# Matrix Approach to Product Planning

The product plan helps resolve issues related the markets, the types of products and the opportunities that the company will invest in and the resources required to support product development. More specifically, the product plan is used to:

- Define an overall strategy for products to guide selection of development projects;
- Define target markets, customers, competitive strengths, and a competition strategy (e.g., competing head-on or finding a market niche);
- Position planned products relative to competitive products and identify what will differentiate or distinguish these products from the competition;
- Rationalize these competing development projects and establish priorities for development projects;
- Provide a high-level schedule of various development projects; and
- Estimate development resources and balance project resource requirements with a budget in the overall business plan.

While a product plan is generally prepared on an annual basis, it should be reviewed and updated at least quarterly, if not monthly. Market conditions will change, new product opportunities will be identified, and new product technology will emerge all causing a potential impact to the product plan. These opportunities need to be evaluated and the product plan changed if needed. These changes may result in re-prioritizing development projects or making a decision to hire additional development personnel to undertake a new development opportunity.

Once a product plan is established which defines the target market and customers, the next step is to plan how to capture these customer's needs for each development project. This includes determining how to identify target customers, which customers to contact in order to capture their needs, what mechanisms to use to collect their needs, and a schedule and estimate of resources to capture the voice of the customer (project plan for product definition phase). As

opportunities are identified, appropriate techniques are used to capture the voice of the customer. The techniques used will depend on the nature of the customer relationship as illustrated below.

In the rush to achieve rapid time-to-market, short-cuts are often taken with the product definition phase. The result is a product that is off target or additional time spent with subsequent requirements definition and redesign iteration. To be successful, a comprehensive, well-defined, continuous process is needed. The starting point is a product plan which defines markets so that proper customer needs can be captured. The requirements definition process needs to be based on a marketing orientation attuned to the voice of the customer (demand "pull" rather than product "push") and regular interaction of development personnel with customers. Further, regular customer input and feedback should be obtained during development. Customer needs have to be translated into technical requirements or a specification.

Quality must be designed into the product, not inspected into it. Quality can be defined as meeting customer needs and providing superior value. This focus on satisfying the customer's needs places an emphasis on techniques such as Quality Function Deployment to help understand those needs and plan a product to provide superior value.

Quality Function Deployment (QFD) is a structured approach to defining customer needs or requirements and translating them into specific plans to produce products to meet those needs. The "voice of the customer" is the term to describe these stated and unstated customer needs or requirements. The voice of the customer is captured in a variety of ways: direct discussion or interviews, surveys, focus groups, customer specifications, observation, warranty data, field reports, etc. This understanding of the customer needs is then summarized in a product planning matrix or "house of quality". These matrices are used to translate higher level "what's" or needs into lower level "how's" - product requirements or technical characteristics to satisfy these needs.

While the Quality Function Deployment matrices are a good communication tool at each step in the process, the matrices are the means and not the end. The real value is in the process of communicating and decision-making with QFD. QFD is oriented toward involving a team of people representing the various functional departments that have involvement in product development: Marketing, Design Engineering, Quality Assurance, Manufacturing/ Manufacturing Engineering, Test Engineering, Finance, Product Support, etc.

The active involvement of these departments can lead to balanced consideration of the requirements or "what's" at each stage of this translation process and provide a mechanism to communicate hidden knowledge - knowledge that is known by one individual or department but may not otherwise be communicated through the organization. The structure of this methodology helps development personnel understand essential requirements, internal capabilities, and constraints and design the product so that everything is in place to achieve the desired outcome - a satisfied customer. Quality Function Deployment helps development personnel maintain a correct focus on true requirements and minimizes misinterpreting customer needs. As a result, QFD is an effective communications and a quality planning tool.

## Quality Function Deployment (QFD)

The process of capturing the voice of the customer is described in the papers on Product Definition and Steps for Performing QFD. It is important to remember that there is no one monolithic voice of the customer. Customer voices are diverse. In consumer markets, there are a variety of different needs. Even within one buying unit, there are multiple customer voices (e.g., children versus parents). This applies to industrial and government markets as well. There are even multiple customer voices within a single organization: the voice of the procuring organization, the voice of the user, and the voice of the supporting or maintenance organization. These diverse voices must be considered, reconciled and balanced to develop a truly successful product. One technique to accomplish this is to use multiple columns for different priority ratings associated with each customer voice in the product planning matrix.

Quality Function Deployment requires that the basic customer needs are identified. Frequently, customers will try to express their needs in terms of "how" the need can be satisfied and not in terms of "what" the need is. This limits consideration of development alternatives. Development and marketing personnel should ask "why" until they truly understand what the root need is. What is needed is to breakdown general requirements into more specific requirements by probing.

Once customer needs are gathered, they then have to be organized. The mass of interview notes,

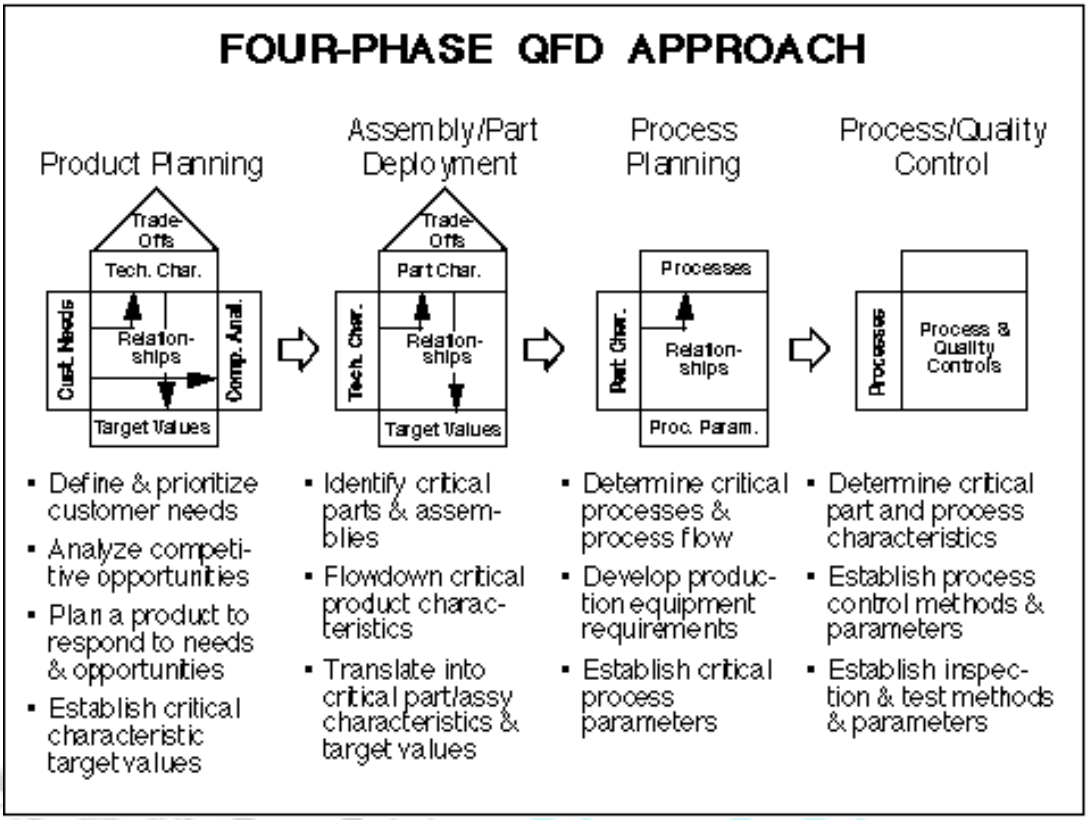
requirements documents, market research, and customer data needs to be distilled into a handful of statements that express key customer needs. Affinity diagramming is a useful tool to assist with this effort. Brief statements which capture key customer requirements are transcribed onto cards. A data dictionary which describes these statements of need is prepared to avoid any misinterpretation. These cards are organized into logical groupings or related needs. This will make it easier to identify any redundancy and serves as a basis for organizing the customer needs for the first QFD matrix.

In addition to "stated" or "spoken" customer needs, "unstated" or "unspoken" needs or opportunities should be identified. Needs that are assumed by customers and, therefore not verbalized, can be identified through preparation of a function tree. These needs normally are not included in the QFD matrix, unless it is important to maintain focus on one or more of these needs. Excitement opportunities (new capabilities or unspoken needs that will cause customer excitement) are identified through the voice of the engineer, marketing, or customer support representative. These can also be identified by observing customers use or maintain products and recognizing opportunities for improvement.



## QFD Methodology Flow

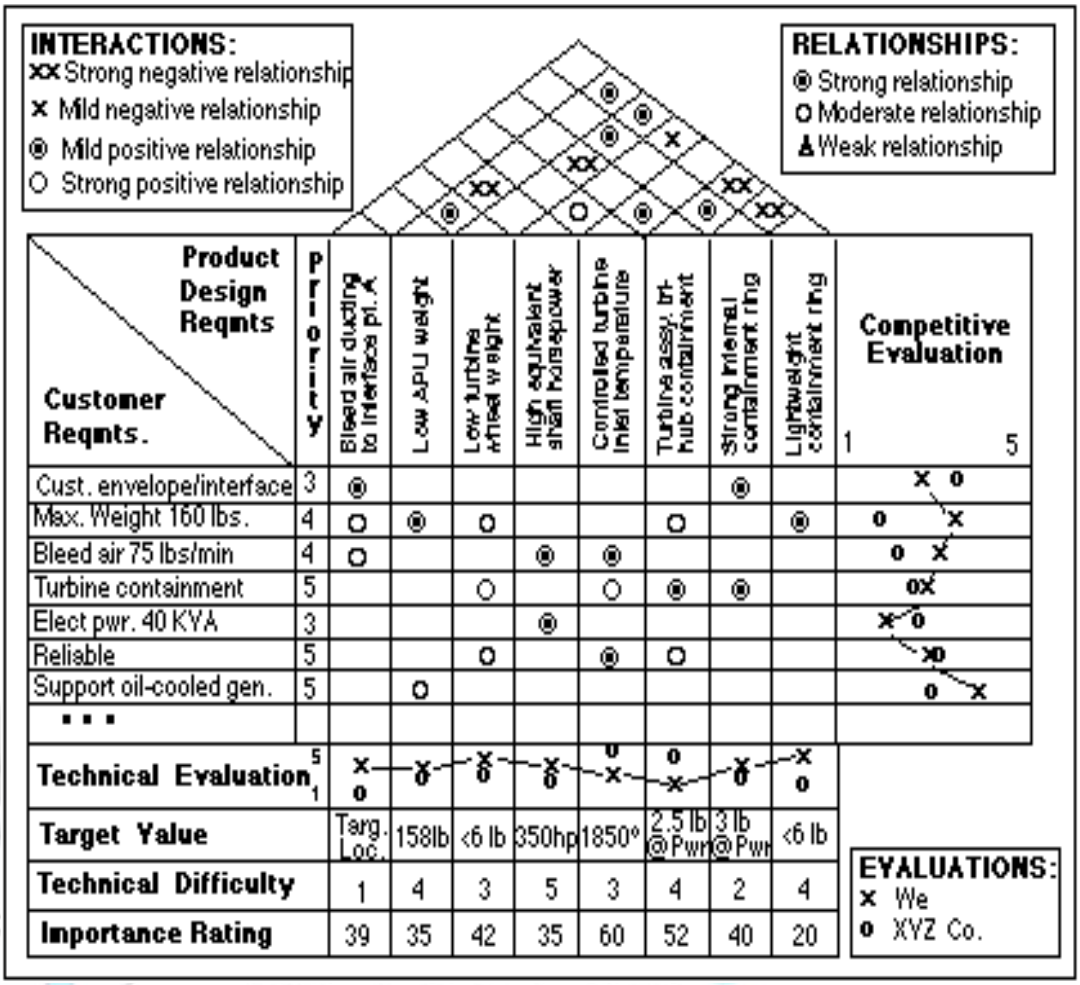
The basic Quality Function Deployment methodology involves four basic phases that occur over the course of the product development process. During each phase one or more matrices are prepared to help plan and communicate critical product and process planning and design information. This QFD methodology flow is represented below.




## Product Planning using QFD

Once customer needs are identified, preparation of the product planning matrix or "house of quality" can begin. The sequence of preparing the product planning matrix is as follows:

1. Customer needs or requirements are stated on the left side of the matrix as shown below. These are organized by category based on the affinity diagrams. Insure the customer needs or requirements reflect the desired market segment(s). Address the unspoken needs (assumed and excitement capabilities). If the number of needs or requirements exceeds twenty to thirty items, decompose the matrix into smaller modules or subsystems to reduce the number of requirements in a matrix. For each need or requirement, state the customer priorities using a 1 to 5 rating. Use ranking techniques and paired comparisons to develop priorities.




2. Evaluate prior generation products against competitive products. Use surveys, customer meetings or focus groups/clinics to obtain feedback. Include competitor's customers to get a balanced perspective. Identify price points and market segments for products under evaluation. Identify warranty, service, reliability, and customer complaint problems to identify areas of improvement. Based on this, develop a product strategy. Consider the current strengths and weaknesses relative to the competition? How do these strengths and weaknesses compare to the customer priorities? Where does the gap need to be closed and how can this be done - copying the competition or using a new approach or technology? Identify opportunities for breakthrough's to exceed competitor's capabilities, areas for improvement to equal competitors' capabilities, and areas where no improvement will be made. This strategy is important to focus development efforts where they will have the greatest payoff.

3. Establish product requirements or technical characteristics to respond to customer

requirements and organize into related categories. Characteristics should be meaningful, measurable, and global. Characteristics should be stated in a way to avoid implying a particular technical solution so as not to constrain designers.

4. Develop relationships between customer requirements and product requirements or technical characteristics. Use symbols for strong, medium and weak relationships. Be sparing with the strong relationship symbol. Have all customer needs or requirement been addressed? Are there product requirements or technical characteristics stated that don't relate to customer needs?

5. Develop a technical evaluation of prior generation products and competitive products. Get access to competitive products to perform product or technical benchmarking. Perform this evaluation based on the defined product requirements or technical characteristics. Obtain other relevant data such as warranty or service repair occurrences and costs and consider this data in the technical evaluation.

6. Develop preliminary target values for product requirements or technical characteristics.

7. Determine potential positive and negative interactions between product requirements or technical characteristics using symbols for strong or medium, positive or negative relationships. Too many positive interactions suggest potential redundancy in "the critical few" product requirements or technical characteristics. Focus on negative interactions - consider product concepts or technology to overcome these potential trade-offs or consider the trade-offs in establishing target values.

8. Calculate importance ratings. Assign a weighting factor to relationship symbols (9-3-1, 4-2-1, or 5-3-1). Multiply the customer importance rating by the weighting factor in each box of the matrix and add the resulting products in each column.

9. Develop a difficulty rating (1 to 5 point scale, five being very difficult and risky) for each product requirement or technical characteristic. Consider technology maturity, personnel technical qualifications, business risk, manufacturing capability, supplier/subcontractor capability, cost, and schedule. Avoid too many difficult/high risk items as this will likely delay development and exceed budgets. Assess whether the difficult items can be accomplished within the project budget and schedule.

10. Analyse the matrix and finalize the product development strategy and product plans. Determine required actions and areas of focus. Finalize target values. Are target values properly set to reflect appropriate trade-offs? Do target values need to be adjusted considering the difficulty rating? Are they realistic with respect to the price points, available technology, and the difficulty rating? Are they reasonable with respect to the importance ratings? Determine items for further QFD deployment. To maintain focus on "the critical few", less significant items may be ignored with the subsequent QFD matrices. Maintain the product planning matrix as customer requirements or conditions change.

One of the guidelines for successful QFD matrices is to keep the amount of information in each matrix at a manageable level. With a more complex product, if one hundred potential needs or requirements were identified, and these were translated into an equal or even greater number of product requirements or technical characteristics, there would be more than 10,000 potential relationships to plan and manage. This becomes an impossible number to comprehend and manage. It is suggested that an individual matrix not address more than twenty or thirty items on each dimension of the matrix. Therefore, a larger, more complex product should have its customers' needs decomposed into hierarchical levels.

To summarize the initial process, a product plan is developed based on initial market research or requirements definition. If necessary, feasibility studies or research and development are undertaken to determine the feasibility of the product concept. Product requirements or technical characteristics are defined through the matrix, a business justification is prepared and approved, and product design then commences.

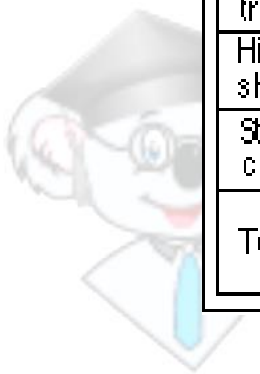
## Concept Selection and Product Design

Once product planning is complete, a more complete specification may be prepared. The product requirements or technical characteristics and the product specification serve as the basis for developing product concepts. Product benchmarking, brainstorming, and research and development are sources for new product concepts. Once concepts are developed, they are analysed and evaluated. Cost studies and trade studies are performed. The concept selection

matrix can be used to help with this evaluation process.

The concept selection matrix shown below lists the product requirements or technical characteristics down the left side of the matrix.

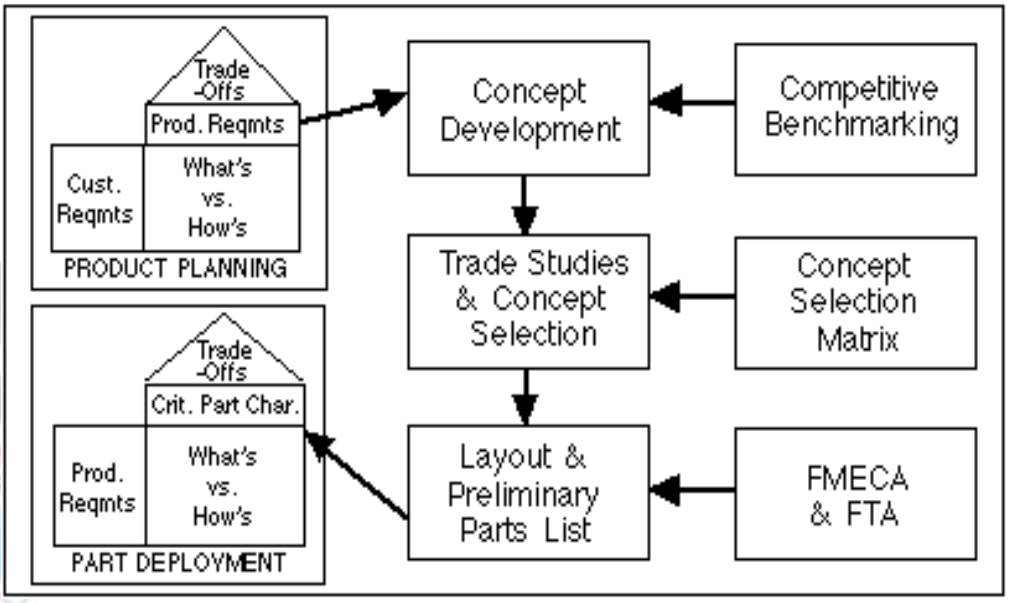
| Criteria | Importance Rating | Concept A | Concept B | Concept C |
|---|---|---|---|---|
| Low APU Weight | 4 | ◉ 20 | ○ 12 | ○ 12 |
| Low turbine wheel weight | 4 | ◉ 20 | ○ 12 | ◉ 20 |
| Controlled turbine inlet temperature | 6 | ○ 18 | ◉ 30 | △ 6 |
| Acceptable turbine assembly life | 5 | ○ 15 | ◉ 25 | ○ 15 |
| Turbine assy tri-hub containment | 5 | ◉ 25 | ◉ 25 | ○ 15 |
| High equivalent shaft horsepower | 4 | △ 4 | ◉ 20 | ◉ 20 |
| Strong internal containment ring | 4 | ○ 12 | ◉ 20 | ○ 12 |
| Total | | 114 | 144 | 100 |



These serve as evaluation criteria. The importance rating and target values (not shown) are also carried forward and normalized from the product planning matrix. Product concepts are listed across the top. The various product concepts are evaluated on how well they satisfy each criterion in the left column using the QFD symbols for strong, moderate or weak. If the product concept does not satisfy the criteria, the column is left blank. The symbol weights (5-3-1) are multiplied by the importance rating for each criterion. These weighted factors are then added for each column. The preferred concept will have the highest total. This concept selection technique is also a design synthesis technique. For each blank or weak symbol in the preferred concept's column, other concept approaches with strong or moderate symbols for that criterion are reviewed to see if a new approach can be synthesized by borrowing part of another concept approach to improve on the preferred approach.

Based on this and other evaluation steps, a product concept is selected. The product concept is represented with block diagrams or a design layout. Critical subsystems, modules or parts are identified from the layout. Criticality is determined in terms of effect on performance, reliability, and quality. Techniques such as fault tree analysis or failure modes and effects analysis (FMEA) can be used to determine criticality from a reliability or quality perspective.

The subsystem, assembly, or part deployment matrix is then prepared. The process leading up to the preparation of the deployment matrix is depicted below.




The product requirements or technical characteristics defined in the product planning matrix become the "what's" that are listed down the left side of the deployment matrix along with priorities (based on the product planning matrix importance ratings) and target values. The deployment matrix is prepared in a manner very similar to the product planning matrix. These product requirements or technical characteristics are translated into critical subsystem, assembly or part characteristics. This translation considers criticality of the subsystem, assembly or parts as well as their characteristics from a performance perspective to complement consideration of criticality from a quality and reliability perspective. Relationships are established between product requirements or technical characteristics and the critical subsystem, assembly or part characteristics. Importance ratings are calculated and target values for each critical subsystem, assembly or part characteristic are established. An example of a part/assembly deployment

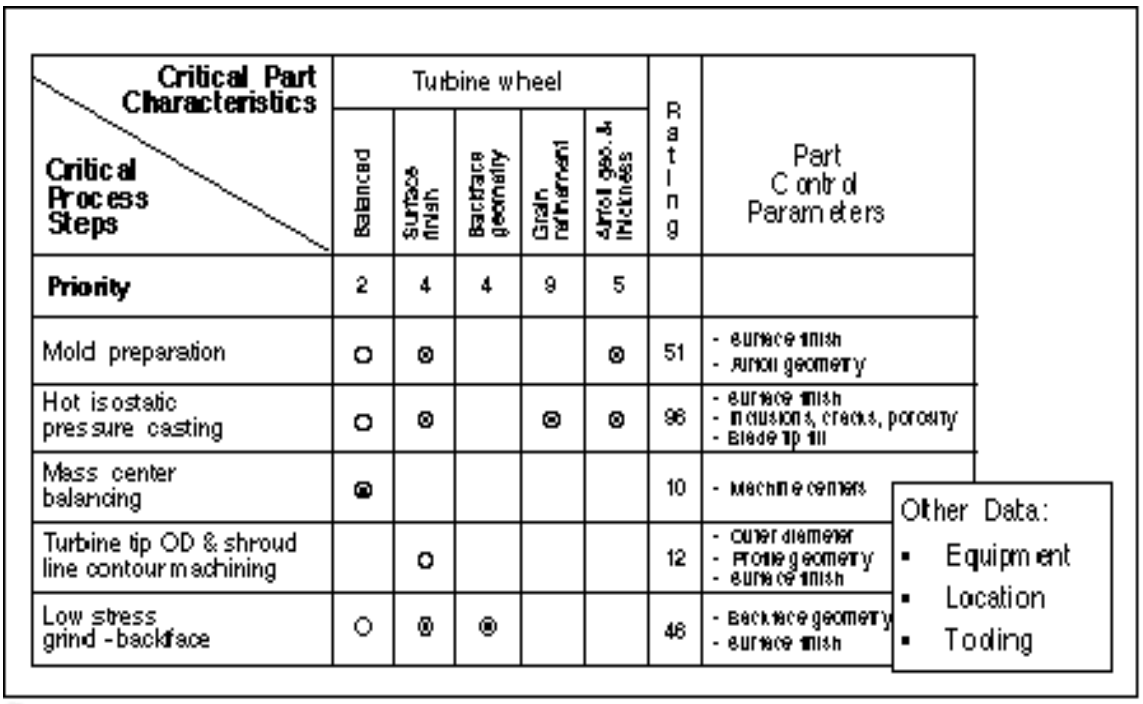
matrix is shown:

| Product Design Requirements | Priority | Critical Part Char. / Targ. Value | Turbine wheel | | | | | Combustor | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Balanced | Surface finish | Backface geometry | Grain refinement | Airfoil geo. & thickness | Material | Liner pattern factor | Nozzle throat area | ... |
| Low APU Weight | 4 | 158 lb | | | | | ◉ | ○ | | | |
| Low turbine wheel weight | 5 | <8 lb | | | ○ | ◉ | ○ | | | | |
| Controlled turbine inlet temperature | 6 | 1850° max | | | | ○ | | | ◉ | ◉ | |
| Acceptable turbine assembly life | 3 | 3,000 hrs | ⊖ | | ⊖ | ⊖ | ⊖ | ⊖ | ⊖ | | |
| Turbine assy tri-hub containment | 4 | 2.5 lb @ PW | | ◉ | ◉ | ◉ | | ○ | | ○ | |
| High equivalent shaft horsepower | 4 | 350 hp | | ◉ | | ○ | | | | ◉ | |
| Importance Rating | | | 15 | 40 | 35 | 90 | 50 | 39 | | | |

◉ Strong relationship
○ Mild relationship

## Process Design

Quality Function Deployment continues this translation and planning into the process design phase. A concept selection matrix can be used to evaluate different manufacturing process approaches and select the preferred approach. Based on this, the process planning matrix shown below is prepared.



| Critical Part Characteristics / Critical Process Steps | Turbine wheel: Balanced | Surface finish | Backface geometry | Grain refinement | Airfoil geo. & thickness | Rating | Part Control Parameters |
|---|---|---|---|---|---|---|---|
| **Priority** | 2 | 4 | 4 | 9 | 5 | | |
| Mold preparation | ○ | ◎ | | | ◎ | 51 | - surface finish<br>- Airfoil geometry |
| Hot isostatic pressure casting | ○ | ◎ | | ◎ | ◎ | 96 | - surface finish<br>- inclusions, cracks, porosity<br>- Blade tip fill |
| Mass center balancing | ◉ | | | | | 10 | - machine centers |
| Turbine tip OD & shroud line contour machining | | ○ | | | | 12 | - cutter diameter<br>- Profile geometry<br>- surface finish |
| Low stress grind - backface | ○ | ◎ | ◉ | | | 46 | - Backface geometry<br>- surface finish |

Other Data:
- Equipment
- Location
- Tooling

Again, the "how's" from the higher level matrix (in this case the critical subsystem, assembly or part characteristics) become the "what's" which are used to plan the process for fabricating and assembling the product. Important processes and tooling requirements can be identified to focus efforts to control, improve and upgrade processes and equipment. At this stage, communication between Engineering and Manufacturing is emphasized and trade-offs can be made as appropriate to achieve mutual goals based on the customer needs.

In addition to planning manufacturing processes, more detailed planning related to process control, quality control, set-up, equipment maintenance and testing can be supported by additional matrices. The following provides an example of a process/quality control matrix.

| Critical Process Steps | Process Control Parameters | Control Points | Control Method | Sample Size & Freq. | Check Method |
|---|---|---|---|---|---|
| Hot isostatic presurre casting | Mat'l temp.<br>Mold temp.<br>Remelt % | Mat'l prop.<br>Heat treat<br>FPI | Cert. | 100% | N/A |
| Mass center balancing | Balance mach. calibration<br>Speed | Detailed balance | Cert. | 100% | N/A |
| Turbine tip OD & shroud line contour machining | Set-up<br>Speeds & feeds<br>Tool wear | Dim. insp.<br>Surface finish | X bar & R chart | 4 pieces/ lot | Elect. gage<br>Check fixture<br>Visual |
| Low stress grind - backface | Speeds & feeds<br>Diamond dressed wheel | Dim. insp.<br>Surface finish | N/A | 100% | CMM<br>Visual |
| Florescent penetrant insp. & proof spin | Speed | Cracks<br>Inclusions<br>O.D. | N/A | 100% | Visual<br>Spin test |

The process steps developed in the process planning matrix are used as the basis for planning and defining specific process and quality control steps in this matrix.

The result of this planning and decision-making is that Manufacturing focuses on the critical processes, dimensions and characteristics that will have a significant effect on producing a product that meets customers' needs. There is a clear trail from customer needs to the design and manufacturing decisions to satisfy those customer needs. Disagreements over what is important at each stage of the development process should be minimized, and there will be greater focus on "the critical few" items that affect the success of the product.

## QFD Process

Quality Function Deployment begins with product planning; continues with product design and process design; and finishes with process control, quality control, testing, equipment maintenance, and training. As a result, this process requires multiple functional disciplines to adequately address this range of activities. QFD is synergistic with multi-function product development teams. It can provide a structured process for these teams to begin communicating, making decisions and planning the product. It is a useful methodology, along with product

development teams, to support a concurrent engineering or integrated product development approach.

Quality Function Deployment, by its very structure and planning approach, requires that more time be spent up-front in the development process making sure that the team determines, understands and agrees with what needs to be done before plunging into design activities. As a result, less time will be spent downstream because of differences of opinion over design issues or redesign because the product was not on target. It leads to consensus decisions, greater commitment to the development effort, better coordination, and reduced time over the course of the development effort.

QFD requires discipline. It is not necessarily easy to get started with. The following is a list of recommendations to facilitate initially using QFD.

Obtain management commitment to use QFD.

Establish clear objectives and scope of QFD use. Avoid first using it on a large, complex project if possible. Will it be used for the overall product or applied to a subsystem, module, assembly or critical part? Will the complete QFD methodology be used or will only the product planning matrix be completed?

Establish multi-functional team. Get an adequate time commitment from team members.

Obtain QFD training with practical hands-on exercises to learn the methodology and use a facilitator to guide the initial efforts.

Schedule regular meetings to maintain focus and avoid the crush of the development schedule overshadowing effective planning and decision-making.

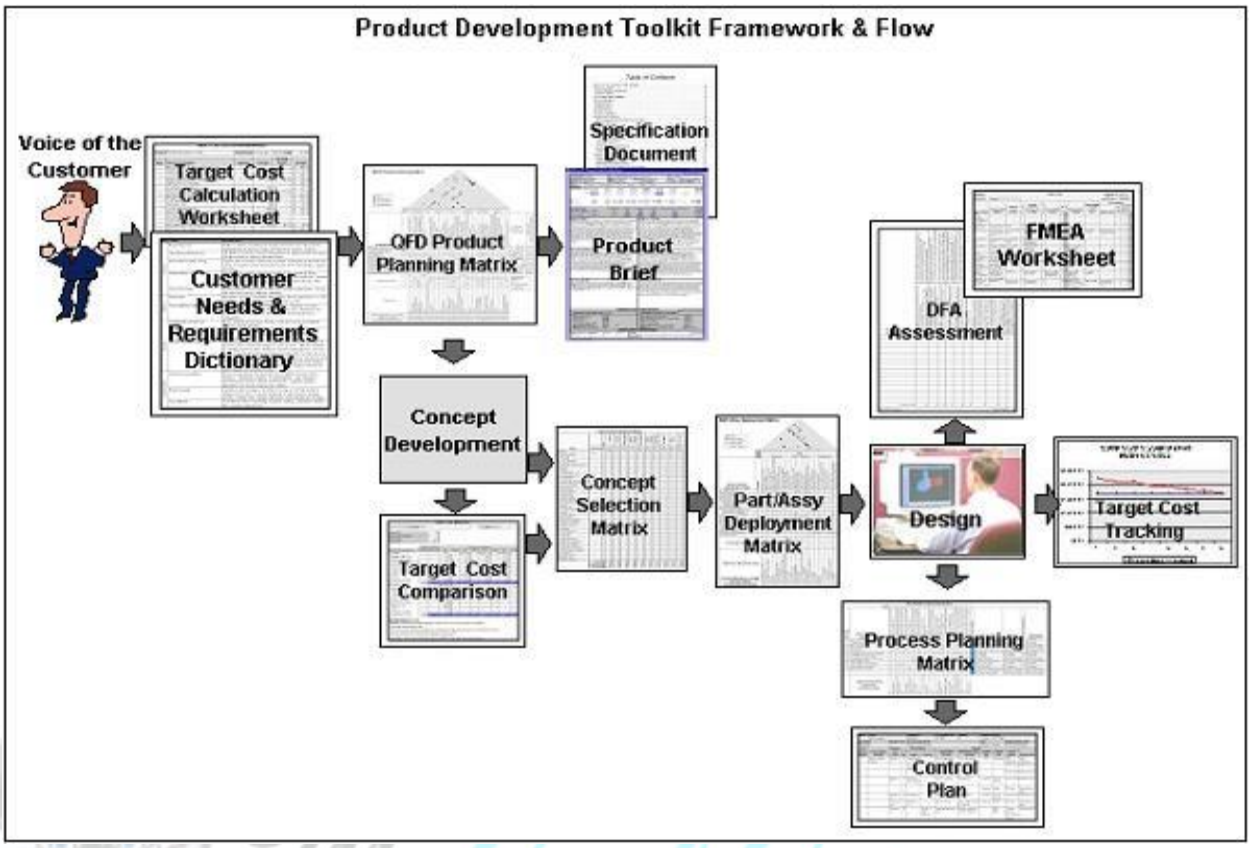
Avoid gathering perfect data. Many times significant customer insights and data exist within the organization, but they are in the form of hidden knowledge - not communicated to people with the need for this information. On the other hand, it may be necessary to spend additional time gathering the voice of the customer before beginning QFD. Avoid technical arrogance and the belief that company personnel know more than the customer.

Quality Function Deployment is an extremely useful methodology to facilitate communication, planning, and decision-making within a product development team. It is not a paperwork exercise or additional documentation that must be completed in order to proceed to the next development milestone. It not only brings the new product closer to the intended target, but reduces development cycle time and cost in the process.

QFD uses a series of matrices to document information collected and developed and represent the team's plan for a product. The QFD methodology is based on a systems engineering approach consisting of the following general steps:

1. Derive top-level product requirements or technical characteristics from customer needs (Product Planning Matrix).
2. Develop product concepts to satisfy these requirements.
3. Evaluate product concepts to select most optimum (Concept Selection Matrix).
4. Partition system concept or architecture into subsystems or assemblies and flow-down higher- level requirements or technical characteristics to these subsystems or assemblies.
5. Derive lower-level product requirements (assembly or part characteristics) and specifications from subsystem/assembly requirements (Assembly/Part Deployment Matrix).
6. For critical assemblies or parts, flow-down lower-level product requirements (assembly or part characteristics) to process planning.
7. Determine manufacturing process steps to meet these assembly or part characteristics.
8. Based in these process steps, determine set-up requirements, process controls and quality controls to assure achievement of these critical assembly or part characteristics.

The QFD process described below is supported by our Product Development Toolkit, which includes QFD software. The matrices and the specific steps in the QFD process are as follows.






## Gather Customer Needs

1. Plan collection of customer needs. What sources of information will be used? Consider customer requirement documents, requests for proposals, requests for quotations, contracts, customer specification documents, customer meetings/interviews, focus groups/clinics, user groups, surveys, observation, suggestions, and feedback from the field. Consider both current customers as well as potential customers. Pay particular attention to lead customers as they are a better indicator of future needs. Plan who will perform the data collection activities and when these activities can take place. Schedule activities such as meetings, focus groups, surveys, etc. Prepare for collection of customer needs. Identify required information. Prepare agendas, list of questions, survey forms, focus group/user meeting presentations.

2. Determine customer needs or requirements using the mechanisms described in step 1. Document these needs. Consider recording any meetings. During customer meetings or focus

groups, ask "why" to understand needs and determine root needs. Consider spoken needs and unspoken needs. Extract statements of needs from documents. Summarize surveys and other data. Use techniques such as ranking, rating, paired comparisons, or conjoint analysis to determine importance of customer needs. Gather customer needs from other sources such as customer requirement documents, requests for proposals, requests for quotations, contracts, customer specification documents, customer meetings/interviews, focus groups, product clinics, surveys, observation, suggestions, and feedback from the field.

3. Use affinity diagrams to organize customer needs. Consolidate similar needs and restate. Organize needs into categories. Breakdown general customer needs into more specific needs by probing what is needed. Maintain dictionary of original meanings to avoid misinterpretation. Use function analysis to identify key unspoken, but expected needs.

4. Once needs are summarized, consider whether to get further customer feedback on priorities. Undertake meetings, surveys, focus groups, etc. to get customer priorities. State customer priorities using a 1 to 5 rating. Use ranking techniques and paired comparisons to develop priorities.



## Product Planning

1. Organize customer needs in the Product Planning Matrix. Group under logical categories as determined with affinity diagramming.

2. Establish critical internal customer needs or management control requirements; industry, national or international standards; and regulatory requirements. If standards or regulatory requirements are commonly understood, they should not be included in order to minimize the information that needs to be addressed.

3. State customer priorities. Use a 1 to 5 rating. Critical internal customer needs or management control requirements; industry, national or international standards; and regulatory requirements, if important enough to include, are normally given a rating of "3".

4. Develop competitive evaluation of current company products and competitive products. Use surveys, customer meetings or focus groups/clinics to obtain feedback. Rate the company's and the competitor's products on a 1 to 5 scale with "5" indicating that the product fully satisfies the customer's needs. Include competitor's customer input to get a balanced perspective.

5. Review the competitive evaluation strengths and weaknesses relative to the customer priorities. Determine the improvement goals and the general strategy for responding to each customer need. The Improvement Factor is "1" if there are no planned improvements to the competitive evaluation level. Add a factor of .1 for every planned step of improvement in the competitive rating, (e.g., a planned improvement from a rating of "2" to "4" would result in an improvement factor of "1.2". Identify warranty, service, or reliability problems & customer complaints to help identify areas of improvement.

6. Identify the sales points that Marketing will emphasize in its message about the product. There should be no more than three major or primary sales points or two major sales points and two minor or secondary sales points in order to keep the Marketing message focused. Major sales points are assigned a weighting factor of 1.3 and minor sales points are assigned a weighting factor of 1.1.



7. The process of setting improvement goals and sales points implicitly develops a product strategy. Formally describe that strategy in a narrative form. What is to be emphasized with the new product? What are its competitive strengths? What will distinguish it in the marketplace? How will it be positioned relative to other products? In other words, describe the value proposition behind this product. The key is to focus development resources on those areas that will provide the greatest value to the customer. This strategy brief is typically one page and is used to gain initial focus within the team as well as communicate and gain concurrence from management.

8. Establish product requirements or technical characteristics to respond to customer needs and organize into logical categories. Categories may be related to functional aspects of the products or may be grouped by the likely subsystems to primarily address that characteristic. Characteristics should be meaningful (actionable by Engineering), measurable, practical (can be determined without extensive data collection or testing) and global. By being global,

characteristics should be stated in a way to avoid implying a particular technical solution so as not to constrain designers. This will allow a wide range of alternatives to be considered in an effort to better meet customer needs. Identify the direction of the objective for each characteristic (target value or range, maximize or minimize).

9. Develop relationships between customer needs and product requirements or technical characteristics. These relationships define the degree to which as product requirement or technical characteristic satisfies the customer need. It does NOT show a potential negative impact on meeting a customer need - this will be addressed later in the interaction matrix. Consider the goal associated with the characteristic in determining whether the characteristic satisfies the customer need. Use weights (we recommend using 5-3-1 weighting factors) to indicate the strength of the relationship - strong, medium and weak. Be sparing with the strong relationships to discriminate the really strong relationships.

10. Perform a technical evaluation of current products and competitive products. Sources of information include: competitor websites, industry publications, customer interviews, published specifications, catalogues and brochures, trade shows, purchasing and benchmarking competitor's products, patent information, articles and technical papers, published benchmarks, third-party service & support organizations, and former employees. Perform this evaluation based on the defined product requirements or technical characteristics. Obtain other relevant data such as warranty or service repair occurrences and costs.

11. Develop preliminary target values for product requirements or technical characteristics. Consider data gathered during the technical evaluation in setting target values. Do not get too aggressive with target values in areas, which are not determined to be the primary area of focus with this development effort.

12. Determine potential positive and negative interactions between product requirements or technical characteristics using symbols for strong or medium, positive or negative relationships. Too many positive interactions suggest potential redundancy in product requirements or technical characteristics. Focus on negative interactions - consider product concepts or technology to overcome the potential trade-offs or consider the trade-offs in establishing target values.

13. Calculate importance ratings. Multiply the customer priority rating by the improvement factor, the sales point factor and the weighting factor associated with the relationship in each box of the matrix and add the resulting products in each column.

14. Identify a difficulty rating (1 to 5 point scale, five being very difficult and risky) for each product requirement or technical characteristic. Consider technology maturity, personnel technical qualifications, resource availability, technical risk, manufacturing capability, supply chain capability, and schedule. Develop a composite rating or breakdown into individual assessments by category.

15. Analyse the matrix and finalize the product plan. Determine required actions and areas of focus.

16. Finalize target values. Consider the product strategy objectives, importance of the various technical characteristics, the trade-offs that need to be made based on the interaction matrix, the technical difficulty ratings, and technology solutions and maturity.

17. Maintain the matrix as customer needs or conditions change.



## Concept Development

1. Develop concept alternatives for the product. Consider not only the current approach and technology, but other alternative concept approaches and technology. Use brainstorming. Conduct literature, technology, and patent searches. Use product benchmarking to identify different product concepts. Develop derivative ideas. Perform sufficient definition and development of each concept to evaluate against the decision criteria determined in the next step.

2. Evaluate the concept alternatives using the Concept Selection Matrix. List product requirements or technical characteristics from the Product Planning Matrix down the left side of the Concept Selection Matrix. Also add other requirements or decision criteria such as key unstated but expected customer needs or requirements, manufacturability requirements, environmental requirements, standards and regulatory requirements, maintainability /

serviceability requirements, support requirements, testability requirements, test schedule and resources, technical risk, business risk, supply chain capability, development resources, development budget, and development schedule

3. Carry forward the target values for the product requirements or technical characteristics from the Product Planning Matrix. Add target values as appropriate for the other evaluation criteria added in the previous step. Also bring forward the importance ratings and difficulty ratings associated with each product requirement or technical characteristic from the Product Planning Matrix. Normalize the importance rating by dividing the largest value by a factor that will yield "5" and post this value to the "Priority" column. Review these priorities and consider any changes appropriate since these are the weighting factors for the decision criteria. Determine the priorities for the additional evaluation criteria added in the prior step. List concepts across the top of the matrix.

4. Perform engineering analysis and trade studies. Rate each concept alternative against the criteria using a "1" to "5" scale with "5" being the highest rating for satisfying the criteria.

5. For each rating, multiply the rating by the "Priority" value in that row. Summarize these values in each column in the bottom row. The preferred concept alternative(s) will be the one(s) with the highest total.

6. For the preferred concept alternative(s), work to improve the concept by synthesizing a new concept that overcomes its weaknesses. Focus attention on the criteria with the lowest ratings for that concept ("1's" and "2's"). What changes can be made to the design or formulation of the preferred concept(s) to improve these low ratings with the product concept? Compare the preferred concept(s) to the other concepts that have higher ratings for that particular requirement. Are there ways to modify the preferred concept to incorporate the advantage of another concept?

## Subsystem/Subassembly/Part Deployment Matrix

1. Using the selected concept as a basis, develop a design layout, block diagram and/or a preliminary parts list. Determine critical subsystems, subassemblies or parts. Consider impact of

subsystems, subassemblies or parts on product performance or with respect to development goals. What parts, assemblies or subsystems present major challenges or are critical to the success and operation of the product? What critical characteristics have a major effect on performance? Consider performing failure mode and effects analysis (FMEA); failure mode, effects and criticality analysis (FMECA); or fault tree analysis (FTA) to help pinpoint critical items and their critical characteristics from a reliability/quality perspective.

2. If there will be multiple Subsystem/Subassembly/Part Deployment Matrices prepared, deploy the technical characteristics and their target values to the appropriate matrices. Carry forward the important or critical product requirements or technical characteristics from Product Planning Matrix (based on importance ratings and team decision) to the Subsystem/Subassembly/Part Deployment Matrix. These "product needs" become the "what's" for this next level matrix. Where appropriate, allocate target values (e.g., target manufacturing cost, mean-time between failures, etc.) to the Subsystem / Subassembly / Part Deployment Matrices. Organize these product requirements or technical characteristics by assembly(ies) or part(s) to be addressed on a particular deployment matrix. Include any additional customer needs or requirements to address more detailed customer needs or general requirements. Normalize the Importance Ratings from the Product Planning Matrix and bring them forward as the Priority ratings. Review these priority ratings and make appropriate changes for the subsystems, subassemblies or parts being addressed. Determine the Priority for any needs that were added.

3. Considering product requirements or technical characteristics, identify the critical part, subassembly or subsystem characteristics. State the characteristics in a measurable way. For higher-level subsystems or sub-assemblies, state the characteristics in a global manner to avoid constraining concept selection at this next level.

4. Develop relationships between product needs (product-level technical characteristics) and the subsystem /subassembly/part technical characteristics. Use 5-3-1 relationship weights for strong, medium and weak relationships. Be sparing with the strong relationships.

5. Develop preliminary target values for subsystem / subassembly / part characteristics.

6. Determine potential positive and negative interactions between the technical part

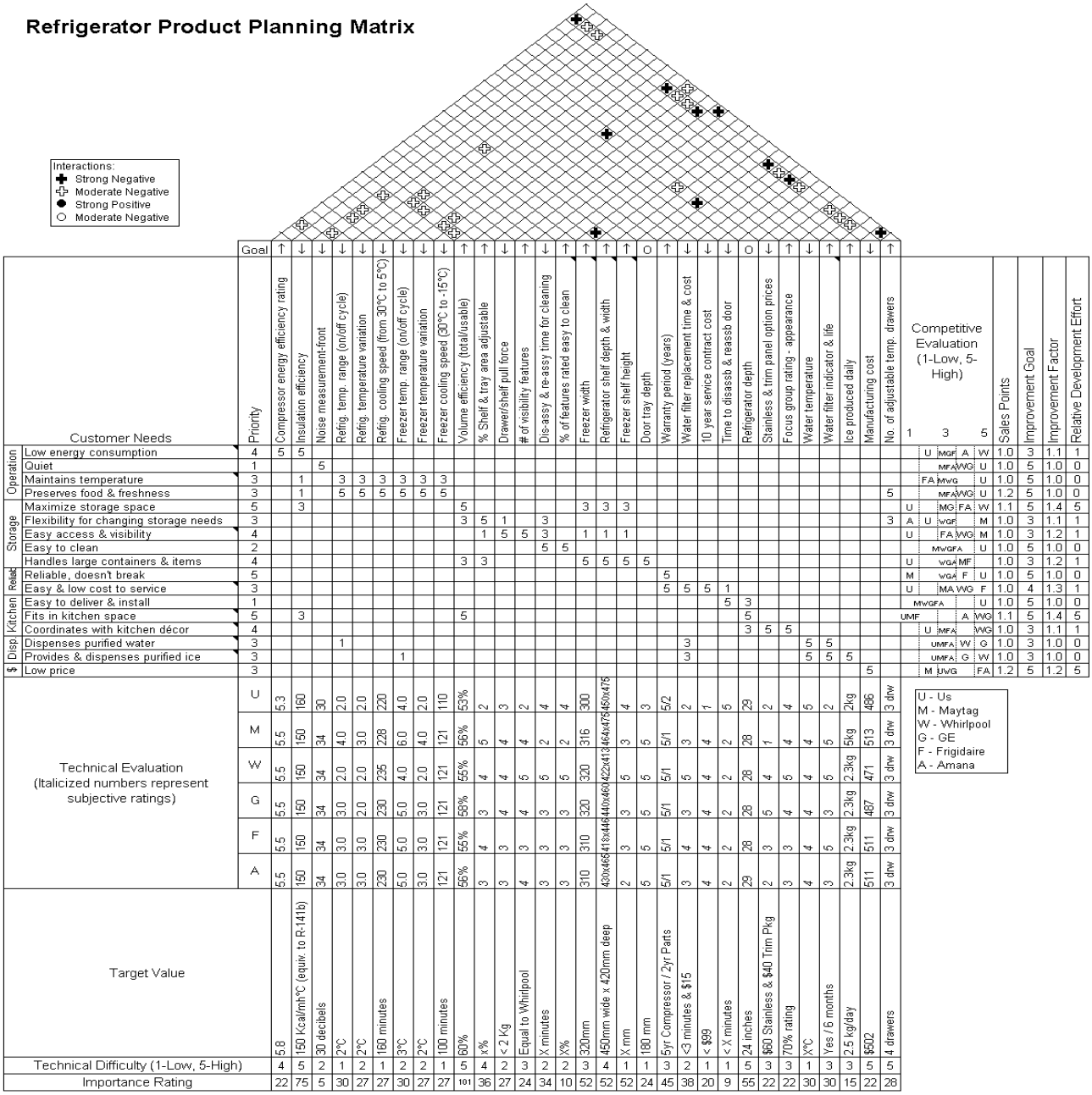
characteristics using symbols for strong or medium, positive or negative relationships. Too many positive interactions suggest potential redundancy in critical part characteristics. Focus on negative interactions - consider different subsystem / subassembly / part concepts, different technologies, tooling concepts, material technology, and process technology to overcome the potential trade-off or consider the trade-off in establishing target values.

7. Calculate importance ratings. Assign a weighting factor to the relationships (5-3-1). Multiply the customer importance rating by the improvement factor (if any), the sales point factor (if any) and the relationship factor in each cell of the relationship matrix and add the resulting products in each column.

8. Identify a difficulty rating (1 to 5 point scale, five being very difficult and risky) for each subsystem / subassembly / part requirement or technical characteristic. Consider technology maturity, personnel technical qualifications, business risk, manufacturing capability, supplier capability, and schedule. Develop a composite rating or breakdown into individual assessments by category. Determine if overall risk is acceptable and if individual risks based on target or specification values are acceptable. Adjust target or specification values accordingly.

9. Analyse the matrix and finalize the subsystem/subassembly/part deployment matrix. Determine the required actions and areas of focus. Finalize target values. Consider interactions, importance ratings and difficulty ratings.

# Sample Format of Matrix-based Product Planning for **Refrigerator**




| | Customer Needs | Priority | Goal | Compressor energy efficiency rating | Insulation efficiency | Noise measurement-front | Refrig. temp. range (on/off cycle) | Refrig. temperature variation | Refrig. cooling speed (from 30°C to 5°C) | Freezer temp. range (on/off cycle) | Freezer temperature variation | Freezer cooling speed (30°C to -15°C) | Volume efficiency (total/usable) | % Shelf & tray area adjustable | Drawer/shelf pull force | # of visibility features | Dis-assy & re-assy time for cleaning | % of features rated easy to clean | Freezer width | Refrigerator shelf depth & width | Freezer shelf height | Door tray depth | Warranty period (years) | Water filter replacement time & cost | 10 year service contract cost | Time to disassb & reassb door | Refrigerator depth | Stainless & trim panel option prices | Focus group rating - appearance | Water temperature | Water filter indicator & life | Ice produced daily | Manufacturing cost | No. of adjustable temp. drawers | Competitive Evaluation (1-Low, 5-High) 1 3 5 | Sales Points | Improvement Goal | Improvement Factor | Relative Development Effort |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Operation | Low energy consumption | 4 | | 5 | | 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | U MGF A W | 1.0 | 3 | 1.1 | 1 |
| | Quiet | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | MFA VWG U | 1.0 | 5 | 1.0 | 0 |
| | Maintains temperature | 3 | | | 1 | | 3 | 3 | 3 | 3 | 3 | 3 | | | | | | | | | | | | | | | | | | | | | | FA MWG U | 1.0 | 5 | 1.0 | 0 |
| | Preserves food & freshness | 3 | | | 1 | | 5 | 5 | 5 | 5 | 5 | 5 | | | | | | | | | | | | | | | | | | | | | 5 | MFA VWG U | 1.2 | 5 | 1.0 | 0 |
| Storage | Maximize storage space | 5 | | | 3 | | | | | | | | 5 | | | | | | 3 | 3 | 3 | | | | | | | | | | | | | U MG FA W | 1.1 | 5 | 1.4 | 5 |
| | Flexibility for changing storage needs | 3 | | | | | | | | | | | 3 | 5 | 1 | | 3 | | | | | | | | | | | | | | | | 3 | A U VGF M | 1.0 | 3 | 1.1 | 1 |
| | Easy access & visibility | 4 | | | | | | | | | | | | 1 | 5 | 5 | 3 | | 1 | 1 | 1 | | | | | | | | | | | | | U FA VWG M | 1.0 | 3 | 1.2 | 1 |
| | Easy to clean | 2 | | | | | | | | | | | | | | | 5 | 5 | | | | | | | | | | | | | | | | MVGFA U | 1.0 | 5 | 1.0 | 0 |
| | Handles large containers & items | 4 | | | | | | | | | | | 3 | 3 | | | | | 5 | 5 | 5 | 5 | | | | | | | | | | | | U VGA MF | 1.0 | 3 | 1.2 | 1 |
| Reliab | Reliable, doesn't break | 5 | | | | | | | | | | | | | | | | | | | | | 5 | | | | | | | | | | | M VGA F U | 1.0 | 5 | 1.0 | 0 |
| | Easy & low cost to service | 3 | | | | | | | | | | | | | | | | | | | | | 5 | 5 | 5 | 1 | | | | | | | | U MA VWG F | 1.0 | 4 | 1.3 | 1 |
| Kitchen | Easy to deliver & install | 1 | | | | | | | | | | | | | | | | | | | | | | | | 5 | 3 | | | | | | | MVGFA U | 1.0 | 5 | 1.0 | 0 |
| | Fits in kitchen space | 5 | | | 3 | | | | | | | | 5 | | | | | | | | | | | | | | 5 | | | | | | | UMF A VWG | 1.1 | 5 | 1.4 | 5 |
| | Coordinates with kitchen décor | 4 | | | | | | | | | | | | | | | | | | | | | | | | | 3 | 5 | 5 | | | | | U MFA VWG | 1.0 | 3 | 1.1 | 1 |
| Disp | Dispenses purified water | 3 | | | | | 1 | | | | | | | | | | | | | | | | 3 | | | | | | | 5 | 5 | | | UMFA VW G | 1.0 | 3 | 1.0 | 0 |
| | Provides & dispenses purified ice | 3 | | | | | | | | 1 | | | | | | | | | | | | | 3 | | | | | | | 5 | 5 | 5 | | UMFA G W | 1.0 | 3 | 1.0 | 0 |
| $ | Low price | 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 | | M UWG FA | 1.2 | 5 | 1.2 | 5 |
| Technical Evaluation (Italicized numbers represent subjective ratings) | | | U | 5.3 | 160 | 30 | 2.0 | 2.0 | 220 | 4.0 | 2.0 | 110 | 53% | 2 | 3 | | 4 | 2 | 300 | 450x475 | 4 | 3 | 5/2 | 2 | 1 | 6 | 29 | 2 | 4 | 5 | 2 | 2kg | 496 | 3 dnv | | | | |
| | | | M | 5.5 | 150 | 34 | 3.0 | 3.0 | 228 | 6.0 | 4.0 | 121 | 56% | 5 | 4 | 4 | 2 | 2 | 316 | 422x413x464x474 | 3 | 3 | 5/1 | 3 | 4 | 2 | 28 | 1 | 4 | 4 | 5 | 5kg | 513 | 3 dnv | | | | |
| | | | W | 5.5 | 150 | 34 | 2.0 | 2.0 | 235 | 4.0 | 2.0 | 121 | 55% | 4 | 4 | 4 | 5 | 2 | 320 | 440x460 | 5 | 5 | 5/1 | 5 | 4 | 2 | 28 | 1 | 4 | 4 | 4 | 2.3kg | 471 | 3 dnv | | | | |
| | | | G | 5.5 | 150 | 34 | 3.0 | 2.0 | 230 | 5.0 | 3.0 | 121 | 58% | 3 | 4 | 4 | 3 | 3 | 320 | 440x460 | 5 | 5 | 5/1 | 3 | 4 | 2 | 28 | 1 | 5 | 4 | 4 | 2.3kg | 487 | 3 dnv | | | | |
| | | | F | 5.5 | 150 | 34 | 3.0 | 3.0 | 230 | 5.0 | 3.0 | 121 | 55% | 4 | 3 | 4 | 3 | 3 | 310 | 418x446 | 3 | 3 | 5/1 | 3 | 4 | 2 | 28 | 1 | 3 | 4 | 4 | 2.3kg | 511 | 3 dnv | | | | |
| | | | A | 5.5 | 150 | 34 | 3.0 | 3.0 | 230 | 5.0 | 3.0 | 121 | 56% | 3 | 3 | 4 | 2 | 3 | 310 | 430x465 | 2 | 5 | 5/1 | 3 | 4 | 2 | 29 | 2 | 3 | 4 | 4 | 2.3kg | 511 | 3 dnv | | | | |
| Target Value | | | | 5.8 | 150 Kcal/m²°C (equiv. to R-141b) | 30 decibels | 2°C | 2°C | 180 minutes | 3°C | 2°C | 100 minutes | 60% | x% | < 2 Kg | Equal to Whirlpool | X minutes | X% | 320mm | 450mm wide x 420mm deep | X mm | 180 mm | 5yr Compressor / 2yr Parts | <3 minutes & $15 | < $39 | < X minutes | 24 inches | $60 Stainless & $40 Trim Pkg | 70% rating | X°C | Yes / 6 months | 2.5 kg/day | $502 | 4 drawers | | | | |
| Technical Difficulty (1-Low, 5-High) | | | | 4 | 5 | 2 | 1 | 2 | 1 | 2 | 2 | 1 | 5 | 4 | 2 | 3 | 2 | 2 | 3 | 4 | 1 | 1 | 3 | 2 | 1 | 1 | 5 | 3 | 3 | 1 | 3 | 3 | 5 | 5 | | | | |
| Importance Rating | | | | 22 | 75 | 5 | 30 | 27 | 27 | 30 | 27 | 27 | 101 | 36 | 27 | 24 | 34 | 10 | 52 | 52 | 52 | 24 | 45 | 38 | 20 | 9 | 55 | 22 | 22 | 30 | 30 | 15 | 22 | 28 | | | | |

U - Us
M - Maytag
W - Whirlpool
G - GE
F - Frigidaire
A - Amana

## Product Evaluation Matrix in a Nutshell

Sometimes there are just too many choices but one has to make one anyway. The evaluation matrix is a great decision making tool for evaluating and prioritizing among from 2 to 20 choices. The evaluation matrix allows you to quickly sort through options by identifying their relative strengths and weaknesses. You can make choices based on that information and can even choose to modify the options to make them more acceptable. This simple method organizes a lot of information into a powerfully compact presentation. Knowledge is power and organizing it so people can have it is enabling.

The following is a simple evaluation matrix with six (6) options/choices listed down the far left column and four (4) criteria listed across the top row. The options are those that we want to make choices from or rank in order of priority. The options should be different enough from one another that a choice matters.

Criteria are selected from those that are most important to us in making the choice. The criteria are different from each other. They must also be parallel to one another in terms of how you would rank them - a high or low numerical ranking should mean the same for each one, good or bad. A good way to start is to develop or ***Brainstorm*** a list of criteria and then select the ones that make the most sense for this choice.

| **OPTIONS** | **CRITERIA** | | | |
|---|---|---|---|---|
| | Criterion A | Criterion B | Criterion C | Criterion D |
| Option 1 | | | | |
| Option 2 | | | | |
| Option 3 | | | | |
| Option 4 | | | | |
| Option 5 | | | | |
| Option 6 | | | | |

To use the evaluation matrix, decide on a ranking scale such on 1 to 5, whereas 1 has the lowest

desirability, 3 middle level, and 5 is the highest desirability. Ask yourself "Will it...?" or "Does it...?" and score the option against the criterion. Work down each column to rank each option for the same criterion. Then go to the next column/criterion. This will reduce the possibility that you will favour one option over the others once you see how you rank it. From the diagram given below, one may understand of how this matrix has been started.

The example criteria chosen here relate to how quickly the option could be accomplished and how big an impact it would have when done. A higher score is better (shorter time to install, lower cost to accomplish, bigger benefit, more management support)

| OPTIONS | CRITERIA | | | |
|---|---|---|---|---|
| | Short Time to Install | Low Cost to Accomplish | Bigger Benefit | Management Support |
| Option 1 | 1 | 1 | 5 | 3 |
| Option 2 | 5 | 5 | 5 | 3 |
| Option 3 | 3 | 3 | 1 | 1 |
| Option 4 | 1 | 3 | 5 | 1 |
| Option 5 | 5 | 5 | 5 | 1 |
| Option 6 | 5 | 1 | 5 | 5 |

In the above case, for the first criterion, Options 1 and 4 are ranked low, Option 3 is ranked at the middle, and Options 2, 5, and 6 are ranked highly.

Once the ranking is done, you may begin the analysis. One approach is to total the scores for each option. In this case, we see the following:

Total Scores of Option 1: 10

Total Scores of Option 2: 18

Total Scores of Option 3: 8

Total Scores of Option 4: 10

Total Scores of Option 5: 16

Total Scores of Option 6: 16

The caution is that the totals alone (nor the process itself) will give you the one right answer! This process allows you to narrow your choices and evaluate your options in an orderly manner. We can see that Options 1, 3, and 4 seem to fall away from the top of the list because of their low scores. And the remaining three are close together. Now, you have to decide what is more important and why. Option 6 has the highest management support but will cost the most to accomplish. Option 2 has the highest scores overall but is not as high in management support. You might now, for example, show your analysis to management and see if you can create more support for Option 2. Or as you can see, you can take other approaches to "fix" the other choices and thus raise their desirability (scores).

***Group approach***: You can have the members of a group do their own rankings and then commingle the results onto one summary report. Some choices may be obvious but where they are not, you have room for discussion. Ask the individuals who ranked a particular choice the highest and lowest to explain their positions. This discussion will help you reach understanding and consensus. Yes, consensus does sometimes take longer but you will have reduced the number of options to debate if, for example, you work with only the top choices overall. If someone feels strongly about an option that is not selected, they can let you know why. Their reasons may be helpful in making further choices and rankings.

**Examples of using the evaluation matrix**

Example 1: A company needed to reduce their costs quickly to address profitability and cash flow problems. A cross-functional team brainstormed options and created a list of 15 candidates.

The list looked good but they knew they didn't have enough time, money, or people to do all of them. They decided on the most important criteria, created an evaluation matrix, and 5 people completed it. The results from the 5 people were totalled and the group met to review the results. The best options became clear from the matrix and the discussions. Two options cost so much because of capital equipment requirements that they couldn't be taken on right away so they were set aside. Five options gave relatively small benefits but were so quick and easy to implement that they were started right away (small amounts can add up quickly). Another four options required a lot or work but had good payoffs so plans were created and they were started quickly. Four ideas were discarded because they had problems. The net result was that the team and the company focused their efforts in the right areas and saved over $100,000 within three months. And savings continued to flow from there.

Example 2: A major capital investment was required to increase capacity. Five options were identified but the choice wasn't clear. An evaluation matrix was constructed using criteria such as: total cost, time to construct, return on investment, capacity, quality, compatibility with existing equipment, and risk. The engineers and management who were involved in the project each rated the options. The evaluation and resulting discussion led to a choice of the second most costly option because its other benefits far outweighed the slight premium in capital cost. Sometimes the choices are not as obvious as they seem.