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Product Development Decision Support System Customer-Based

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ABSTRACT

Quality Function Deployment (QFD) has been traditionally used as a planning tool primarily for product development and quality improvement. In this context, many people have used QFD for making decisions on how to prioritize critical product areas from a customer perspective. However, it is the position of the author that the QFD process can be viewed as a decision support system that would encompass multiple facets of information to enhance the quality and output of the decision making process in the course of product development. In this paper, the author submits the QFD process in combination with other engineering decision making tools such as the Pugh concept selection and the Kepner-Tregoe analysis technique as a decision making and modeling process that is as old as management science itself. Specifically, the attempt is made to illustrate how QFD provides an iterative sequence of steps involved in decision making, from the initial problem identification to a proposal for the actual implementation plan. To make this position more applicable to the reader, the subject has been approached from an actual business environment.

Keywords: Quality function deployment (QFD), Voice of the Customer (VOC), Decision making process, Customer-driven decision making process, Kepner-Tregoe analysis, Pugh concept selection, models

1. INTRODUCTION

Decision-making is a process of choosing among alternative courses of action or choices for the purpose of attaining a goal or goals. Ronald Howard (1980) says, *decision making is what you do when you don't know what to do*. Particularly in a managerial product development decision making context, the decisions one is faced with are becoming increasingly complex, where intuitive and unaided decision processes are incapable of adequately addressing the complexity of the situation. Furthermore, in this era of fierce competition in order to be successful in the market, the decisions made with respect to the development of a product or service must be customer-focused and requirements-driven. These complex decision situations can generally be dealt with effectively, and decisions made can be effectively supported by a robust decision making process that is focused on the customer and driven by their requirements.

The major objectives of decision models are to **support** the decisions made and to **provide insight** about decision situations. In this sense, the decision models are prescriptive rather than descriptive. For product development decision situations a purely intuitive approach is not a wise strategy, because important points can be learned and better solutions developed from decision analysis. Decision analysis involves the **decomposition** of the elements of a decision situation to allow detailed separate and yet integrated study of those elements.

Decision analysts do not suggest to replace intuitive processes with purely analytic processes, but rather to mold together these two processes so that the analysis support the intuition. Herbert A. Simon (1977) says, *managerial decision making is synonymous with the whole process of management*. Management can be defined as the process of developing decisions and taking actions to direct the activities of people and usage of resources within organizations toward common objectives. For example, the important managerial function of planning involves a series of decisions such as: *What should be done? For whom? When should it be done? How should it be done? Where should it be done? And by whom?*

Therefore, planning implies decision making/decision analysis. Other functions of the managerial decision process like design; production and implementation can also be viewed as decision making/decision analysis.

2. THE DECISION MAKING PROCESS

The operations research community and systems analysts are in general agreement with respect to a process that they use for the purpose of making decisions. The process is shown in Figure 1. This process, as described by Efrain Turban (1990) has four stages, namely, *intelligence, design, choice,* and *implementation*. The intelligence phase involves investigating the environment, either intermittently or continuously. It contains several activities that are aimed at identifying the decision situations. The design phase is engaged with inventing, developing, and analyzing possible courses of actions. Understanding the decision situation, generating solutions for the decision situation and feasibility study of these solutions are among activities that belong to this phase. Also, a model of the decision situation is constructed, tested, and validated in this phase. The choice phase involves the search, evaluation, and discovery of an appropriate solution for the model developed in the design phase. The boundary between the design and choice phases is somewhat fuzzy because there are certain activities that are performed in both of these phases. Solution to the model developed in the design phase does not represent a solution to the decision situation. It does, however, yield recommendations toward the situation in question. Only if this recommended solution is successfully implemented is the decision situation considered to be handled.

In applying this process, decision makers and analysts do not typically follow a linear straightforward path through the phases. Rather, they do a lot of lateral thinking which involves many jumps from one phase to another, and also the feeding of information forward or backward in order to make appropriate decisions. For instance, sensitivity analysis can and often should be conducted as an integral part of every single phase of the entire process. Also worth mentioning is the fact that although the analysis of decision situations is aimed at achieving definite answers, *many practitioners achieve much benefit from the analysis process itself*. The decision making process, forces the decision maker to think very hard about the situation in hand in a systematic and consistent manner.

2.1. Models

An important characteristic of this process, which needs some explanation, is the inclusion of model and model building capability. The basic idea is to execute the decision analysis on a model of a real system rather than the real system itself.

A *model* is a simplified representation or *abstraction* of reality. It is an object or concept that is used to represent something else[1]. It is reality scaled down and converted to a form we can comprehend. When we think about real things, what are we really doing? As a first step in dealing with any situation involving the real world, we must somehow describe, explain, demonstrate, analyze, test or even predict that part of reality in which the situation under consideration is embedded. The one fact, which stands out at the beginning, is that our thinking goes on *inside* our head, and we cannot get the relevant chunks of reality into our head. Since the reality always remains external, the only thing we can do is get *thoughts* about reality into our brains. Our thoughts, then, are *abstractions* from real situations, i.e., reality.

Models of a typical situation consist of a few concepts, often represented by words, corresponding to those few aspects, which we consider relevant to the real situation that we are trying to deal with. We have a fuzzy, incomplete, abstract idealization of the actual situation, and it is with that abstract construction, our models, that we handle the real situation. The power of a model in dealing with real life situations comes from the fact that it does not correspond to reality except in those details pertinent to the situation at hand.

THE DECISION MAKING PROCESS

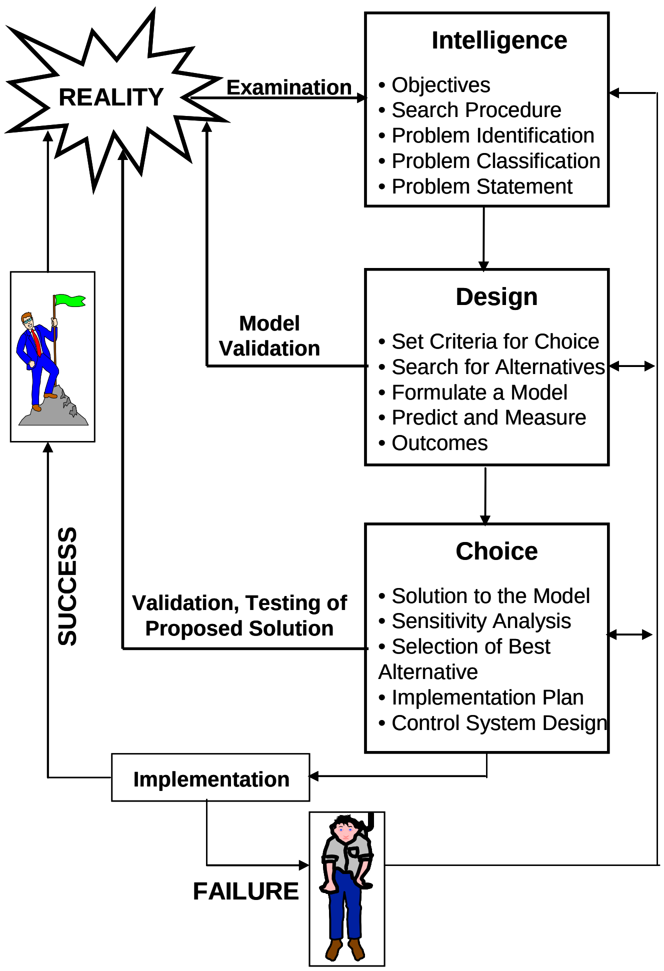

Figure 1

Source: Turban, E. Decision Support and Expert Systems: Management Support Systems, Second Ed, New York, NY: Macmillan Publishing Co., 1990.

Many different types of models exist. Mangers and decision-makers construct models of decision situations. We could classify models into the following categories, which are used to describe or visualize the abstract models that we form in our minds:

1. Symbolic models:
   a) Verbal models
   b) Mathematical models.

2. Physical models:
   a) Analog models
   b) Iconic or scale models

We sometimes use the physical models as stand-ins for the real-world situation that we are concerned about. While we could just as well regard a physical model, such as a wind tunnel for an automobile, as another way of describing our own ideas about the corresponding real thing, it is probably a good idea to separate out the physical models as a group. Symbolic models are by far the most interesting to the decision makers, since the situations they typically are faced with do not lend themselves to modeling in physical form. Engineers make use of both the physical models and symbolic models in order to deal with the real systems. The aim of these models whether mathematical[2], analog[3], or iconic[4], is to provide **information** for **decision** making purposes.

3. THE CUSTOMER-DRIVEN MANAGERIAL DECISION MAKING PROCESS

If we take the classic decision making process as described earlier and depicted in Figure 1, we see a valid process for general decision making. Inclusion of the QFD methodology and other revisions provides an enhanced process that drives decisions from the customer viewpoint. We refer to this process as the Customer-Driven Managerial Decision-Making Process. In the context of this process, the "Reality" portion of the process and its initial driver becomes the market place and the Voice of the Customer. We generally tend to think of the "customer" as the ultimate purchaser of our end product, sometimes referred to as “consumer.” However, in the context of our process, we view the customer in a much more general manner. That is, the customer may be external to our business or an internal down-stream user of our product, process, or service. Independent of how we define the term customer, the only way to ensure successful decision making is to start with their Voice and continue to validate and verify alternative decision solutions against those initial requirements.

Let’s now draw our attention to our customer-driven process as depicted in Figure 2. There are many similarities to the more classic process of Figure 1. The four main stages of development still remain the same; however, we have now identified them as *planning, design, production,* and *implementation*. Validation of the developed models and verification of the proposed solutions also still remain intact, as do feedback loops from subsequent stages to previous stages in the event of a solution failure. Additions to the process besides the critical Voice of the Customer information include organizational or corporate objectives that are also used to initialize the process. Exiting each major phase, a "deliverable" has been identified that is used as the input for the following phase. Within each major phase box, certain key initiatives, processes, or methodologies have been identified. These are exemplary in nature and do not indicate an all-inclusive list of activities to be accomplished. Next, each phase will be described in further detail.

3.1. Planning

Planning is a purposeful, dynamic activity concerned with achieving a desired goal or objective. The desired goal for our organization is to build great cars and trucks such that the customers are enthused and it can make profit.

Planning starts with the identification of organizational goals and objectives. Effective planning requires an adequate account of interaction of the system with relevant environmental, social, regulatory, technological, and economic factors. One must consider projections of all these factors to produce a convincing product plan that describes the product's state under various assumptions. "Organizational objectives," shown in Figure 3, reflect all these other factors, besides the customer requirements. QFD/VOC is an excellent tool for the planning phase of the product development.

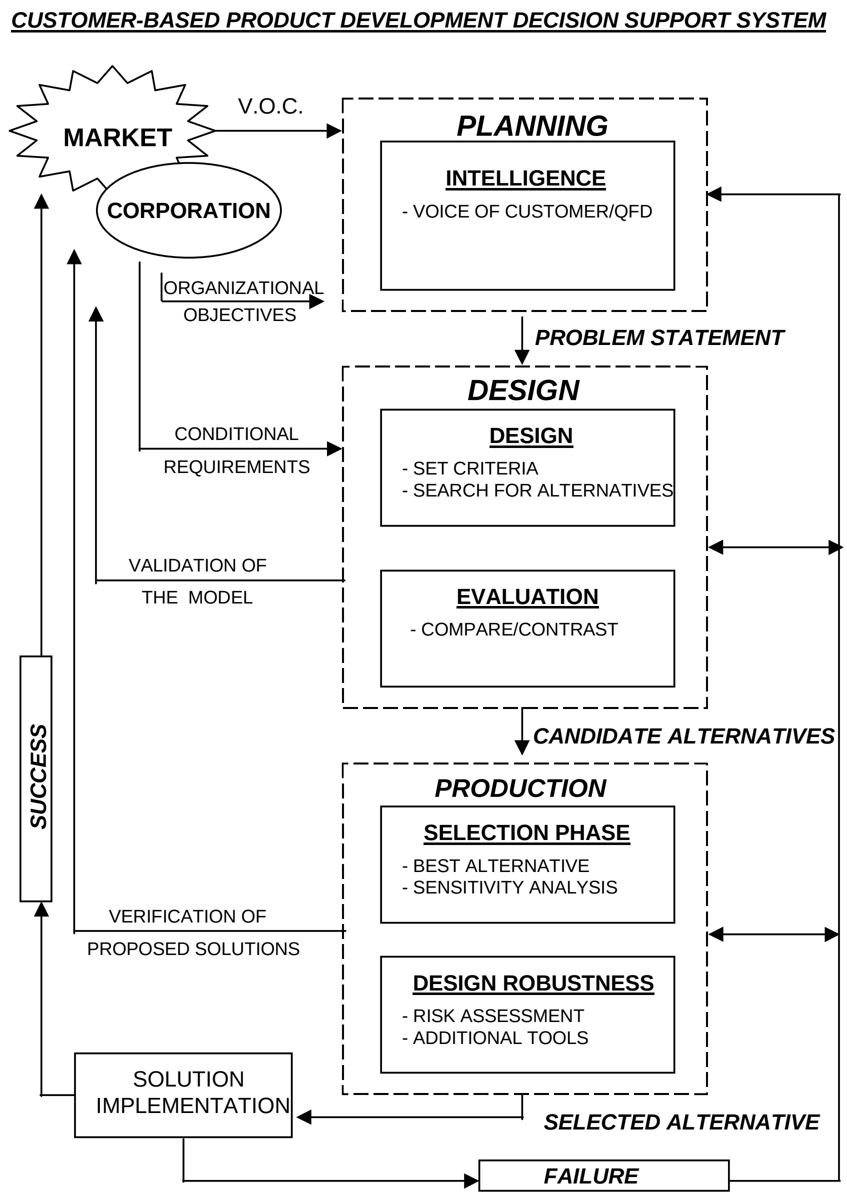

Figure 2

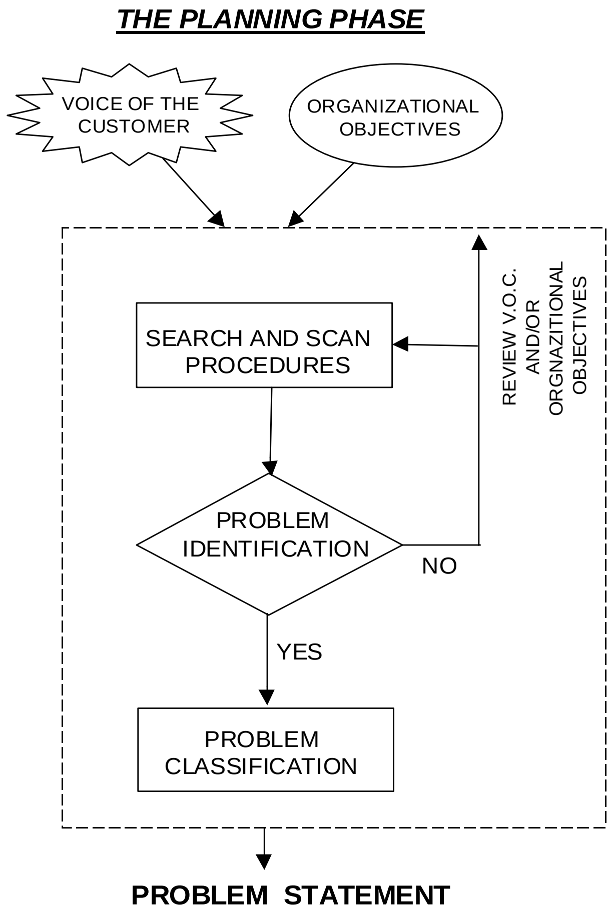

Figure 3

4. THE DESIGN PHASE

Once the decision situation has been clearly identified and stated, the task of developing and analyzing possible courses of action can begin. Modeling of the decision situation is one of the primary outcomes of this phase of the decision making process. This phase mandates the establishment of clearly defined criteria and the development of separate and distinct alternative solutions for evaluation. Customer-driven managerial decision making requires a methodical approach to maintain and focus on decisions that are in the best interest of the customer and ultimately the goals of the organization. Such an approach will help to better ensure success in the competitive marketplace.

A six-step approach shown in Figure 4 is offered for the design phase incorporating the following iterative activities

1. Set Criteria
2. Generate Concepts
3. Develop Models
4. Qualitative Selection
5. Predict and Measure
6. Quantitative Selection

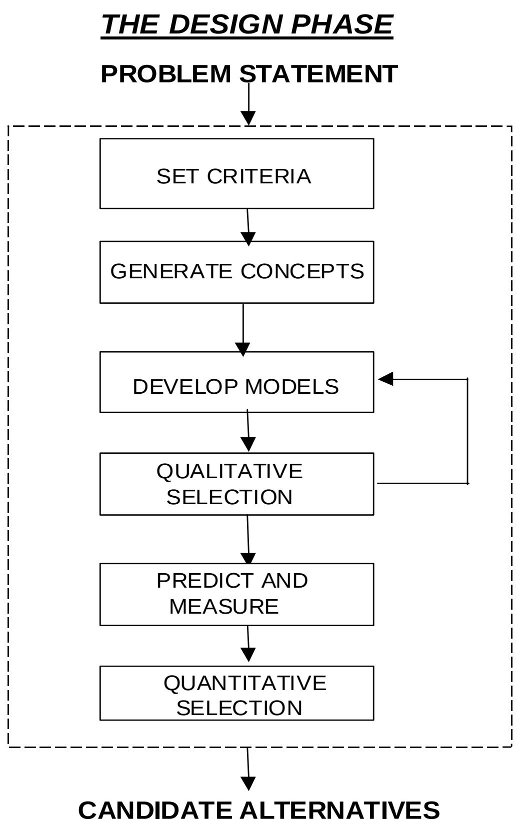

Figure 4

similar to a generalized design for six sigma (DFSS) process of identify, define, develop, optimize and verify (IDDOV), Chowdhury (2002). Where, steps 1 and 2 relate to identify and define; step 3 relates to develop and the last three steps relate to optimize and verify. Execution of these activities by a select cross-disciplined group of the organization will provide a more objective and unbiased view of how the decision situation can best be addressed and consequently solved. Each of these steps will be looked at in some detail.

4.1. Set Criteria Using VOC/QFD

In order to rationally evaluate multiple alternatives in a timely manner, a sound, objective and clearly defined set of criteria must first be established. Customer-driven managerial decision making would suggest that such evaluation criteria be initialized from Voice of the Customer research and subsequent QFD activity. This explicit reference to the customer in the beginning stages of this analysis phase helps to establish the commitment that the customer(s) will be the first party served in the decision making process.

If we view the QFD methodology as a prioritization process that assists in the development of objective criteria to address the matrix inputs or "Whats" (left side of the House of Quality - HOQ), we can easily adopt those criteria as our starting point for future alternative evaluation. The critical translated characteristics or "Hows" (topside of the HOQ) that are ***new***, ***difficult*** and/or ***important*** to addressing the condition (product, process, or service) under study provide the criteria most crucial from the customer's perspective. Truly we can think of these criteria as customer-driven.

Though these criteria may be objective and clearly defined, it is not necessarily complete. A complete set of criteria takes into account not only the major issues of the marketplace or "outside environment", but also the objectives or the constraints of the organization. Generally speaking, in the automotive industry and at a vehicle level we tend to think of these objectives or constraints as cost, fuel economy (FE), mass, quality (warranty frequency and cost and J.D. Power problems per hundred) and timing of a particular program. These are pragmatic business concerns that cannot be ignored but must be dealt with in an orderly fashion to prevent overriding the customers' concerns and thus, satisfaction. By orderly fashion we mean looking at these parameters with a systems viewpoint.

Perhaps in the past we have tended to focus on these parameters in a singular way. For instance, as a program came closer to production, we may have realized that the cost targets had been exceeded. A somewhat common practice at that point may have been to begin to bring the cost figures more in line with the original targets even though it may greatly negatively impact customer satisfaction with the product. Nothing could be more hazardous to an organization than to "optimize" its internal constraints and goals to the detriment of the group they need to please the most; the customer.

To varying degrees, some consideration of these "internal criteria" may have already occurred during the QFD process. Additionally, some of these criteria may also have been derived from the QFD HOQ matrix. It is important to visit these criteria again and ensure the existence of a correct and complete list that is pertinent to the study at hand. If these criteria were consciously excluded from the QFD study, the cross-disciplined team can generate a discrete list of "heavy-hitters" to be factored into the alternative selection criteria.

4.2. Generate Concepts

Concept generation provides the first link in development of the actual potential solutions for the decision making process. To better understand this step we must first define what we mean by the term "concept". Concept can be defined simply as an abstract idea or solution to a problem in a very general sense. A concept may not provide the capability to explicitly demonstrate the ability to meet the requirements of a problem. Consequently, a concept can be viewed as a thought, notion, idea or a mental model.

With this in mind, we often talk about putting our thoughts on paper. This is basically what we are trying to accomplish during concept generation. The concepts may be somewhat esoteric at first, but will later be defined in more tangible and understandable parameters for evaluation. Concepts can be generated by a host of techniques such as Pugh's concept generation and selection process (1991) and Theory of Inventive Problem Solving (TIPS), which is a translation for the Russian's acronym TRIZ (Altshuller, 1996). No one technique is proposed or recommended over another. Usually the methods used for concept generation are based on the organization's familiarity and experience with the study topic, the resources (people, money, time) available, and the critical nature of the study.

Though it is not the purpose here to provide a detailed discussion of concept generation techniques, some of the more common methods include:

- Brainstorming
- Functional analysis (fishbone and morphological charts)
- Literature searches
- Competitive analysis and benchmarking

4.3. Develop Models

As we complete concept generation there is a need to begin to objectively evaluate and analyze the concepts. To do this effectively, we must move from the "conceptual" phase to the more tangible aspects of a model. The model begins to provide us with the "hard points" for effective analysis. Model can be defined as a description of the concept that will help to either visualize or demonstrate the ability of the concept to meet the requirements of a problem. This ability to visualize or demonstrate performance to requirements sets a definite demarcation between a concept and a model.

The demonstration capability of the model may be either qualitative and/or quantitative in nature. The key is that the model, and not necessarily the concept, allows for a relative comparison between and among other models using the established criteria for performance evaluation. As we move through various levels of an organization in the decision making process, we may note that at one level what may be considered a "model", is only "conceptual" at a higher level. That is, in a lower level the previously defined concept may not allow for a relative comparison analysis.

To clarify this point, let us look at an example. From a product perspective, this may be somewhat easier to visualize. At a vehicle level we may want to describe alternative propulsion systems for an automobile. From this simple description such alternative models could include an internal combustion engine, electric motors, turbines, etc. As we move from a vehicle level to a detailed analysis of the major subsystem of powertrain, an internal combustion engine at this point becomes more conceptual. Until we frame this concept in terms of the ability to meet the requirements of the problem through visualization or actual demonstration, we cannot fully evaluate the alternative. However, if we offer both gasoline and diesel engines as the models for the internal combustion engine concept, we can now begin to formulate more detailed evaluations of these alternatives and demonstrate their capability against the requirements. Often times we may observe that a single concept may lead to multiple models.

4.4. Qualitative Selection

With a discrete, yet complete set of evaluation criteria and alternatives that have the ability to visualize or demonstrate the performance to requirements, the process of qualitative selection can be performed. Qualitative selection implies more than just what the name states. Beyond just down-selecting a single or set of models for further analysis and evaluation, qualitative selection provides the opportunity for additional and hybrid alternative generation. Hybrid generation begins to address solutions that are robust in critical criteria areas. As we execute this step, we begin to see that qualitative selection fosters an iterative process of evaluation and further model development. This iteration continues until the most optimum solution(s) are obtained that meet the customer-driven managerial decision making criteria.

Qualitative selection is perhaps best characterized by the Pugh concept selection process developed by Dr. Stuart Pugh of the University of Strathclyde (1991). This process establishes a datum to compare distinctly unique alternatives to a common set of criteria, assess and enhance negative characteristics of the alternatives, and provide a new reference point or datum for comparison. Through a series of “plus (+)”, “minus (-),” and “same (S or zero 0)” ratings, alternatives can quickly be assessed in a qualitative manner, and hybrid alternatives generated that best meet the established criteria. It is our experience that this methodology works best with product related issues, but can also be easily adapted for process and service oriented concepts.

4.5. Quantitative Selection

Like Qualitative Selection, Quantitative Selection also assesses multiple alternatives against a common set of criteria. Rather than simply determine a "directional" performance to the criteria [i.e. better (plus), worse (minus), or same (0)] relative to a datum or reference model however, Quantitative Selection begins to assess the magnitude of the performance. Consequently, a great deal of data gathering and analysis must take place to objectively demonstrate or measure better or worse performance in each criteria area by the respective alternatives or models. Additionally, we may want to group the criteria into two major categories of "absolute need" and "preferred want" to further evaluate models' performance and viability toward an optimum solution. Models not performing acceptably in "absolute need" criteria, for instance, can be de-selected.

One method of Quantitative Selection is offered by the Kepner-Tregoe (1997) approach to alternative selection. Alternatives are compared on a relative basis using criteria that is categorized into both "must" and "want" characteristics. This method requires that alternatives demonstrate, in objective numerical terms, performance compared to the criteria and consequently to each other. Additionally, the process uses both a 'weighting' and "rating" technique for further evaluation of performance in the "want" criteria. Based on a pre-determined rating scale, alternatives can be assessed and ultimately scored in terms of performance to individual criteria and overall performance. Because of the rigor involved in gathering the data and performing the analyses on the models, usually fewer alternatives are compared relative to the Pugh concept selection process.

Completion of this process will yield a clearer understanding of various models' performance relative to the selected criteria. This understanding is made possible in part by a demonstration of the magnitude of the performance to each of the weighted criteria. Candidates can then be selected based on performance that is optimal to the decision criteria.

5. THE PRODUCTION PHASE

The production phase is the last phase in the decision making process prior to the actual implementation of the selected solution. This phase employs several techniques and tools to pare down the candidate alternatives to the select optimal alternative. At this point we begin to look at the remaining alternatives in further detail and try to assess both sensitivity and risk, identify contingencies where appropriate, and finally devise the implementation plan. The importance of the planning phase and its associated direct impact on this production phase cannot be stressed enough. A dedicated effort to a well-devised and executed planning phase will help greatly to reduce the effort and increase the value of this phase. The production phase is depicted in Figure 5.

5.1. Sensitivity Analysis

A sensitivity analysis enhances the value of the alternative selection results and should be conducted to determine the robustness or volatility of the alternatives. This is especially important where performance estimates are developed without the benefit of actual operational data. Additionally, the sensitivity analysis helps to identify the critical areas for continuous improvement. The deliverable of a sensitivity analysis is to clearly understand the reasons for the sensitivity, and begin to formulate a root cause approach to provide a robust resolution to the key issues for the customer-driven decision making process.

If we were to revisit our earlier example of the gasoline and diesel engine models, we might at this point look at sensitivity around some of the critical criteria for these models. Such criteria may include both performance and fuel economy characteristics of the model. The "weighting" of these criteria will obviously greatly depend on what market segment (and consequently what customer requirements) these alternatives could be deployed to address. That is why again, the planning phase is so crucial to the successful implementation of the process. However, regardless of the market segment, these two criteria usually tend to be at odds with one another. It is precisely this type of criteria "trade-off' that should be explored in the sensitivity phase.

"Weightings" of these criteria can be adjusted to reflect possible fluctuations in the internal environment (corporate goals, capabilities, resources, program timing, etc.) as well as, external environment swings (due to international policy, governmental legislation, global factors, etc.). Adjustments to this type of criteria can be assessed and the models re-evaluated in light of these considerations. Significant changes in the scoring of the alternatives should be noted. Determination must be made if the model(s) with the highest score originally, still remain the highest scoring, most viable model(s).

THE PRODUCTION PHASE

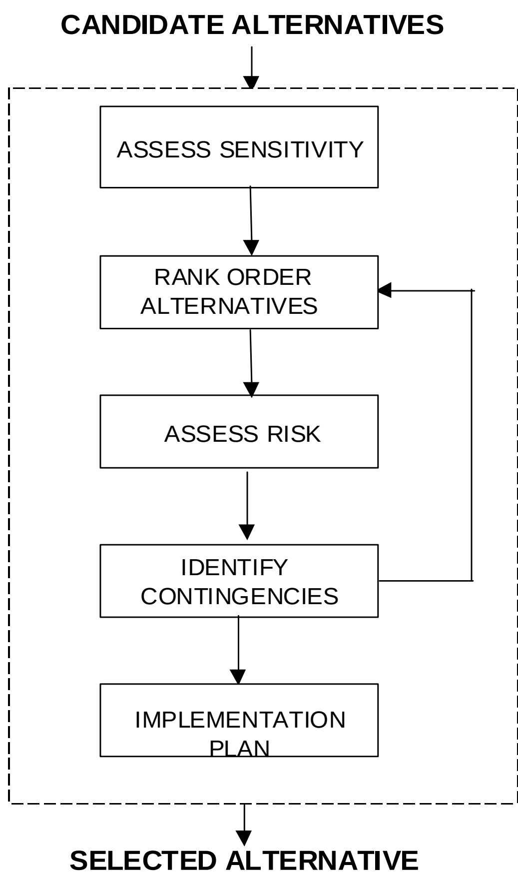

Figure 5

If there is a change in the ordering, then some or all of the models may be sensitive to certain selected criteria. It is imperative to fully understand the reasons for these changes. Ultimately, we must eliminate alternatives that are too sensitive by generating new models through modification to minimize the sensitivities. If the sensitivity issues can be resolved, the highest scoring, least sensitive model should be selected for further study. The remaining models may be rank ordered and held for future reference.

5.2. Risk Assessment/Analysis

In an attempt to better satisfy the customer requirements and become more competitive, often times the alternatives that are selected from the previous efforts tend to be the ones that have the most risk. In the customer-driven managerial decision making process it is important to identify the associated risk with the alternatives and develop a feasible mitigation plan to address and moderate this risk. Risk assessment and analysis addresses the following three issues:

1.) What could happen?
2.) What are the chances of it happening?
3.) What is the effect of it happening?

These three issues become central in determining if the alternatives are still viable. The "best" solutions for the decision making process may no longer be the best in respect to the risk assessment. Therefore, a clear understanding of the respective risks and the potential problems/opportunities associated with the alternatives must be effectively communicated in a timely manner.

Identification of the uncertainties involved with the alternatives is handled through the studying of the first issue, i.e., what could happen? Here we are trying to uncover any areas of potential trouble that may limit the successful implementation of the alternative. Each of these uncertainties should be clearly differentiated so that an effective analysis can be conducted for each one. Next, we deal with the second issue, what are the chances of it happening? Handling of this issue involves the probability of occurrence of the actual uncertain event. At this stage we often look at the probability of success associated with such issues as technical maturity, complexity, and system interdependence. The third issue relates to, what is the effect of it happening? Here we substantiate the actual consequence of occurrence of the uncertain event. Most often we associate this consequence to impacts on bottom-line measures of cost, schedule, and technical performance (i.e., quality).

In assessing and analyzing risk, we should focus on both the probability of success and failure and their consequences. But we tend to focus on the probability of success and its consequence. Computations in varying degrees of detail can be made to determine a relative risk factor for each alternative. Ultimately, the alternative can be judged somewhat subjectively and scaled in a low, medium, or high-risk category.

Awareness of an alternative's risk level can lead to a more concise mitigation plan for that risk, and also to potential contingency plans if the risk cannot indeed be fully mitigated for the alternative for various reasons. In contingency planning we again see an iterative process whereby we re-visit the set of viable alternatives previously held for future reference and determine risk associated with these candidates. This allows for substitutions of alternatives to occur to provide a fallback position if the selected alternative later becomes prohibitive to implement.

6. CONCLUSION

The customer-driven managerial decision making process is similar in design to the operations research and system analyst communities classical decision making process. The prime driver for the customer-driven decision making process, however, is realized in the actual Voice of the

Customer that the organization as a whole must satisfy. Use of the Quality Function Deployment methodology is a method that provides a structured approach to gathering, analyzing, deploying, and assimilating the voice into actionable requirements to initialize this decision making process. As the decision making process is implemented, continual validation and verification of the models and proposed solutions is made against the customer requirements to ensure successful solution implementation.

It is the author's contention that the customer-driven decision making process is nothing more than good systematic and systemic common business sense. Certainly, the more successful organizations appear to incorporate a good deal of the principles proposed here and, elements taken singularly from this process do not necessarily offer major philosophical changes in the science of decision making. It is my belief, however, that the fundamental understanding of concept and model as proposed here, in addition to this process taken as a whole, may offer an incremental advantage in applying a systematic, systemic and successful decision process.

Footnotes

[1] The distinction between *model* and *concept* is a matter of the *degree of abstraction*. Concept has been defined as an abstract solution to a problem. It is a general abstract solution without the capability to explicitly demonstrate the ability to meet the requirements of a problem. On the other hand, model can be defined as a *description* of the concept that will help to either *visualize* or *demonstrate* the ability of the concept to meet the requirements of a problem. This distinction between the model and concept will be helpful as we get to the next section of the paper, which deals with requirement flow and product development. In this context, "model" as defined at one level in the requirements flowdown and solution generation process may be defined as a "concept' at another level in that process.

[2] The complexity of relationships in some systems cannot he represented physically, or the physical representation may be cumbersome and time-consuming. Therefore, a more abstract model is used with the aid of mathematics. A mathematical model is a model whose parts are mathematical concepts, such as constants, variables, functions, equations, inequalities, etc. Mathematical models are themselves classified into quantitative vs. qualitative, probabilistic vs. deterministic, ready-made vs. custom-made, descriptive vs. optimizing, and analytic mode vs. numeric mode.

[3] An analog model does not look like the real system but behaves like it. It is less abstract than a mathematical model. These are usually two-dimensional charts or diagrams. That is, they could be physical models, but the shape of the model differs from that of the actual system. Some examples are blueprints, maps, charts, graphs, speedometer, thermometer, and an organizational chart that depicts structure, authority, and responsibility relationships.

[4] An iconic model, the least abstract model is a physical replica of a real system, usually based on a different scale from the original. Iconic models may appear to scale in three dimensions such as a complete car, body or cockpit of a car, or production line. Photographs are another type of iconic models but in only two dimensions.

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