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Title: *Using Attribute Classes during Conceptual Product Design to Anticipate Unarticulated Product Value*

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DRAFT: USING ATTRIBUTE CLASSES DURING CONCEPTUAL PRODUCT DESIGN TO ANTICIPATE UNARTICULATED PRODUCT VALUE

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ABSTRACT

A key challenge for product designers is to create products that customers will perceive as delivering sustained value over the life of the product. The perceived value of a product by its stakeholders changes over time as a result of many different factors such as experience with use of the product, changes within the regulatory environment or marketplace, availability of new technologies, and emergent needs. During the concept phase, designers elicit stakeholder needs and desired product attributes though various methods, yet there is often significant unarticulated or latent value that remains uncovered until later in the product lifecycle. A method is presented that uses *attribute classes* to aid the product designer in understanding perceived value in context of an overall *value spectrum*. Desired product attributes are characterized using several value classes including: articulated value, free latent value, cheap latent value, accessible value and inaccessible value. Illustrative examples are presented to examine how this method can aid the designer in a deeper exploration of product attributes to uncover latent value during the conceptual product design phase. Implications of this method for improving the overall product design process are discussed, including strategies for bearing the costs of latent value.

1 INTRODUCTION

One problem that faces all system designers is that of creating value by having the perceptions of a system meet the expectations of system stakeholders. It is the creation of value that motivates the design effort, without which, systems face failure and developers face the consequences of that failure. Dynamic contexts due to environment changes, new expectations of stakeholders as they learn or are influenced by others, and introduction of new technologies and new competitors, can significantly affect the perceived success for a system. Instead of resisting the inevitable change in stakeholder value expectations, system designers can proactively embrace the possibilities of change by building into the system the ability to provide future value. The concept of attribute classes is introduced as a framework for thinking about actual and potential value perception by stakeholders.

The distinguishing characteristic that determines an attribute classification is the cost to "display" or "activate" an attribute when a stakeholder desires to see such an attribute. Unarticulated value, that which is not explicitly communicated, perhaps because it is unrecognized, can be explicitly managed through the attribute classification system by increasing the potential for a system to meet needs as they become expressed. As the cost to redesign a system increases, the importance increases for a designer to be able to anticipate and design in latent value that will increase the likelihood of sustaining system success through continued perception of delivering value to stakeholders. The ultimate goal of design using attribute classes is to be able to match dynamic system characteristics to dynamic value expectations.

2 VALUE DEFINED

Value can be defined as relative worth, utility, or importance; it is the quality of a thing considered in respect of its power and validity for a specified purpose or effect. The concept of value is at once abstract and yet pervasively accessible. The pursuit of value motivates exchange in markets, both formal and informal, as well as impacting the discipline of design. Due to its inherently subjective nature, perceptions of value must be effectively communicated between value-

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consuming and value-creating entities in order to ensure needs are met. The communication, or articulation, of value is a core concept in the design process, often represented as "needs identification" in traditional development processes [8].

The notion of articulated value is discussed in [5,6] and for the purposes of this paper will be assumed to include the explicitly communicated desires, or elicited attribute set, for each decision maker. The unexpressed, or unarticulated, values include those "somethings" that give value to a given decision maker, but for one reason or another were not elicited in the attribute set. Reasons for decision makers having unarticulated values range from "could not" to "would not" to "should not" say.

Keeney [3] discusses the approach called "value-focused thinking" as opposed to "alternatives-focused thinking." The key differentiator between these approaches is to recognize that understanding the core value propositions of a decision maker can enable decision opportunities, especially to create new or additional value, as opposed to trying to seek criteria for already offered alternatives.

3 ELICITING VALUE

The typical approach to elicitation is through the traditional requirements engineering elicitation approach. The strength of this approach is that it uses a structured approaches and enabling techniques to identify and capture the stakeholder needs and preferences. Some of the weaknesses that have been cited with this approach include: (1) stakeholders have incomplete understanding of their needs; (2) product users and the needs elicitation analyst speak difference languages; (3) boundaries of the product system are ill defined; (4) unnecessary and confusing design or implementation information may be given instead of identifying the core need; and (5) it is often the case that "obvious" information is omitted and thought by the stakeholder to be assumed by the designer.

4 PERCEIVED VALUE SPECTRUM

In the dialogue between the decision maker and the elicitor, the designer seeks to identify the maximal value through the articulation of objectives, requirements, and attributes. There always remains unarticulated value within the overall value spectrum, as shown in Figure 1, given that there are aspects that the decision makers can't say, don't say, or won't say during the elicitation process.

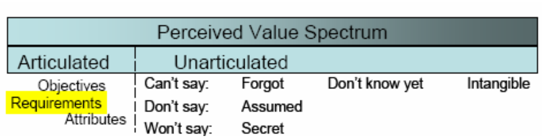

Figure 1. Perceived Value Spectrum

This formalized spectrum of perceived value reminds the designer of possible types to consider. Elucidators, or mechanisms, to move the values from the unarticulated to the articulated perceived-value categories include the following: personal reflection (time); conversations with mediators (facilitation); experience with the system (learning by doing); interactions with system context (competition, test-driving); and change in context (change of the "rules").

A key question confronting the designer at this point is how to deliver value in the face of various value-perceptions. One process, utilized extensively in economic market analyses is that of revealed preferences. Revealed preferences are preferences captured through the behavior of decision makers, based on statistical analysis of their choices. Presumably decision makers choose systems that deliver value and thus reveal information about their preference structure, or tastes.

In certain situations, however, such data is often unavailable due to the limited and or specialized nature of the system products, as well as the limited number of purchase or acquisition decisions. The unique context of each system need may entail a specialized set of preferences that cannot be garnered from past behavior. Instead of relying on statistical analysis of past behavior, revealed preferences could be captured through conversations with decision makers about hypothetical system choices in the current context. Unfortunately the process of preference elicitation typically does not give a complete picture to the designer. Additionally, conflicting preferences of decision makers may be revealed that do not point the designer to an obvious aggregate preference set for maximizing delivered value.

The causes of apparent dynamic preferences of the decision maker to the designer include: (1) personal drift of the decision maker's thinking; (2) changing context affecting the dilemma being considered by the decision maker; and (3) the movement of needs from unarticulated to articulated. In any case, in order to maximize delivery of value, the designer must match the dynamic current preferences to the best extent possible. Since the decision maker's personal drift is the most difficult to ascertain, attention to the context as well as to the needs articulation should be a significant focus of the designer.

5 VALUE METRICS: ATTRIBUTES

The stakeholder role represents those individuals, groups, and entities who derive value from association with the product or system. Stakeholders in general, however, often have little direct influence over the creation of the system itself. If the goal of the designer were to maximize value delivered to the entire stakeholder set, some method for capturing each stakeholder's value proposition would be necessary in order to have a direct effect. Even if such an under-taking were possible, the picture would still be incomplete. In addition to need, a system requires resources. Resources are the raw and mediating materials, processes, and expertise, both tangible and intangible, which are used to create the system. The gatekeepers for both the need and resources are the decision makers, who have significant influence over either the driving need or resource allocation that affects system creation. Since the decision maker wields the power over whether a system is created, the designer should focus on maximizing value to the decision maker. Each decision maker has a set of objectives about which decisions are made.

Attribute-based value is an effort to operationalize the concept of objective driven decision-making. The following is a question to pose to decision makers when eliciting attributes: "when making a decision about a particular option, what are the characteristics that you would look at?" Those characteristics are the attributes. An attribute is a decision maker-perceived metric that measures how well a decision maker-defined objective is met. The characteristics of an attribute include its definition, units, and range from least to most acceptable values. The definition should be developed in concert with the decision maker in order to ensure the decision maker actually has value perception over it. The range reflects the fact that value is perceived for multiple attribute levels, and in the limit the range converges to a point, the attribute becomes a requirement. Of course a decision maker could have multiple objectives and therefore a set of attributes. According to Keeney and Raiffa [4], an attribute set must be complete, operational, decomposable, non-redundant, minimal, and perceived independent. Operational means that the decision maker actually has preferences over the attributes. Decomposable means that they can be quantified. Non-redundant means none are double-counted. Minimal and complete are in tension, since a designer seeks to capture as many of the predominant decision metrics as possible, while keeping in mind human cognitive limitations. In practice, no set can be simply guaranteed to have all of these properties. The problem of completeness applies just as easily in the requirement generation process in standard engineering practice. Designers must do the best they can.

6 SOURCES OF VALUE: ATTRIBUTE CLASSES

The elicitation of attributes, both articulated and unarticulated, can be done through a facilitation process mediated by system designers. The literature on requirements generation can inform the elicitation process. Section 3.2, "Preference Capture," of [5] describes the general concept of attribute elicitation for use within Multi-Attribute Utility Analysis and Prospect Theory, two decision-analytic theories that can be used to improve engineering design decision-making. [1,3]. Putting attributes into a temporal discovery context, [9] provides a framework for thinking about the evolution of articulated needs from fuzzy wants through attribute definition down to concrete requirements. Formal interviews, group discussions, learning by doing ("playing" or "test driving" the system), and introspection are just a few of the methods that can be used to elicit value propositions from decision makers.

Throughout elicitation, it is important to keep in mind the concept of "framing." Framing represents the cognitive context from which a decision maker considers a problem. For example the same outcome could be cast in terms of a "cost" or in terms of an "uncompensated loss" and will be perceived differently by the decision maker. Cognitive bias as a result of framing is a well documented phenomenon in the psychology literature. Kahneman and Tversky [2]. contains a collection of several dozen such papers, including descriptions of Prospect Theory, a theory of value combining insights of cognitive biases from Psychology into an Economic model of choice. Consistency and care in the framing of attribute elicitation is essential to ensure reliable and repeatable value perceptions. It is important for the analyst to be able to distinguish changes in value perception due to a real underlying value perception change versus errors in measurement due to cognitive biases or inconsistencies in framing for attribute elicitation.

In terms of capturing value propositions, the previously developed concept of attributes can be used as a metric to ascertain how well objectives deliver value. Spanning the range from known articulated value to unknown unarticulated value, attribute classes can be defined as shown in Table 1 below.

Class	Name	Property of Class	Cost to Display
0	Articulated Value	Exist and assessed	0
1	Free Latent Value	Exist, not assessed	0
2	Cheap Latent Value	Can exist by recombining class 0/1	Small
3	Accessible Value	Can be added through changing the design variable set (scale or modify)	Small→large
4	Inaccessible Value	Cannot be added through changing design variable set (system too rigid)	Large→infinite

Table1. Attribute classification (0 to 4)

In order to deliver value, an attribute must be perceived by a decision maker and be "displayed" by the system. The "existence" of an attribute means that the system has either the form or function specified by the attribute and is thus "displayed." "Articulation" refers to explicit communication by a decision maker that a particular attribute or set of attributes is value-perceived. "Potential" attributes are those that could be "displayed" by the system if the system were changed in some way. For the following attribute class definitions, a state 1 system is the "original" or "as-designed" system, while a state 2 system is the "changed" system.

7 ATTRIBUTE CLASSES

Four attribute classes are defined in the framework to define articulated value, free latent value, cheap latent value, accessible value and inaccessible value. The classes are described and illustrated in the following sections.

7.1. Class 0 Attributes: Articulated Value

The first of the classes of attributes to consider are those that are typically included in tradespace analysis: the articulated attribute set, as shown in Figure 2. The *class 0 attributes* are those that are designed into and "displayed" by the system and are explicitly communicated as an expectation by a decision maker. The "cost" to add class 0 attributes to a state 2 system is zero since the attributes already exist.

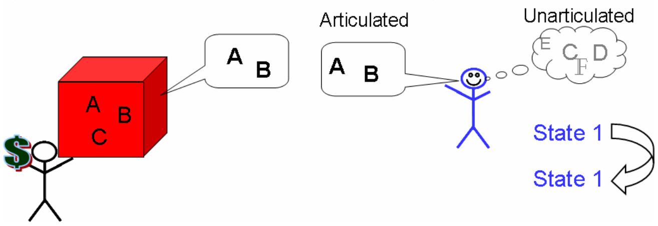

Figure 2 Class 0 Attributes: Articulated Value

As an example, class 0 attributes are equivalent to the requirements currently met by the system. A cell phone that provides, and was designed to provide, good sound quality, few dropped calls, and durable design meets the articulated values of the consumer who explicitly demands such attributes.

7.2. Class 1 Attributes: Free Latent Value

In addition to displayed attributes that are value-perceived, a system can display a number of other attributes, which are not value-perceived as shown in Figure 3. The *class 1 attributes* represent a type of latent value. If a decision maker adds such an attribute to his value-perceived set, no "cost" is incurred to change the system since it is already displayed. These attributes represent "free latent value."

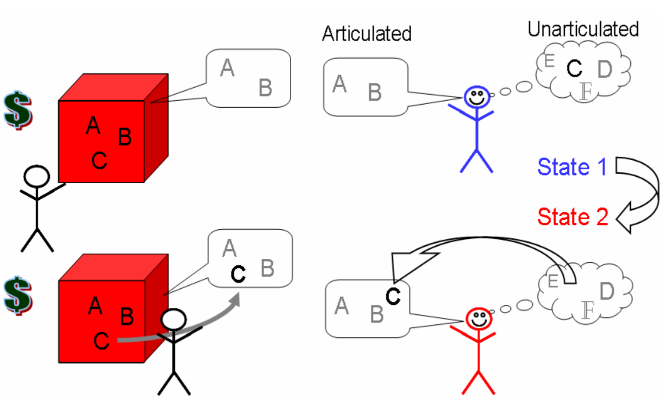

Figure 3. Class 1 Attributes: Free Latent Value

As an example, consider a customer seeking to purchase a new car. Going into the showroom, the customer may consider body styling and gas efficiency as his decision criteria: articulated attributes. Upon test driving a few cars, he comes to realize that comfort also generates value and was a previously unarticulated value. Cars being considered already "display" the comfort attribute and thus do not require modification to deliver comfort value to the customer. In this example comfort is a free latent value for the already existing car.

7.3. Class 2 Attributes: Cheap Latent Value

The next class of attributes captures the other type of latent value in a system: those that can be introduced into the system through small cost by recombining existing attributes. The system itself does not require a change, rather the interpretation of the existing attributes may require minor change as shown in Figure 4. The cost of such recombination is much less than that which would be required to change the initial system itself, thus these *class 2 attributes* are "cheap latent value."

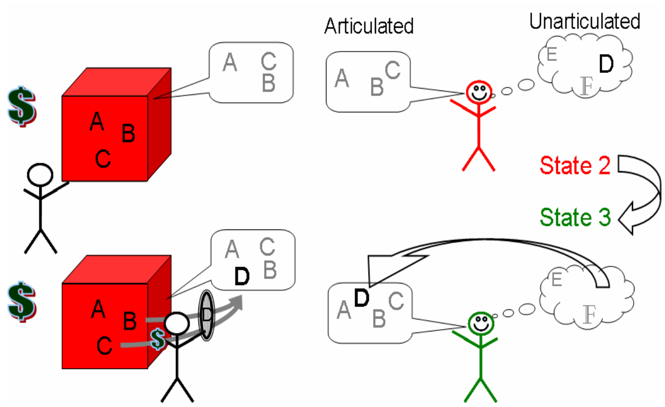

Figure 4 Class 2 Attributes: Cheap Latent Value

As an example, consider the GPS system, with its two attributes: ability to provide time and position data. Initially, the decision maker cares about these two capabilities, which are his attributes. Later the decision maker realizes that he also cares about his velocity. The system designer wants the system to continue to deliver value. Luckily the new attribute, velocity, can be derived from a recombination of existing capabilities. The system itself requires no change, rather a hand held device or other such interpretive system, can be used to derive the new attribute. Another example of cheap latent value for GPS is the interactive navigation system in cars, providing real time driving directions to destinations of interest. Compared to changing the GPS system, such new capability is very "cheap."

7.4. Class 3 Attributes: Accessible Value

When the system itself must be changed in order to "display" a new attribute, such an attribute belongs to class 3, if the cost is not unreasonable. The cost of such a change can vary from small to large, and each decision maker subjectively defines the reasonability of that cost. Even though the system must be changed, the attributes created in this way are "accessible value" as illustrated in Figure 5.

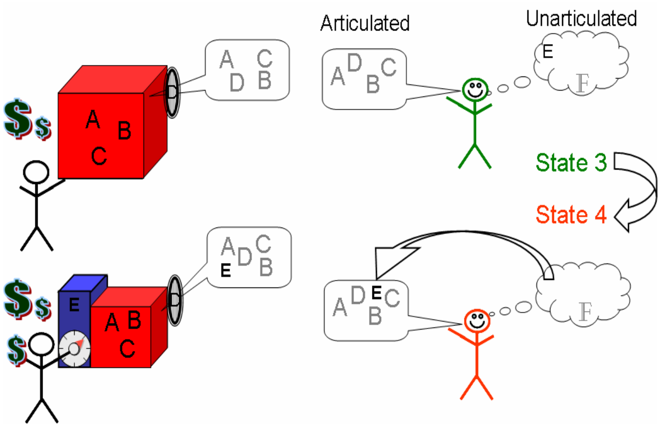

Figure 5. Class 3 Attributes: Accessible Value

As an example, consider an audiophile consumer with an adequate stereo system. Suppose the consumer wishes to add to the system the ability to play MP3 format audio files. In order to add this capability, the system itself requires modification. Options include replacing the CD player with an MP3-compatible player, or perhaps modification of the current system software to enhance audio decoding. In any case, the system must be changed to display MP3-playing capability.

7.5. Class 4 Attributes: Inaccessible Value

When the system cannot be changed or the cost incurred is too extreme to enable the system to display a new attribute, such an attribute belongs to *class 4 attributes*. These attributes do not flow from the particular system concept being considered, or perhaps represent an unreasonable burden to include, and are "inaccessible value" to the system under consideration.

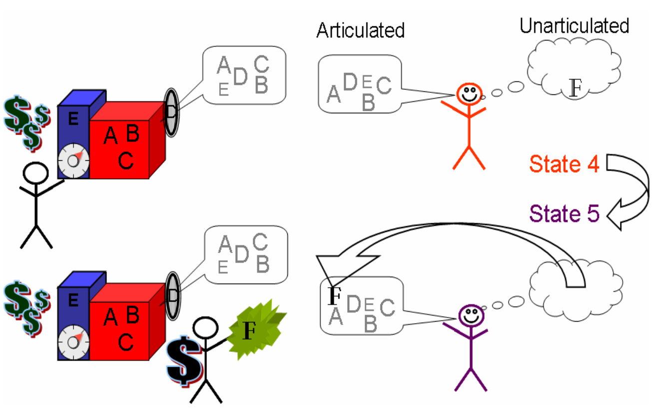

Figure 6. Class 4 Attributes: Inaccessible Value

As an example, consider the desire to include a food preparation capability into a passenger car. While having that capability might add value to a particular decision maker, the cost of doing so is either prohibitive, or would require the concept of car to be revisited. A camper, however, often does include a kitchen and could readily accommodate such a new attribute, but the transition from passenger car to camper is not cheap and requires discontinuity in concept.

8 DISCUSSION

One important aspect of change in perceived value is how the stakeholder's value perception will change with operational use of the product or system. As illustrated in Figure 7, these are two distinct perceptions of value. Oftentimes the requirements generation process constrains a decision maker to have only a static view of the future system or product. When the system comes into operation, many constraints may impact the value realization, and the experience of using the system may be very different than envisioned during concept development. Thus, the experienced value may be different from the original decisional value. Since disappointment is derived from the difference between expectations and experiences, it is important for the designer to realize and anticipate the potential value difference to the best extent possible.

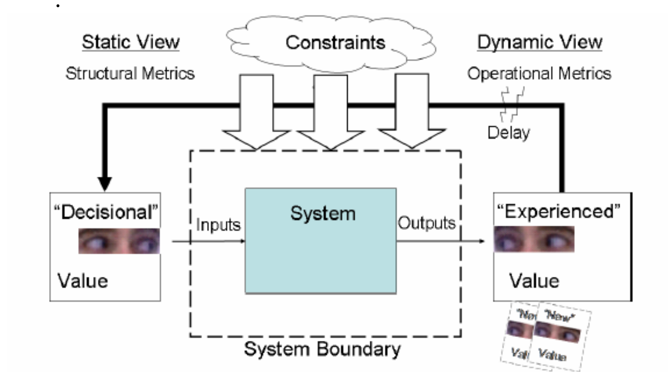

Figure 7. Decisional versus Experienced Value.

The designer's challenge is to anticipate the inevitable changing needs of stakeholders. In some cases, the designer will be able to foresee future needs and provide free or cheap latent value as needs change. It will often be the case that the designer will also need to enhance the product or system in order to access new value. Also, different stakeholder sets may need to access different sets of value for the same product or system, and the key challenge is to find resource effective ways to do so. The authors' research [7] is exploring new constructs that offer mechanisms for delivering accessible value using the *system shell,* a value robust construct for mitigating the effect of changes in context and expectations by decoupling the system from the sources of change.

Bearing costs of latent value is an issue that the designer will need to consider. Building in latent product value, which may or may not ever be expected and desired by users, may be a difficult proposition, especially due to the potential for costs that may not be offset in the future. Strategic business decisions will need to be made to consider the worth of investing in attributes to deliver future value, given future uncertainty. Ongoing research seeks to understand product architecture choices that maximize future latent value at minimum cost.

Sometimes the presence of attributes may detract from perceived product value. Such is the case with products with excessive features that increase the perceived cost of usage. The casual phone user seeking a basic telephony experience is turned off by the camera, music-playing, feature-rich internet phone. In cases where attributes may detract from perceived value, it may be necessary to have the ability to "hide" these attributes from the users who do not which to see them. During design, costs and strategies for hiding presently unnecessary product functionality must be considered, along with the costs to activate, or unhide, this functionality if stakeholders change their expectations.

The cost of designing in future value and the cost of activating, adding, deactivating, and subtracting attributes needs to be considered in trade studies and product strategy. Using the attribute classification system is anticipated to result in long run cost savings and greater product success, however, the cost of the analysis must be considered. The authors are researching the effectiveness of such decision making through ongoing and planned case studies in our research program.

9 CONCLUSION

The product designers challenge to create products to deliver sustained perceived value is impacted by factors such as experience after use, changes within regulatory environment or marketplace, new technologies, and other emergent needs. Contemporary requirements elicitation processes, while sound, frequently do not adequately uncover unarticulated or latent value attributes during concept development. A method has been described that uses *attribute classes* to enhance a product designer's ability to anticipate new value expectations in the context of an overall value spectrum. The formal classification of product attributes within classes of articulated value, free latent value, cheap latent value, accessible value and inaccessible value is a structured framework for thinking about the types of value and the cost to realize it. The authors' systems engineering advancement research program at the Massachusetts Institute of Technology seeks to further develop the *designing for value robustness* methodology, including frameworks, methods, and value realization mechanisms.

10 ACKNOWLEDGMENTS

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