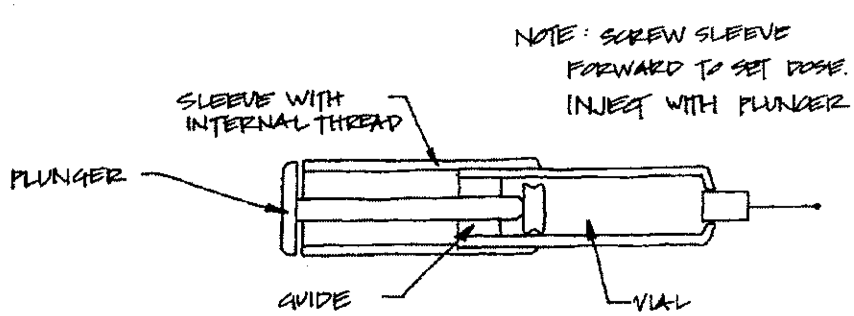
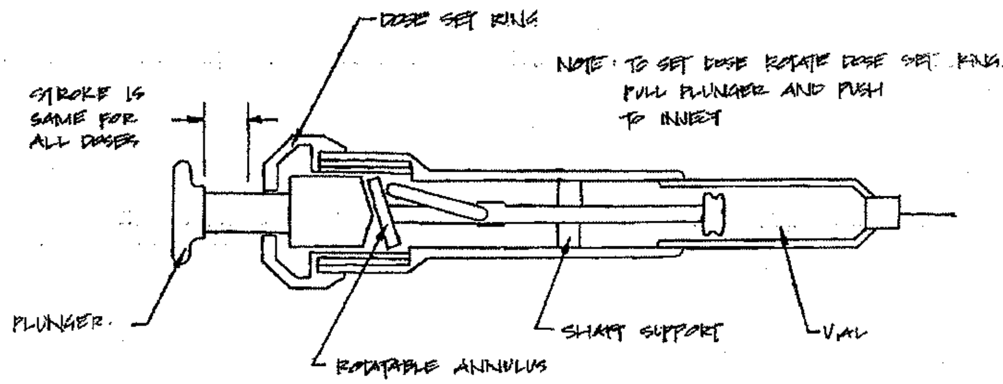
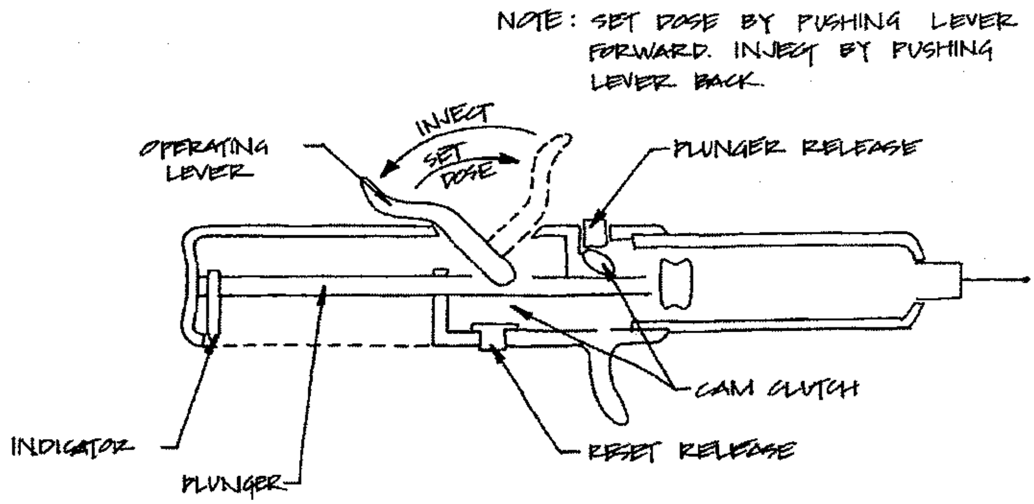


EXHIBIT 7-3 Seven concepts for the outpatient syringe. The product development team generated the seven sketches to describe the basic concepts under consideration.

Concept E: Swash Ring



Concept F: Lever Set



Concept G: Dial Screw

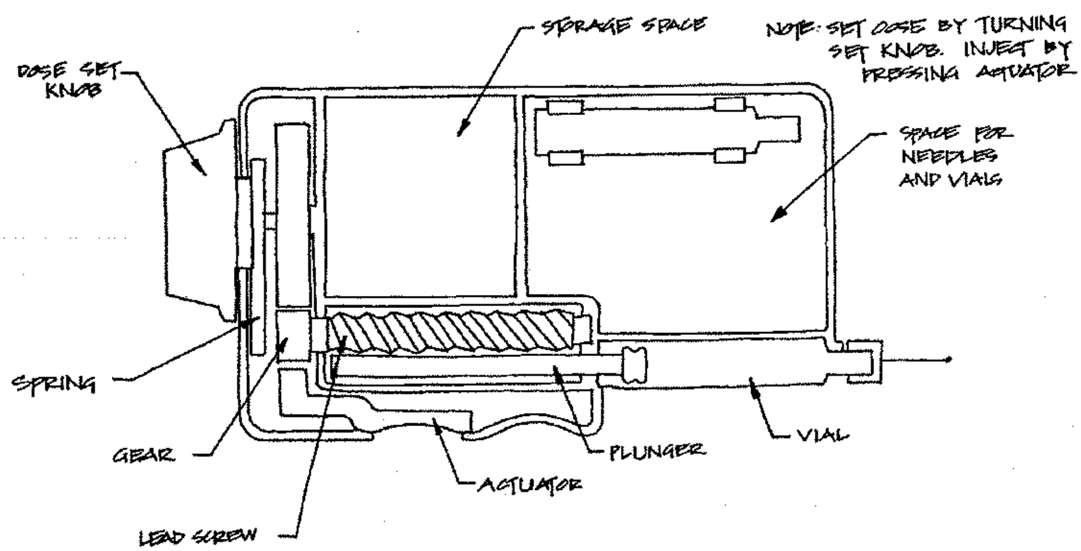


EXHIBIT 7-3 *Continued*

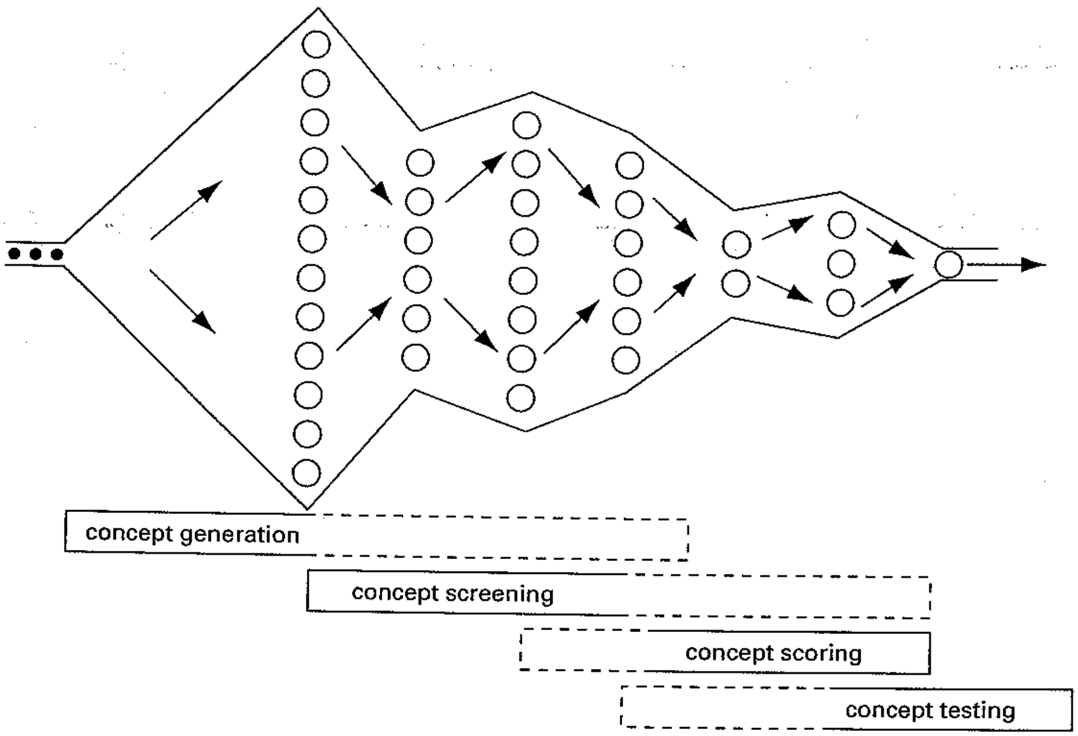


EXHIBIT 7-4 Concept selection is an iterative process closely related to concept generation and testing. The concept screening and scoring methods help the team refine and improve the concepts, leading to one or more promising concepts upon which further testing and development activities will be focused.

A Structured Method Offers Several Benefits

All of the front-end activities of product development have tremendous influence on eventual product success. Certainly the response of the market to a product depends critically on the product concept, but many practitioners and researchers also believe that the choice of a product concept dramatically constrains the eventual manufacturing cost of the product. A structured concept selection process helps to maintain objectivity throughout the concept phase of the development process and guides the product development team through a critical, difficult, and sometimes emotional process. Specifically, a structured concept selection method offers the following potential benefits:

- ***A customer-focused product:*** Because concepts are explicitly evaluated against customer-oriented criteria, the selected concept is likely to be focused on the customer.
- ***A competitive design:*** By benchmarking concepts with respect to existing designs, designers push the design to match or exceed their competitors' performance along key dimensions.
- ***Better product-process coordination:*** Explicit evaluation of the product with respect to manufacturing criteria improves the product's manufacturability and helps to match the product with the process capabilities of the firm.

- ***Reduced time to product introduction:*** A structured method becomes a common language among design engineers, manufacturing engineers, industrial designers, marketers, and project managers, resulting in decreased ambiguity, faster communication, and fewer false starts.
- ***Effective group decision making:*** Within the development team, organizational philosophy and guidelines, willingness of members to participate, and team member experience may constrain the concept selection process. A structured method encourages decision making based on objective criteria and minimizes the likelihood that arbitrary or personal factors influence the product concept.
- ***Documentation of the decision process:*** A structured method results in a readily understood archive of the rationale behind concept decisions. This record is useful for assimilating new team members and for quickly assessing the impact of changes in the customer needs or in the available alternatives.

Overview of Methodology

We present a two-stage concept selection methodology, although the first stage may suffice for simple design decisions. The first stage is called *concept screening* and the second stage is called *concept scoring*. Each is supported by a decision matrix which is used by the team to rate, rank, and select the best concept(s). Although the method is structured, we emphasize the role of group insight to improve and combine concepts.

Concept selection is often performed in two stages as a way to manage the complexity of evaluating dozens of product concepts. The application of these two methods is illustrated in Exhibit 7-4. Screening is a quick, approximate evaluation aimed at producing a few viable alternatives. Scoring is a more careful analysis of these relatively few concepts in order to choose the single concept most likely to lead to product success.

During concept screening, rough initial concepts are evaluated relative to a common reference concept using the *screening matrix*. At this preliminary stage, detailed quantitative comparisons are difficult to obtain and may be misleading, so a coarse comparative rating system is used. After some alternatives are eliminated, the team may choose to move on to concept scoring and conduct more detailed analyses and finer quantitative evaluation of the remaining concepts using the *scoring matrix* as a guide. Throughout the screening and scoring process, several iterations may be performed, with new alternatives arising from the combination of the features of several concepts. Exhibits 7-5 and 7-7 illustrate the screening and scoring matrices, using the selection criteria and concepts from the syringe example.

Both stages, concept screening and concept scoring, follow a six-step process which leads the team through the concept selection activity. The steps are:

1. Prepare the selection matrix.
2. Rate the concepts.
3. Rank the concepts.
4. Combine and improve the concepts.
5. Select one or more concepts.
6. Reflect on the results and the process.

Although we present a well-defined process, the team, not the method, creates the concepts and makes the decisions that determine the quality of the product. Ideally, teams are made up of people from different functional groups within the organization. Each member brings unique views that increase the understanding of the problem and thus facilitate the development of a successful, customer-oriented product. The concept selection method exploits the matrices as visual guides for consensus building among team members. The matrices focus attention on the customer needs and other decision criteria and on the product concepts for explicit evaluation, improvement, and selection.

Concept Screening

Concept screening is based on a method developed by the late Stuart Pugh in the 1980s and is often called *Pugh concept selection* (Pugh, 1990). The purposes of this stage are to narrow the number of concepts quickly and to improve the concepts. Exhibit 7-5 illustrates the screening matrix used during this stage.

Step 1: Prepare the Selection Matrix

To prepare the matrix, the team selects a physical medium appropriate to the problem at hand. Individuals and small groups with a short list of criteria may use matrices on paper similar to Exhibit 7-5 or Appendix A for their selection process. For larger groups a chalkboard or flip chart is desirable to facilitate group discussion.

Next, the inputs (concepts and criteria) are entered on the matrix. Although possibly generated by different individuals, concepts should be presented at the same level of detail for meaningful comparison and unbiased selection. The concepts are best portrayed by both

	Concepts						
Selection Criteria	**A Master Cylinder**	**B Rubber Brake**	**C Ratchet**	**D (Reference) Plunge Stop**	**E Swash Ring**	**F Lever Set**	**G Dial Screw**
Ease of handling	0	0	–	0	0	–	–
Ease of use	0	–	–	0	0	+	0
Readability of settings	0	0	+	0	+	0	+
Dose metering accuracy	0	0	0	0	–	0	0
Durability	0	0	0	0	0	+	0
Ease of manufacture	+	–	–	0	0	–	0
Portability	+	+	0	0	+	0	0
Sum +'s	2	1	1	0	2	2	1
Sum 0's	5	4	3	7	4	3	5
Sum –'s	0	2	3	0	1	2	1
Net Score	2	–1	–2	0	1	0	0
Rank	1	6	7	3	2	3	3
Continue?	Yes	No	No	Combine	Yes	Combine	Revise

EXHIBIT 7-5 The concept screening matrix. For the syringe example, the team rated the concepts against the reference concept using a simple code (+ for "better than," 0 for "same as," – for "worse than") in order to identify some concepts for further consideration. Note that the three concepts ranked "3" all received the same net score.

a written description and a graphical representation. A simple one-page sketch of each concept greatly facilitates communication of the key features of the concept. The concepts are entered along the top of the matrix, using graphical or textual labels of some kind.

If the team is considering more than about 12 concepts, the *multivote* technique may be used to quickly choose the dozen or so concepts to be evaluated with the screening matrix. Multivoting is a technique in which members of the team simultaneously vote for three to five concepts by applying "dots" to the sheets describing their preferred concepts. The concepts with the most dots are chosen for concept screening. It is also possible to use the screening matrix method with a large number of concepts. This is facilitated by a spreadsheet and it is then useful to transpose the rows and columns. (Arrange the concepts in this case in the left column and the criteria along the top.)

The selection criteria are listed along the left-hand side of the screening matrix, as shown in Exhibit 7-5. These criteria are chosen based on the customer needs the team has identified, as well as on the needs of the enterprise, such as low manufacturing cost or minimal risk of product liability. The criteria at this stage are usually expressed at a fairly high level of abstraction and typically include from 5 to 10 dimensions. The selection criteria should be chosen to differentiate among the concepts. However, because each criterion is given equal weight in the concept screening method, the team should be careful not to list many relatively unimportant criteria in the screening matrix. Otherwise, the differences among the concepts relative to the more important criteria will not be clearly reflected in the outcome.

After careful consideration, the team chooses a concept to become the benchmark, or *reference concept,* against which all other concepts are rated. The reference is generally either an industry standard or a straightforward concept with which the team members are very familiar. It can be a commercially available product, a best-in-class benchmark product which the team has studied, an earlier generation of the product, any one of the concepts under consideration, or a combination of subsystems assembled to represent the best features of different products.

Step 2: Rate the Concepts

A relative score of "better than" (+), "same as" (0), or "worse than" (–) is placed in each cell of the matrix to represent how each concept rates in comparison to the reference concept relative to the particular criterion. It is generally advisable to rate every concept on one criterion before moving to the next criterion. However, with a large number of concepts, it is faster to use the opposite approach—to rate each concept completely before moving on to the next concept.

Some people find the coarse nature of the relative ratings difficult to work with. However, at this stage in the design process, each concept is only a general notion of the ultimate product, and more detailed ratings are largely meaningless. In fact, given the imprecision of the concept descriptions at this point, it is very difficult to consistently compare concepts to one another unless one concept (the reference) is consistently used as a basis for comparison.

When available, objective metrics can be used as the basis for rating a concept. For example, a good approximation of assembly cost is the number of parts in a design. Similarly, a good approximation of ease of use is the number of operations required to use the device. Such metrics help to minimize the subjective nature of the rating process. Some objective metrics suitable for concept selection may arise from the process of establishing target specifications for the product. (See Chapter 5, Product Specifications, for a discussion of metrics.) Absent objective metrics, ratings are established by team consensus, although secret ballot or other methods may also be useful. At this point the team may also wish to note which selection criteria need further investigation and analysis.

Step 3: Rank the Concepts

After rating all the concepts, the team sums the number of "better than," "same as," and "worse than" scores and enters the sum for each category in the lower rows of the matrix. From our example in Exhibit 7-5, concept A was rated to have two criteria better than, five the same as, and none worse than the reference concept. Next, a net score can be calculated by subtracting the number of "worse than" ratings from the "better than" ratings.

Once the summation is completed, the team rank-orders the concepts. Obviously, in general those concepts with more pluses and fewer minuses are ranked higher. Often at this point the team can identify one or two criteria which really seem to differentiate the concepts.

Step 4: Combine and Improve the Concepts

Having rated and ranked the concepts, the team should verify that the results make sense and then consider if there are ways to combine and improve certain concepts. Two issues to consider are:

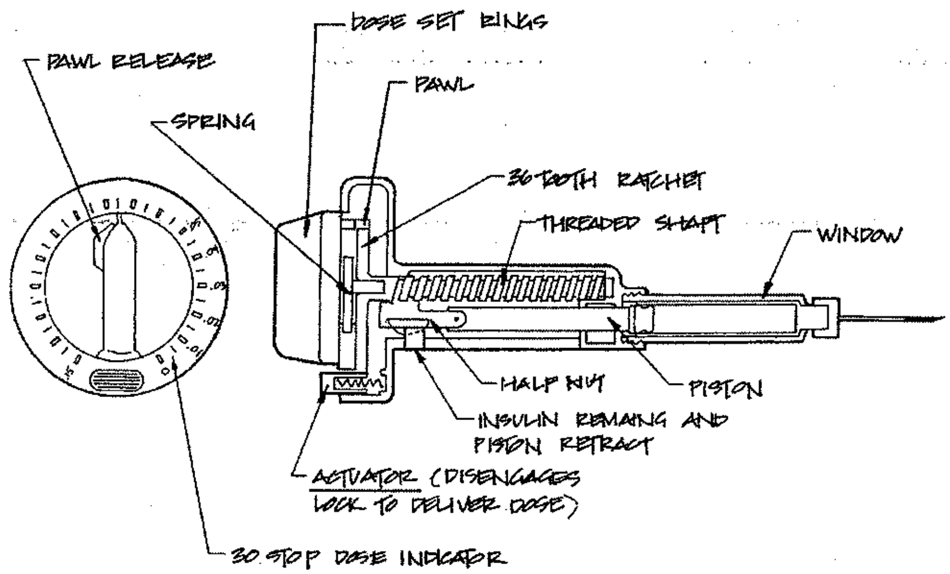
- Is there a generally good concept which is degraded by one bad feature? Can a minor modification improve the overall concept and yet preserve a distinction from the other concepts?
- Are there two concepts which can be combined to preserve the "better than" qualities while annulling the "worse than" qualities?

Combined and improved concepts are then added to the matrix, rated by the team, and ranked along with the original concepts. In our example, the team noticed that concepts D and F could be combined to remove several of the "worse than" ratings to yield a new concept, DF, to be considered in the next round. Concept G was also considered for revision. The team decided that this concept was too bulky, so the excess storage space was removed while retaining the injection technique. These revised concepts are shown in Exhibit 7-6.

Step 5: Select One or More Concepts

Once the team members are satisfied with their understanding of each concept and its relative quality, they decide which concepts are to be selected for further refinement and analysis. Based upon previous steps, the team will likely develop a clear sense of which are the most promising concepts. The number of concepts selected for further review will be limited by team resources (personnel, money, and time). In our example, the team selected concepts A and E to be considered along with the revised concept G+ and the new concept DF. Having determined the concepts for further analysis, the team must clarify which issues need to be investigated further before a final selection can be made.

Concept G+: Dial Screw+



Concept DF: Lever Stop

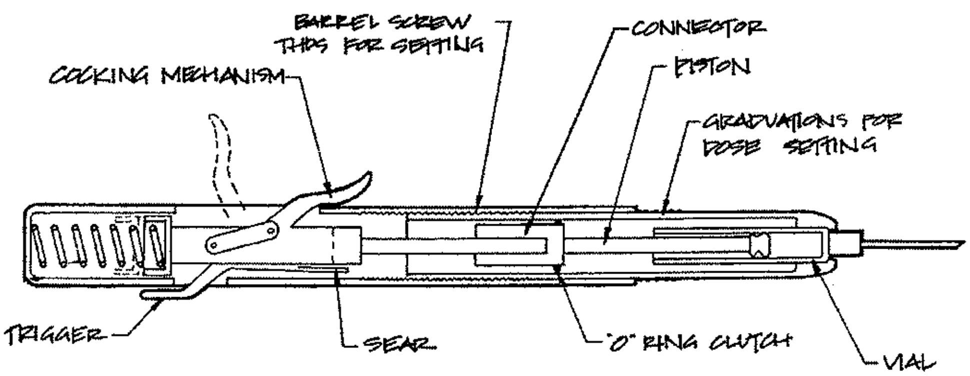


EXHIBIT 7-6 New and revised concepts for the syringe. During the selection process, the syringe team revised concept G and generated a new concept, DF, arising from the combination of concepts D and F.

The team must also decide whether another round of concept screening will be performed or whether concept scoring will be applied next. If the screening matrix is not seen to provide sufficient resolution for the next step of evaluation and selection, then the concept-scoring stage with its weighted selection criteria and more detailed rating scheme would be used.

Step 6: Reflect on the Results and the Process

All of the team members should be comfortable with the outcome. If an individual is not in agreement with the decision of the team, then perhaps one or more important criteria are missing from the screening matrix, or perhaps a particular rating is in error, or at least is not clear. An explicit consideration of whether the results make sense to everyone reduces the likelihood of making a mistake and increases the likelihood that the entire team will be solidly committed to the subsequent development activities.

		Concept							
		A (Reference) Master Cylinder		DF Lever Stop		E Swash Ring		G+ Dial Screw+	
Selection Criteria	**Weight**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**
Ease of handling	5%	**3**	0.15	3	0.15	4	0.2	4	0.2
Ease of use	15%	**3**	0.45	4	0.6	4	0.6	3	0.45
Readability of settings	10%	2	0.2	**3**	0.3	5	0.5	5	0.5
Dose metering accuracy	25%	**3**	0.75	3	0.75	2	0.5	3	0.75
Durability	15%	2	0.3	5	0.75	4	0.6	**3**	0.45
Ease of manufacture	20%	**3**	0.6	3	0.6	2	0.4	2	0.4
Portability	10%	**3**	0.3	3	0.3	3	0.3	3	0.3
	Total Score	2.75		3.45		3.10		3.05	
	Rank	4		1		2		3	
	Continue?	No		Develop		No		No	

EXHIBIT 7-7 The concept scoring matrix. This method uses a weighted sum of the ratings to determine concept ranking. While concept A serves as the overall reference concept, the separate reference points for each criterion are signified by **bold** rating values.

Concept Scoring

Concept scoring is used when increased resolution will better differentiate among competing concepts. In this stage, the team weighs the relative importance of the selection criteria and focuses on more refined comparisons with respect to each criterion. The concept scores are determined by the weighted sum of the ratings. Exhibit 7-7 illustrates the scoring matrix used in this stage. In describing the concept scoring process, we focus on the differences relative to concept screening.

Step 1: Prepare the Selection Matrix

As in the screening stage, the team prepares a matrix and identifies a reference concept. In most cases a computer spreadsheet is the best format to facilitate ranking and sensitivity analysis. The concepts that have been identified for analysis are entered on the top of the matrix. The concepts have typically been refined to some extent since concept screening and may be expressed in more detail. In conjunction with more detailed concepts, the team may wish to add more detail to the selection criteria. The use of hierarchical relations is a useful way to illuminate the criteria. For the syringe example, suppose the team decided that the criterion "ease of use" did not provide sufficient detail to help distinguish among the remaining concepts. "Ease of use" could be broken down, as shown in Exhibit 7-8, to include "ease of injection," "ease of cleaning," and "ease of loading." The level of criteria detail will depend upon the needs of the team; it may not be necessary to expand the criteria at all. If the team has created a hierarchical list of customer needs, the secondary and tertiary needs are good candidates for more detailed selection criteria. (See

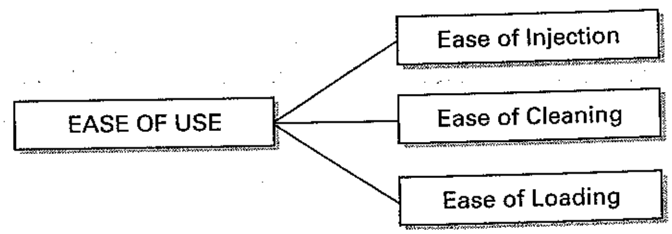


EXHIBIT 7-8 Hierarchical decomposition of selection criteria. In conjunction with more detailed concepts, the team may choose to break down criteria to the level of detail necessary for meaningful comparison.

Chapter 4, Identifying Customer Needs, for an explanation of primary, secondary, and tertiary needs, and see Appendixes A and B for examples of hierarchical selection criteria.)

After the criteria are entered, the team adds importance weights to the matrix. Several different schemes can be used to weight the criteria, such as assigning an importance value from 1 to 5, or allocating 100 percentage points among them, as the team has done in Exhibit 7-7. There are marketing techniques for empirically determining weights from customer data, and a thorough process of identifying customer needs may result in such weights (Urban and Hauser, 1993). However, for the purpose of concept selection the weights are often determined subjectively by team consensus.

Step 2: Rate the Concepts

As in the screening stage, it is generally easiest for the team to focus its discussion by rating all of the concepts with respect to one criterion at a time. Because of the need for additional resolution to distinguish among competing concepts, a finer scale is now used. We recommend a scale from 1 to 5:

Relative Performance	Rating
Much worse than reference	1
Worse than reference	2
Same as reference	3
Better than reference	4
Much better than reference	5

Another scale, such as 1 to 9, may certainly be used, but finer scales generally require more time and effort.

A single reference concept can be used for the comparative ratings, as in the screening stage; however, this is not always appropriate. Unless by pure coincidence the reference concept is of average performance relative to all of the criteria, the use of the same reference concept for the evaluation of each criterion will lead to "scale compression" for some of the criteria. For example, if the reference concept happens to be the easiest concept to manufacture, all of the remaining concepts will receive an evaluation of 1, 2, or 3 ("much worse than," "worse than," or "same as") for the ease-of-manufacture criterion, compressing the rating scale from five levels to three levels.

To avoid scale compression, we recommend using different reference points for the various selection criteria. Reference points may come from several of the concepts under consideration, from comparative benchmarking analysis, from the target values of the product specifications, or other means. It is important that the reference point for each criterion be well understood to facilitate direct one-to-one comparisons. Using multiple reference points does not prevent the team from designating one concept as the overall reference for the purposes of ensuring that the selected concept is competitive relative to this benchmark. Under such conditions the overall reference concept will simply not receive a neutral score.

Exhibit 7-7 shows the scoring matrix for the syringe example. The team believed that the master cylinder concept was not suitable as a reference point for two of the criteria, and other concepts were used as reference points in these cases.

Appendix B illustrates a more detailed scoring matrix for which the team rated the concepts on each criterion with no explicit reference points. These ratings were accomplished by discussing the merits of every concept with respect to one criterion at a time and arranging the scores on a 9-point scale.

Step 3: Rank the Concepts

Once the ratings are entered for each concept, weighted scores are calculated by multiplying the raw scores by the criteria weights. The total score for each concept is the sum of the weighted scores:

$$S_j = \sum_{i=1}^{n} r_{ij} w_i$$

where

r_{ij} = raw rating of concept j for the ith criterion
w_i = weighting for ith criterion
n = number of criteria
S_j = total score for concept j

Finally, each concept is given a rank corresponding to its total score, as shown in Exhibit 7-7.

Step 4: Combine and Improve the Concepts

As in the screening stage, the team looks for changes or combinations that improve concepts. Although the formal concept generation process is typically completed before concept selection begins, some of the most creative refinements and improvements occur during the concept selection process as the team realizes the inherent strengths and weaknesses of certain features of the product concepts.

Step 5: Select One or More Concepts

The final selection is not simply a question of choosing the concept that achieves the highest ranking after the first pass through the process. Rather, the team should explore this initial evaluation by conducting a sensitivity analysis. Using a computer spreadsheet, the team can vary weights and ratings to determine their effect on the ranking.

By investigating the sensitivity of the ranking to variations in a particular rating, the team members can assess whether uncertainty about a particular rating has a large impact on their choice. In some cases they may select a lower-scoring concept about which there is little uncertainty instead of a higher-scoring concept that may possibly prove unworkable or less desirable as they learn more about it.

Based on the selection matrix, the team may decide to select the top two or more concepts. These concepts may be further developed, prototyped, and tested to elicit customer feedback. See Chapter 8, Concept Testing, for a discussion of methods to assess customer response to product concepts.

The team may also create two or more scoring matrices with different weightings to yield the concept ranking for various market segments with different customer preferences. It may be that one concept is dominant for several segments. The team should also consider carefully the significance of differences in concept scores. Given the resolution of the scoring system, small differences are generally not significant.

For the syringe example, the team agreed that concept DF was the most promising and would be likely to result in a successful product.

Step 6: Reflect on the Results and the Process

As a final step the team reflects on the selected concept(s) and on the concept selection process. In some ways, this is the "point of no return" for the concept development process, so everyone on the team should feel comfortable that all of the relevant issues have been discussed and that the selected concept(s) have the greatest potential to satisfy customers and be economically successful.

After each stage of concept selection, it is a useful reality check for the team to review each of the concepts that are to be eliminated from further consideration. If the team agrees that any of the dropped concepts is better overall than some of those retained, then the source of this inconsistency should be identified. Perhaps an important criterion is missing, not weighted properly, or inconsistently applied.

The organization can also benefit from reflection on the process itself. Two questions are useful in improving the process for subsequent concept selection activities:

- In what way (if at all) did the concept selection method facilitate team decision making?
- How can the method be modified to improve team performance?

These questions focus the team on the strengths and weaknesses of the methodology in relation to the needs and capabilities of the organization.

Caveats

With experience, users of the concept selection methods will discover several subtleties. Here we discuss some of these subtleties and point out a few areas for caution.

- ***Decomposition of concept quality:*** The basic theory underlying the concept selection method is that selection criteria—and, by implication, customer needs—can be evaluated independently and that concept quality is the sum of the qualities of the concept relative to each criterion. The quality of some product concepts may not be easily decomposed into a set of independent criteria, or the performance of the concept relative to the different criteria may be difficult to relate to overall concept quality. For example, the overall appeal or performance of a tennis racquet design may arise in a highly complex way from its weight, ease of swinging, shock transmission, and energy absorption. Simply choosing a concept based on the sum of performance relative to each criterion may fail to capture complex relationships among these criteria. Keeney and Raiffa (1993) discuss the problem of multiattribute decision making, including the issue of nonlinear relationships among selection criteria.

- ***Subjective criteria:*** Some selection criteria, particularly those related to aesthetics, are highly subjective. Choices among alternatives based solely on subjective criteria must be made carefully. In general, the development team's collective judgment is not the best way to evaluate concepts on subjective dimensions. Rather, the team should narrow the alternatives to three or four and then solicit the opinions of representative customers from the target market for the product, perhaps using mock-ups or models to represent the concepts. (See Chapter 8, Concept Testing.)
- ***To facilitate improvement of concepts:*** While discussing each concept to determine its rating, the team may wish to make note of any outstanding (positive or negative) attributes of the concepts. It is useful to identify any features which could be applied to other concepts, as well as issues which could be addressed to improve the concept. Notes may be placed directly in the cells of the selection matrix. Such notes are particularly useful in step 4, when the team seeks to combine, refine, and improve the concepts before making a selection decision.
- ***Where to include cost:*** Most of the selection criteria are adaptations of the customer needs. However, "ease of manufacturing" and "manufacturing cost" are not customer needs. The only reason customers care about manufacturing cost is that it establishes the lower bound on sale price. Nevertheless, cost is an extremely important factor in choosing a concept, because it is one of the factors determining the economic success of the product. For this reason, we advocate the inclusion of some measure of cost or ease of manufacturing when evaluating concepts, even though these measures are not true customer needs. Similarly, there may be needs of other stakeholders that were not expressed by actual customers but are important for economic success of the product.
- ***Selecting elements of aggregate concepts:*** Some product concepts are really aggregations of several simpler concepts. If all of the concepts under consideration include choices from a set of simpler elements, then the simple elements can be evaluated first and in an independent fashion before the more complex concepts are evaluated. This sort of decomposition may follow partly from the structure used in concept generation. For example, if all of the syringes in our example could be used with all of several different needle types, then the selection of a needle concept could be conducted independently of the selection of an overall syringe concept.
- ***Applying concept selection throughout the development process:*** Although throughout this chapter we have emphasized the application of the method to the selection of a basic product concept, concept selection is used again and again at many levels of detail in the design and development process. For example, in the syringe example, concept selection could be used at the very beginning of the development project to decide between a single-use or multiple-use approach. Once the basic approach had been determined, concept selection could be used to choose the basic product concept, as illustrated in this chapter. Finally, concept selection could be used at the most detailed level of design for resolving decisions such as the choice of colors or materials.

Summary

Concept selection is the process of evaluating concepts with respect to customer needs and other criteria, comparing the relative strengths and weaknesses of the concepts, and selecting one or more concepts for further investigation or development.

- All teams use some method, implicit or explicit, for selecting concepts. Decision techniques employed for selecting concepts range from intuitive approaches to structured methods.
- Successful design is facilitated by structured concept selection. We recommend a two-stage process: concept screening and concept scoring.
- Concept screening uses a reference concept to evaluate concept variants against selection criteria. Concept scoring may use different reference points for each criterion.
- Concept screening uses a coarse comparison system to narrow the range of concepts under consideration.
- Concept scoring uses weighted selection criteria and a finer rating scale. Concept scoring may be skipped if concept screening produces a dominant concept.
- Both screening and scoring use a matrix as the basis of a six-step selection process. The six steps are:
  1. Prepare the selection matrix.
  2. Rate the concepts.
  3. Rank the concepts.
  4. Combine and improve the concepts.
  5. Select one or more concepts.
  6. Reflect on the results and the process.
- Concept selection is applied not only during concept development but throughout the subsequent design and development process.
- Concept selection is a group process that facilitates the selection of a winning concept, helps build team consensus, and creates a record of the decision-making process.

References and Bibliography

Many current resources are available on the Internet via
www.ulrich-eppinger.net

The concept selection methodology is a decision-making process. Souder outlines other decision techniques.

Souder, William E., *Management Decision Methods for Managers of Engineering and Research,* Van Nostrand Reinhold, New York, 1980.

For a more formal treatment of multiattribute decision making, illustrated with a set of eclectic and interesting case studies, see Keeney and Raiffa.

Keeney, Ralph L., and Howard Raiffa, *Decisions with Multiple Objectives: Preferences and Value Trade-Offs,* Cambridge University Press, New York, 1993.

Pahl and Beitz's influential engineering design textbook contains an excellent set of systematic methods. The book outlines two concept selection methods similar to concept scoring.

Pahl, Gerhard, Wolfgang Beitz, Jörg Feldhusen, and Karl-Heinrich Grote, *Engineering Design: A Systematic Approach,* third edition, K. Wallace and L. Blessing, translators, Springer-Verlag, New York, 2007.

Weighting alternatives for selection is not a new idea. The following is one of the earlier references for using selection matrices with weights:

Alger, J.R., and C.V. Hays, *Creative Synthesis in Design,* Prentice Hall, Englewood Cliffs, NJ, 1964.

The concept-screening method is based upon the concept selection process presented by Stuart Pugh. Pugh was known to criticize more quantitative methods, such as the concept-scoring method presented in this chapter. He cautioned that numbers can be misleading and can reduce the focus on creativity required to develop better concepts.

Pugh, Stuart, *Total Design,* Addison-Wesley, Reading, MA, 1990.

Concept scoring is similar to a method often called the Kepner-Tregoe method. It is described, along with other techniques for problem identification and solution, in their text.

Kepner, Charles H., and Benjamin B. Tregoe, *The Rational Manager,* McGraw-Hill, New York, 1965.

Urban and Hauser describe techniques for determining the relative importance of different product attributes.

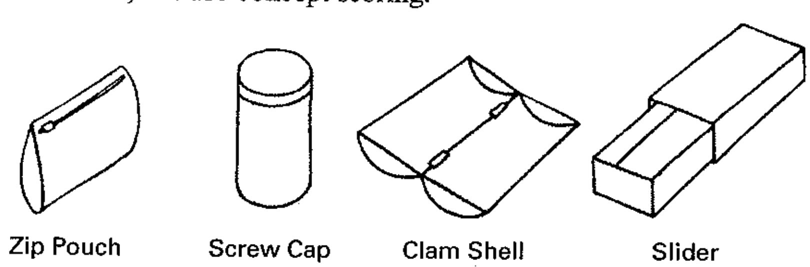
Urban, Glen L., and John R. Hauser, *Design and Marketing of New Products,* second edition, Prentice Hall, Englewood Cliffs, NJ, 1993.

Otto and Wood present a method to include certainty bounds with the ratings given to concepts in concept scoring. These can be combined to derive an estimate of the error in selecting the highest-scoring concept and to compute a confidence interval for the results.

Otto, Kevin N., and Kristin L. Wood, "Estimating Errors in Concept Selection," *ASME Design Engineering Technical Conferences,* Vol. DE-83, 1995, pp. 397–412.

Exercises

1. How can the concept selection methods be used to benchmark or evaluate existing products? Perform such an evaluation for five automobiles you might consider purchasing.
2. Propose a set of selection criteria for the choice of a battery technology for use in a portable computer.
3. Perform concept screening for the four pencil holder concepts shown below. Assume the pencil holders are for a member of a product development team who is continually moving from site to site.
4. Repeat Exercise 3, but use concept scoring.



Thought Questions

1. How might you use the concept selection method to decide whether to offer a single product to the marketplace or to offer several different product options?
2. How might you use the method to determine which product features should be standard and which should be optional or add-ons?
3. Can you imagine an interactive computer tool that would allow a large group (say, 20 or more people) to participate in the concept selection process? How might such a tool work?
4. What could cause a situation in which a development team uses the concept selection method to agree on a concept that then results in commercial failure?

Appendix A

Concept-Screening Matrix Example

This matrix was created and used by a development team designing a collar to hold weights onto a barbell.

Selection Criteria	Handcuff	Master Lock	Velcro Belt	Rubber Belt	Alligator Clip	4-Part Latch (REF)	Torsional Spring	Screw Type	Wing Nut	Clothespin	Hose Clamp	C-Clamp	Spring-Loaded Bar	Magnetic Plates	Threaded Bar
Functionality															
Lightweight	+	0	+	+	+	0	+	–	–	+	0	0	+	+	0
Fits different bars	+	0	+	+	+	0	0	0	0	+	0	+	0	–	0
Weights secured laterally	0	0	–	–	0	0	0	–	+	–	0	0	–	0	+
Convenience															
Tighten from end/side	0	0	0	0	0	0	–	–	–	0	–	0	+	+	–
Does not roll	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Change weights without removing collar	0	0	0	0	0	0	0	0	0	0	0	0	+	+	0
Convenience of placement when changing weights	0	0	+	+	0	0	–	–	–	0	–	0	+	+	–
Ergonomics															
Secure/release (one motion)	+	0	–	–	+	0	–	–	–	0	–	–	+	–	–
Low force to secure/release	0	0	0	0	–	0	–	0	0	0	0	0	+	–	0
RH/LH usage	0	0	0	0	0	0	0	–	–	0	–	–	0	0	–
Not slippery when wet	0	0	+	+	0	0	0	0	0	0	0	0	+	+	0
Use with one hand	+	0	0	0	+	0	0	0	0	0	0	0	+	+	0
Durability															
Longevity	–	–	–	–	0	0	0	+	0	0	+	+	–	–	+
Other															
Cost of raw materials	0	0	+	+	0	0	0	0	–	+	0	0	–	–	–
Manufacturability	0	–	+	+	0	0	0	+	–	+	+	0	–	–	–
Uses existing weight bars	0	0	0	0	0	0	0	0	0	0	0	0	–	0	–
Sum +'s	4	0	6	6	4	0	1	2	1	4	2	2	8	6	2
Sum 0's	11	14	7	7	11	16	11	8	8	11	10	12	3	4	7
Sum –'s	1	2	3	3	1	0	4	6	7	1	4	2	5	6	7
Net Score	3	–2	3	3	3	0	–3	–4	–6	3	–2	0	3	0	–5
Rank	1	10	1	1	1	7	12	13	15	1	10	7	1	7	15

Appendix B

Concept-Scoring Matrix Example

A development team generated this matrix while selecting a new concept for a spillproof beverage holder to be used on boats. Note that in this case the team chose not to define a single concept as the reference for all of the selection criteria.

		Concept A		Concept C		Concept F		Concept I		Concept J		Concept K		Concept O	
Selection Criteria	**Weight**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**
Flexible Use	20														
Use in different locations	15	7	105	7	105	8	120	6	90	6	90	5	75	7	105
Holds different beverages	5	5	25	5	25	3	15	4	20	5	25	3	15	3	15
Maintains Drink Condition	15														
Retains temperature of drink	13	5	65	5	65	5	65	1	13	5	65	5	65	5	65
Prevents water from getting in	2	5	10	7	14	5	10	5	10	5	10	5	10	5	10
Survives Boating Environment	5														
Doesn't break when dropped	1	6	6	6	6	9	9	7	7	5	5	9	9	6	6
Resists corrosion from sea spray	2	7	14	7	14	8	16	8	16	5	10	9	18	7	14
Floats when it falls in water	2	5	10	6	12	8	16	4	8	5	10	8	16	7	14
Keeps Drink Container Stable	20														
Prevents spilling	7	3	21	4	28	3	21	5	35	5	35	3	21	3	21
Prevents bouncing in waves	6	7	42	8	48	7	42	5	30	5	30	7	42	7	42
Will not slide during pitch/roll	7	5	35	5	35	5	35	5	35	5	35	5	35	5	35
Requires Little Maintenance	5														
Easily stored when not in use	1	7	7	6	6	8	8	9	9	4	4	8	8	7	7
Easy to maintain a clean appearance	2	6	12	6	12	3	6	4	8	5	10	5	10	6	12
Allows liquid to drain out bottom	2	5	10	5	10	5	10	5	10	5	10	5	10	5	10
Easy to Use	15														
Usable with one hand	5	7	35	7	35	7	35	6	30	5	25	7	35	7	35
Easy/comfortable to grip	5	8	40	8	40	6	30	5	25	5	25	6	30	8	40
Easy to exchange beverage containers	2	5	10	5	10	5	10	8	16	5	10	5	10	5	10
Works reliably	3	3	9	3	9	3	9	3	9	4	12	4	12	3	9
Attractive in Environment	10														
Doesn't damage boat surface	5	8	40	8	40	8	40	8	40	8	40	6	30	8	40
Attractive to look at	5	7	35	8	40	3	15	4	20	5	25	5	25	8	40
Manufacturing Ease	10														
Low-cost materials	4	5	20	4	16	7	28	8	32	4	16	8	32	6	24
Low complexity of parts	3	4	12	3	9	7	21	4	12	3	9	8	24	5	15
Low number of assembly steps	3	5	15	5	15	8	24	3	9	3	9	8	24	6	18
Total Score			578		594		585		484		510		556		587
Rank			4		1		3		7		6		5		2