Product Concept Testing and Development Utilizing Internet-Based Visualization and Interaction

by

Jared D. Clark

Bachelor of Science
Western Michigan University, 1990

Bachelor of Mechanical Engineering
University of Detroit, 1998

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Signature of Author______
System Design and Management Program
December, 2000

Certified by______________
Ely Dahan
Assistant Professor of Marketing
Thesis Supervisor

Accepted by______________
Paul A. Lagace
LFM/SDM Co-Director
Professor of Aeronautics & Astronautics and Engineering Systems

Accepted by______________
Stephen C. Graves
LFM/SDM Co-Director
Abraham Siegel Professor of Management

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Abstract

Efficiently communicating a product concept to potential customers is a challenge to all PD organizations. Market testing that employs the use of virtual prototyping has been shown to yield predictions of customer preference that approach accuracy of results gathered from physical prototype testing. However, limited empirical data exists that supports these findings in the area of automotive exterior styling/theme market research. For development in this area, there is a deep reliance on costly physical prototypes to test and confirm product styling characteristics. Improvements in visual depiction technologies provide the ability to convey an extensive amount of information to be shared between designers and engineers today in the development of a product. These methods should be equally utilized as ways of sharing information between a development organization and its customers. It is clear this change will occur, however, when considering these methods as disruptive technologies moving from engineering to marketing, there are several inhibitors that require analysis.

Research was done to determine what information exists for visualization of the product within the PD process, what the sources are, when it is available and how clean is it for presenting to the customer. A particular focus of the analysis will be the issues and complexities involved in collecting and presenting solid models of large assemblies. Issues are addressed of how much detail to present, what organization collects the data and what preparation efforts are involved. Also, an evaluation of what technologies exist for presenting graphics over the Internet was performed, including what the limitations are today and what future trends are expected. Experimentation methods were proposed to effectively determine what visual depiction mode is most effective for each product characteristic or attribute. The research shows that inhibitors of an efficient transition of widespread use of these methods can be traced to the following: 1) transfer of information between functional organizations; 2) level of trust in customer articulation of preferences; 3) total product data integration; 4) management of legacy product data.

Thesis Supervisor: Ely Dahan
Title: Assistant Professor of Marketing

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1 Introduction

1.1 Background

Given the current state and future trends of technological capabilities in the area of computer graphics and broadband networking, this paper examines what processes and organizational alignments a company such as Ford Motor Company should be adopting to optimize the utility of visual product information to best capture customer preferences. This research sets a primary focus on automotive exterior styling and theme development.

The particular focus of the analysis will be the issues and complexities involved in collecting and presenting models of large assemblies. Issues are presented of how much detail to present, what organization collects the data and what preparation efforts are involved or required. Further analysis will involve an evaluation of what technologies exist for presenting graphics over the Internet, what the limitations are today and what future trends we can expect.

1.2 Problems with conveying visuals

Communicating a product concept to potential customers is a challenge to all PD organizations. Improvements in visual depiction technologies provide the ability to convey an extensive amount of information to be shared between designers and engineers today in the development of a product. These methods should be equally utilized as ways of sharing information between a development organization and its customers. It is clear this change will occur; however, when considering these methods as disruptive technologies moving from engineering to marketing, there are several inhibitors that require analysis.

A reliance on full-scale physical prototypes for market testing results in very few customer reviews of vehicle concepts due to cost and timing constraints. When concept selection is performed, the concepts shown have not gone through extensive engineering, manufacturing and cost feasibility studies. Between the time a vehicle program is kicked-off with a chosen concept theme and the outer surface development is frozen and transferred to engineering for detailed design, there are approximately 16 months. During this time, numerous modifications are made to outer surface and other elements of the selected theme. In that time there is a "disconnect" with the customer, decisions for many changes, esthetic and functional, are handled internally without customer feedback. This paper examines the difficulties and barriers to effectively conveying a complex product visually. Even with the sophisticated graphics technologies used within the product development community, very seldom is this type of information used. This raises many questions of why virtual concept testing is under utilized. Is this a conscious decision management has made until key parameters change, or do key organizational and procedural conflicts override this decision for full utilization?

Under this premise, the following research reviews and supports two basic theories: 1) Enhanced media richness and interactivity will influence the results of market research, specifically, with the use varying levels of visual representation of a product in an Internet-based environment. Reference to previous research will show that the attention of the respondent will be captured more successfully with use of elevated media richness, leading to more accurate revenue and market share predictions; 2) The current state of implementation of visualization is not optimal at Ford Motor Company. There is a lack of effort to test and correlate between physical and virtual market testing in the area of exterior styling. Ford should be further along but has specific problems or barriers it is trying to overcome. Under this assumption, the following are theorized as being key in the implementation and advancement of product visualization in market research.

- **Organizational and procedural**
    1. Total product data integration
    2. Management of legacy product data
    3. Corporate control – trust in customer articulation
    4. Extending product visualization from engineering to the consumer–organizational and technical barriers
- **Appropriation of design concepts**
- **Technological limitations –bandwidth and data compression**

The above are considered to be key barriers that are unique to a large organization that is involved in the commercialization of products that are complex systems requiring a product development community to be divided among many module and attribute teams. Specifically, the products that must compete in the marketplace on attributes of aesthetics, appearance and feel as well as those that can be quantified by an engineering specification. This paper examines the importance of achieving the ability to convey visuals quickly and clearly and what organizations need to be aware of to facilitate a transition to this new method of conveying a product concept to a customer.

2 Market Demand for product visualization information

2.1 The Internet – a driving force in market research evolution

The advent of the Internet and supporting technologies provides the framework and necessity for the research done in this article. The term Internet as used in this research is meant to include all internal (intranet) and external information or communication technologies used within or by an organization. A Forrester industry report discusses how key advantages of the Internet lie in the fact that most essential barriers previously faced by product marketers are removed by the use of such technologies. Past barriers, including geographical location, time zones, physical accessibility, and language are eliminated. This provides a business environment with very few constraints that existed prior to the existence of the Internet. The business processes and corporate culture that has been developed with these constraints ingrained are in need of analysis for consideration for adaptation to an Internet-based business environment. The primary driver of the recent expansion of the Internet (the WWW) is that of product and service marketing initiatives. Companies have been using it primarily as a resource for providing product information to potential consumers. Essentially, it has been used as another form of advertising media. However, the key benefits that will be realized as the Internet develops and bandwidth increases, are those gained from a transaction of information with present and future consumers. Companies, especially those with global markets, have the potential to easily include the consumer in the development of new products and the refinement of existing product lines.

Quelch and Klein [1] show that data collected over the last several years on Internet usage demonstrate that retail sales of new products have been limited to or concentrated within certain product categories. This is due to 1) distinctive demographic profile; 2) type of product information most easily presented electronically; 3) trade regulations; and 4) transaction security concerns. These barriers are predicted to also be major contributors to implementation and utilization of product visualization data as companies start to use the Internet as an information-transaction vehicle for market research in the development of new products. For example, market research demands a homogeneous population to sample to accurately develop needs-based segmentation do "first choice" concept testing. A comparison of demographic profiles of Internet users, both foreign and domestic, showed that audiences are skewed toward college-educated white males in their thirties [6]. As Internet usage maintains its dramatic growth rate, these adopter profiles will become much more heterogeneous and become a more attractive avenue for feedback to marketers. Other issues, such bandwidth limitations and data security, that exist for the consumer when making a purchase decision over the Internet will become critical, also, for virtual concept testing and market research. PD organizations trying to convey the visual information that yields effective responses need to work within the constraints of the network and may decide to conduct market research without using the Internet. This is because they may feel their concepts are not represented sufficiently graphically or because the risk of failure in transaction security is too high based on the level of innovation being conveyed. These concepts are explored in more detail later in this research.

2.2 Visualization in product development

In support of the assertions contained in this research, it is important understand the past and future trends of the visual culture within a product development engineering community. As organizations move to more customer-oriented design methods, it will be critical that the benefits of visualization are incorporated in the development of the new market research tools brought about by new communication and information technologies. It is possible that optimal visualization techniques have, or will, lag in usage for marketing new products to consumers. For example, just as upper management of a business unit will require detailed product renderings to make a decision, a consumer requires probably the same level of information to make a purchase decision. Henderson introduces the term, “conscription device”, to describe how engineering visuals operate as network-organizing devices. Under this construct, visuals are used to enlist group participation and are receptacles of knowledge that are created and adjusted through group interaction with a common goal. To participate at all in a design process, actors need to engage each other through use of visual depictions of the conscription device. Participants, or respondents, will then focus their communications in reference to the visual device [16]. Dahan and Hauser identify three categories of capabilities that have been dramatically enhanced by advancements in Internet and broadband technologies. These new dimensions of web-based customer input are: Communication, Conceptualization, and Computation. These capabilities are identified as key to allowing for rapid customer input to provide the consumer driven products needed to compete in the market today. Particularly, Conceptualization utilizes the graphic capabilities of multimedia computers to depict virtual products and product features. PD team can test their ideas and preliminary design earlier in the process, well before physical prototypes are built. Although prior research has used virtual prototypes and information acceleration in central-location interviewing, these capabilities are now available on the web and, further, the multimedia prototypes are easier to develop and can be rendered more realistically [24].

Also, Dahan and Hauser point out that in this rapid communication environment, respondents will be providing feedback from the comforts of their home or workplace, often in isolation. Unlike the controlled, structured environment of a traditional central facility, respondents are free and more apt to terminate or avoid an on-line interview if they feel the incentives provided do not justify their time. To win use of their time, interfaces that are engaging, interesting, and convey information as quickly as possible will be extremely desirable. Therefore, optimal visualization techniques will be at premium in this environment.

2.3 Effects of media richness on customer preferences and perceptions

As stated earlier, it is hypothesized that enhanced media richness and interactivity will influence the results of market research, specifically, with the use varying levels of visual representation of a product in an Internet-based environment when applied to automotive exterior theme evaluations. When there is an increase in the level of graphic quality and detail, as well as interactivity with that visual, there is a corresponding increase in the ability for a respondent to understand what is being conveyed. Particularly, an Increase in media richness will provide an accelerated or increased understanding of vehicle *craftsmanship* and *proportions*. These characteristics are the most difficult to convey without a true feeling of presence felt by a respondent when asked to evaluate a vehicle in those terms. Technologies providing increasing media richness are a point where, in many cases, the ability exists to convey the above characteristics and get responses that approach those received from viewing the physical object. Therefore, it is predicted that there will be an increase in the confidence of the response or decision in a comparative market study. And, that an increase in media richness will foster more detailed and creative feedback in a subjective survey.

Craftsmanship

In recent years, vehicle exteriors have become very similar. Aerodynamic shapes, which are driven by a desire for good fuel economy has had a dramatic influence on overall styling. Cars and truck are not differentiated as they were in prior decades. Since, in recent years, vehicle themes have evolved to having very similar styling cues and features, there is an increased focus on craftsmanship.

Consumer purchase factors have evolved over the years. During the ‘60s, styling was a key purchase feature. With the OPEC oil embargo during the ‘70s, a key purchase motivator became cars that provided good fuel economy. Quality and reliability in vehicle purchases were key motivators during the ‘80s. Japanese products, which had great quality and competitive prices, took over the market. With the improved quality from Ford products and other American-made products, the costs of vehicles became very important to the consumer during the ‘90s. As the ‘90s came to a close, and quality has leveled out among vehicles, the extra detail in vehicle design, craftsmanship have become a deciding factor.

Craftsmanship has become a key attribute to be met by vehicle program teams in satisfying customer wants. It can be considered to cover the consumer's vehicle perception in the areas of what is seen, touched, and heard. However, the term craftsmanship, in this paper, refers specifically to visual aspects of the product in question. In general, good craftsmanship draws the attention of a customer and conveys a perception of high quality.

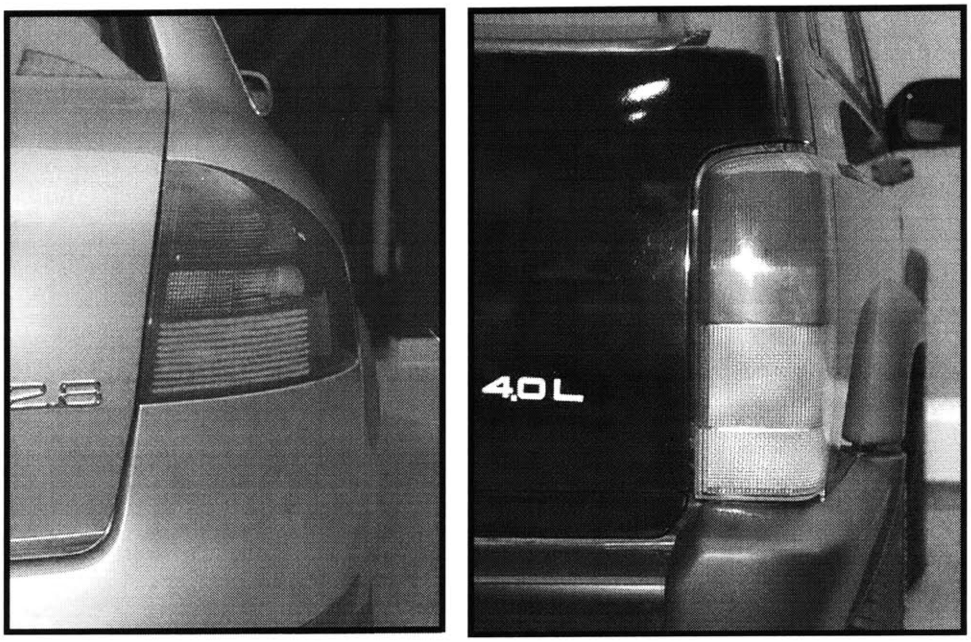


Figure 1 - Craftsmanship Comparison

For example, in Figure 1 above, two vehicles are compared in terms of their craftsmanship in the tail lamp area. The image on the left is that of an Audi A6, which receives the highest of subjective craftsmanship ratings and used by most competing manufacturers in its segment for benchmarking purposes. The vehicle on the right is a Jeep Grand Cherokee, which has been given amongst the lowest of subjective craftsmanship ratings. Though these vehicles are in different market segments, the images demonstrate the aspect of visual craftsmanship. In this context, good craftsmanship means small margins between body panels and also very little variation in those margins. Also, it is a measure of how "cleanly" subsystems on the vehicle interface with each other. For example, stylists often try to minimize the number of margins, or interfaces, coming together and maintain a consistent flow of how these edges align, even when disrupted by other mating vehicle subsystems, in this case lighting. This example demonstrates the subtleties of craftsmanship. A customer needs to have very precise, detailed visual information to assess preferences for this type of attribute. Clearly, a certain level of presence, or perception thereof, is necessary to achieve this. It is contended that visualization technologies now approach this level.

Proportions

Correct vehicle proportions are considered to be one of the key challenges to styling a vehicle in a way that is appealing to the average car buyer. Good vehicle proportions can be defined as a coming together of subsystems and features in a way that optimizes the systems' visual appeal in terms of relative size, location and shape relative to each other and the surrounding environment. A manager within one of Ford Motor Company's design studio stated:

> *"The customer can only articulate to an extent, for example, they might say 'something doesn't look quite right, but I don't know what it is,' this often can be quickly interpreted by a skilled designer as bad proportions."*

Figure 2 - Establishing a Sense of Proportion

The above statement was made during a discussion of why it is so important to do market research on styling themes using a full-scale physical prototype. Proportions are viewed as being very difficult to convey using most visual media. Even with the use of detailed CAD/CAID (computer-aided design / computer-aided industrial design) models of the vehicle, design managers feel that a realistic environment is still required. The example images in Figure 2 illustrate the contrast between different levels of media richness that affect the sense of proportions observed by a respondent in a market test.

The image on the left represents a typical image that may be viewed using a VRML format in an Internet–based survey. The model can be manipulated, scaled in or out, and reoriented. However, it fails to communicate a sense of proportions as the image on the right does when shown within an environment. Proportions can also be communicated to different extents using visual media without modeling or showing the entire environment, as in the photograph. This can be achieved by including other objects as references in the scene, such as a virtual model of an occupant standing by or sitting in, the vehicle. Also, it is theorized that as the image quality and interactivity is increased, the sense of proportion conveyed is also increased. For example, a very high-resolution display used with a 3D model that can be manipulated and scaled with very little loss of detail, will give a respondent more information on how the vehicle is styled. By having the ability to view the product from an infinite number of perspectives and distances (zoom scale), the respondent will choose what information is needed to establish his/her own sense of proportion.

Comfort (ergonomics)

Conveying how a vehicle feels in terms of comfort and roominess is very difficult using visual depiction. This applies to evaluation of vehicle interior packages. Today, physical prototypes are developed very early in the program to be used in market research clinics in order to obtain customer feedback on interior roominess, reach comfort, and visibility within the vehicle. Feedback obtained from a virtual simulation using the latest technologies approaches the accuracy of a physical test. However, this will require advancement in haptic-response technologies. It is theorized that companies will eventually utilize virtual ergonomic market tests, but this will occur much later than the adoption of virtual simulations that assess visual responses. This will be due, in part, to the fact that physical prototypes, fabricated for ergonomic studies, are usually very simple representations of the vehicle and are relatively inexpensive to make, compared with a prototype used for appearance or theme approval.

2.4 Experimentation in Visual depiction and interactivity

With the advent of the Internet and rapid development of visualization technologies in computer aided-design, there is much interest generated in its application for product development, market research, and retail. However, there is still much experimentation required to establish what defines interactivity and a virtual experience through visual depiction for various product classes and characteristics. This research focuses on the inherent problems of presenting a product visually to a customer. The basis of this research assumes that visual depiction and increased media richness improves the quality of market research results. What needs more clarification is how "realistic" these visuals must be to achieve a point of diminishing returns relative to the results achieved from a test with a physical prototype. It is theorized that current technology, when utilized effectively, could be more than enough to gain effective insights from customers. Managers, however, still have an unjustified reliance on traditional methods because of limited empirical data for each product and product characteristic.

Although it has been proven that direct consumer experience in marketing is a much more effective mode of communication than traditional advertising, Wright and Lynch identified a distinction between search attributes and experience attributes [17]. They found that direct experience (which advanced Internet or computer-based visuals try to emulate) was effective for communicating experience attributes, but not necessarily search attributes. Experience attributes are generally attributes that are categorized as those a person would relate to taste, fit, and feel [18]. It is theorized in this research that styling attributes, such as craftsmanship and proportions, fall into this category. Although they are visual aspects of a vehicle they elicit a certain emotion or "feel" from a customer.

Klein examines what determines a consumer response in a decision-making environment. This work supports the contention, in this research, that high quality visuals are beneficial. Here the construct of telepresence is identified as key to transmitting information, facilitating learning, and formulating beliefs when using this advanced medium [12]. Telepresence can be defined as a sense of presence in a remote environment that is greater than the sense of presence in the physical one. Research by Reeves and Nass demonstrated that even computer-mediated environments produced by technologies that are considered to be "outdated" are more than adequate in providing a sense of telepresence.

> *Even the simplest of media are close enough to the real people, places, and things they depict to activate rich social and natural responses. Many of our studies generate these responses with rather pathetic representations of real life: simple textual and pictorial material shown in garden-variety technology. The equation still holds, however. Mediated life equals real life ... [There exists] a critical human tendency to confuse what is real with what only* seems *to be real [19].*

The creation of telepresence, according to Klein, requires 2 key media characteristics. These are, interactivity and media richness. Interactivity is define and operationalized in terms of potential for user control over the environment [12]. Media richness represents the sensory breadth and depth of the stimuli [20]. Klein's experimentation shows that the higher the levels of interactivity and media richness of a computer-mediated environment, the greater the level of learning, as measured by recall, recognition, accessibility and retention of attribute claims. This is accompanied by an increased level of persuasion, as measured by the strength, accessibility, and retention of attribute beliefs. Also, overall attitudes formed, as measured by attitude intensity, accessibility, and persistence over time will be stronger [12]. These cited responses are what is to be expected from the utilization of the engineering CAD/CAID product data that is examined in this paper.

Englis and Solomon analyze a Web-based data collection technique called Life/Style Online©. They argue that today's Web-based marketing techniques do not fully exploit the capabilities of online media to probe deeply into consumers' motivations and preferences [14]. Existing methodologies are still largely focused on written or spoken words and need to adapt to the enhanced possibilities for visual research on the Internet. The *uses and gratifications theory* is cited to point out the shortcoming of the passive perspective of traditional mass communications, such as print ads, television, or radio. These traditional methods basically project a message repeatedly to consumers in the hope that there will be some attitudinal or behavioral response generated in the form of increased liking or purchase intent. This theory argues that the audience is active and goal-directed. Therefore, interactive, visually oriented media provides more information to marketers because if they receive information about what respondents do with the media, not just how they were affected by it. Life/Style Online© was developed to identify fashion trends among young female consumers. This project successfully enhanced the responsiveness of the American apparel and textile industry in this rapidly changing market. The basis of the method was that it was the Web-based interactive data collection technique that allowed respondents to manipulate visual images of products as a means of expressing their preferences. These preferences in fashion were also placed into the context of other lifestyle choices. This type of technique is directly applicable to any product that competes on styling attributes.

Another technique, known as information acceleration (IA), has been used on several consumer products in the past. IA is a method that employs a virtual representation of a product and uses computer-mediated visuals as a key source of conveying product information. For example, IA was used to create a virtual showroom for an electric vehicle in which the potential customer could "walk around" the car, "climb in" and discuss the car with a salesperson. The customer could access television advertising and consumer magazines and even read prices from a virtual newspaper. All of this information was simulated on a multimedia computer [13]. This technique was applied to forecasting the purchase probability of a two-seat Buick sports car. A control car, a Mazda RX-7, was used to help validate that there were no significant differences between a virtual and physical showroom. Results from analysis by Urban and Hauser suggest through internal validation that there was no significant difference between showroom type, but there was a significant difference between automobile types [13].

The interactive environment offered by a visually oriented Web-based market research tool can be viewed as an advanced method of allowing the respondent to control the information being received. Ariely presented a general model for understanding Information-Control and how it impacts a consumer's decision quality, memory, knowledge, and confidence. Results from experimentation show that controlling the information flow can help consumers better match their preferences and increase confidence in judgment [15]. Negative effects must also be considered as interactive research environments are developed. Results from experimentation suggest that respondents may be overwhelmed by the task of managing information flow, resulting in a limitation in their cognitive resources. Therefore, an effective interface between marketer and consumer will be dependent upon having a low complexity interface or a respondent base that can handle the high cognitive load imposed by an interactive virtual environment. This means that, as consumers become more accustomed to a high-information control environment, their cognitive efforts will be reduced. This aspect will take part in the rate at which market researchers adopt new interactive research techniques, because the accuracy of results will increase over time, accelerating acceptance by the product development management community.

2.5 Concept selection – visual data availability

Reduced time to market and increased new product introduction rates are now shaping the auto industries product development processes. This new environment is the result of efforts to keep pace with new technological clock speeds and consumer mass customization needs. Along with this is an increased need to be customer driven which is resultant of the extremely competitive environment, which is characteristic of a mature industry. Therefore, the challenge becomes getting accurate and timely information from the customer during product definition and development. The possibility of gathering this information through market research presenting customers with virtual representations of concepts has become more cost effective in recent years due to advancement in visualization software and supporting hardware. Also, increased Internet bandwidth and usage have increased to a point where quite accurate market test sampling can be achieved efficiently though internet-based research. The automotive industry could be considered to be in a transitional phase where there is a movement from physical to digital prove-out of product concepts. The design studios develop advanced digital surface renderings and eventually hand this approved surface data to engineers and designers for detailed design and CAD solid model development. Even though this process could be done entirely with computer modeling, most often management will rely on iterations of clay or dense urethane foam models for surface approval as well as attribute prototype builds to prove-out functionality or performance rather than sign-off on analytical simulations using CAD/CAE methods. Even though 3d models are developed and maintained throughout the PD process to allow visualization of the product, this information is used as an enabler for communication of the current design intent between engineers, management and suppliers. Presentation of this information to the customer for evaluation may not be effective because it often is not "clean" or detailed enough. As product visualization and design tools become more advanced management reliance on intermediary physical prove-out models will no longer be required and virtual modeling will become the baseline for evaluation and development until confirmation prototypes are produced.

In a vehicle program, concept selection is performed using visual product data that has not gone through extensive engineering, manufacturing and cost feasibility studies. There is approximately 16 months (between kick-off<KO> and surface transfer<ST>) of iterations to the selected theme that happen as engineering feasibility is negotiated with the design studio. In that time there is often a “disconnect” with the customer. Decisions for many changes, aesthetical and functional, are handled internally without customer feedback. Cost and difficulties in generating up to date visuals for presentation to the customer drive this disconnect.

Since it has been shown that Web-based approaches to market research that utilizes visualization and interaction is more engaging for respondents, resulting in improved decision quality and memorization, concept testing with virtual models taken from mainstream PD process will prove to be an ideal and cost-effective method. An evaluation of the utility of these virtual models for market testing needs to be performed as this transition phase occurs. Dahan and Srinivasan introduce an Internet-based product concept test method that incorporates the visuals of virtual prototypes of new product concepts, in place of physical prototypes. The approach explores the effects of displaying static and animated virtual prototypes over the Internet using three-dimensional representations. In this research environment, the shopping experience is limited to a computer-mediated interactive Web page for the respondents. Their results show that both static and animated virtual prototype testing produced market share predictions with high correlation to results obtained from physical prototype testing. Results also outperformed those obtained from text based, attribute-only conjoint analysis [23].

Currently, the technology exists to accurately model and present visually (in web-based format) almost any desired level of detail to the consumer at effective interaction speeds. Questions then arise, not only of how the accuracy of results compares to traditional testing, but also, how much effort, cost and resources are drained from a product development program.

3 Product visualization information – methods and processes

3.1 Image generation and depiction methods

There are numerous combinations of image types and multimedia data representation methods available that can be used for conveying product information in Web-based environments. Table 1, below, summarizes these image types and techniques along with their respective origins. Prior to discussing why each representation method may best depict a particular product characteristic, the difficulties, costs, and key requirements associated with each method is analyzed. The software and hardware technologies that drive the computer graphics industry in terms of functionality, efficiency, and quality are changing rapidly with an extremely high rate of product introductions and upgrades. The intent of this portion of the research is not to determine the best or latest methods/tools on the market but to identify what methods are currently being utilized in the automotive PD environment to communicate information within the organization. Below, a look at how these various formats could be presented in a Web-based user interactive environment, are first discussed, followed by a discussion of image-generation methods.

Depiction Method	Image Type	Origins
Static	Artist's sketch	Virtual
	3D CAD model	Virtual
	3D CAID rendering	Virtual
	Photographic imagery	Physical
Dynamic	Live video (.avi, Quicktime)	Physical
	2D animation (.avi, Quicktime)	Virtual
	3D CAD model animation (EAI)	Virtual (CAD)
Manipulative	Dynamic imaging (i.e. IPIX)	Physical
	VRML / 3D CAD model	Virtual
	3D acquisition (Eyetronics,Metaflash)	Physical
	Multipath animations(i.e. B3D.com)	Virtual
	VRML / photogrammetry	Physical

Table 1 – Example Visualization Media Modes

3.1.1 Representation media

It is worthwhile give definition to the visual representation media mentioned in Table 1. All can be considered or made "interactive"; however, each offers an incremental level of control over the visual depictions experienced by a respondent in a market research application.

Static

Static media refer to the display of a still image embedded in a Web-based application. The content of the image may have been generated from any of the methods described below. This could be anything from a digitized artist's rendering to a still image of a computer-rendered digital model with shading, textures and depth perspectives.

However, the respondent interacting with the image sees only a single instance of the object at a set scale and orientation.

Dynamic

This form of visual representation introduces motion to the respondent's viewing experience, this can be achieved by using several image-generation procedures. This medium offers no additional control to the respondent over the visual. However, it does supply and require significantly more information than a static medium. A live video requires a physical prototype and a virtual animation requires extensive 3D model generation, rendering and animation skills, software and hardware. Also, significant product data management processes must be in place in a large company to bring the information together. These tasks are analyzed in more depth later.

Manipulative

A Manipulative representation medium introduces additional information and control over the visual the respondent is interacting with. This form of visual allows or gives the perception of changing scale, view orientation, or perspective of a model or image. High quality manipulative imaging can be achieved easily by using a high-end local processor. However, considerable limitations exist when these visuals are employed in a Web-based environment. A standard file format, such as VRML, offers a solution with several key constraints that result in barriers to full utilization of these technologies in market research.

3.1.2 Image generation and depiction methods

There are numerous methods available for developing or capturing an image of a product concept for representation within a PD organization or to a consumer. These methods should be divided into two distinct categories in terms of the origin of its graphic content, either physical or virtual. Images generated from virtual origins precede physical prototype modeling and, in most cases, will be the low-cost alternative for communicating the product visually to the consumer or the product development community. Adopting the low-cost alternative has been proven to be critical in any mature competitive industry. Specifically, research done by Stevens and Burley [25] show that only a small number of product concepts released into the market actually become profitable. This notion, along with research done by Dahan and Mendelson [22] show that, through the use of extreme value theory, the optimal number of prototypes tested in parallel increases when time-to-market is critical and cost of producing prototypes significantly affects the economics of the product development program.

These theories clearly apply to the mature automotive industry. In addition to several documented first-to-market advantages, reduction in time-to-market is extremely important for products with aesthetic or fashion-oriented attributes Automotive exterior stylist attempt to capture future styling trends as a vehicle is developed, their forecast predictions become less accurate as this time is increased. In terms of prototype costs, it is important to point out Utterback's [2] theories of product and process trends resulting from the emergence of a dominant design. Clearly, the automotive industry has long since established a dominant vehicle design and has moved to stages of incremental product innovations and focuses much effort on process innovation in order to maintain competitive pricing in the marketplace (see Figure 3).

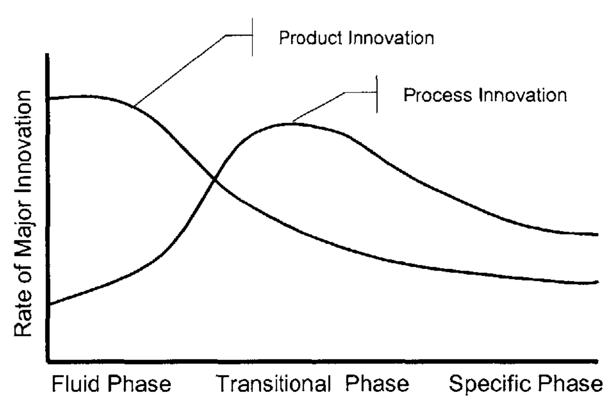


Figure 3 - The Rate of Product Innovation [2]

This notion provides a major incentive to reduce prototype costs. In this latter phase of process innovation, automotive firms need to direct financial resources at methods to produce vehicles cheaper and, at the same time, minimize product development costs. Also in this phase, innovation in vehicle development that improves product performance at small increments become less likely unless the customer can easily evaluate in comparison to competitor products. This fact supports the necessity for a high number of concept variations to be market-tested in parallel. In short, the competing firms need to maximize their sales and market shares by focusing on development processes that clearly capture attributes that matter to potential customers.

When the above notions are considered when making decisions on how to approach concept testing of complex systems such as automobiles, alternatives for images of physical or virtual origin should now be considered in term of their associated costs and benefits. Under the assumption that a Web-based medium is used for market research, physical prototypes may, in some instances, be optimal for reasons of virtual modeling complexities or due to the types of product attributes being tested. Benefits, limitations and costs associated with developing visuals that originate from physical or virtual modeling will be discussed along with an analysis of what considerations need to be taken in the selection process. These considerations, of course, will be primarily dependent upon the phase of the PD process.

The following is a discussion describing each image type mentioned in Table 1 and how they are developed from the perspective within a typical automotive PD organization.

Artist's sketch

Artist's sketch will be defined in this research as any type of artistic depiction of a concept that is drawn manually by an industrial designer by use of visual or mental imagery. Visuals that fall into this category are those that are images with 2D and 3D content depicted in a two-dimensional medium. This type of visualization technique is the quickest and does not necessarily require computer resources to be allocated.

Although most often these types of images are input electronically using a graphic tablet and software such as *Alias/Wavefront 2D* . They are often drafted manually and converted to a digital format by use of an optical scanner. This is the medium that has traditionally been utilized for automotive exterior/interior theme development in early phases of vehicle a program. A typical sketch depicting a vehicle's exterior theme is shown in Figure 4. These types of images are currently used extensively for theme development and as a method of communicating this effort internally among designers and program management. This occurs primarily in the phase between when program specific work starts <KO> and when strategic intentions are established <SI> (see Figure 13).

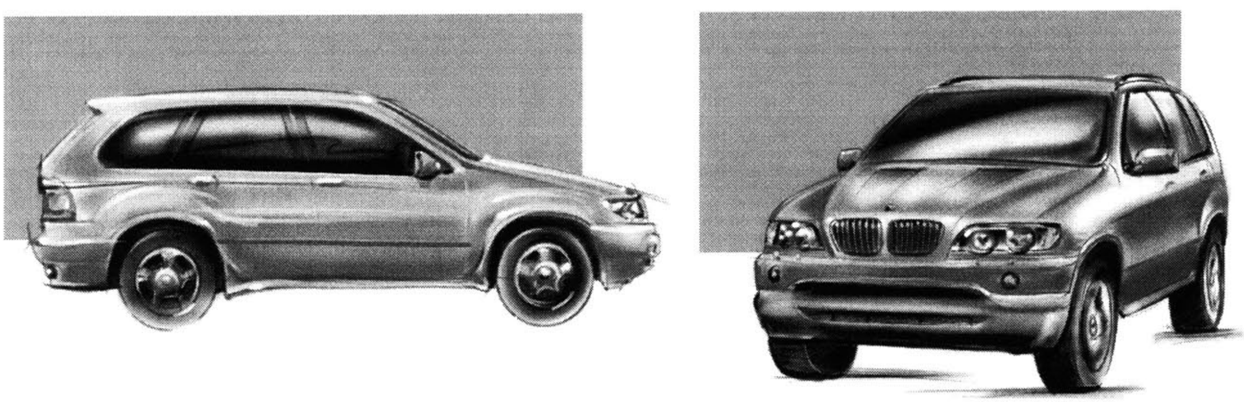


Figure 4 – Artist's Sketchs for Concept Development

3D CAD model

Computer-aided design can be divided in to three different model types when working in a 3D environment: *wireframe*, *surface*, and *solids*. Each model type is still utilized within most product development organizations. The visualization information that becomes available for marketing research depends on what type of modeling is performed, when it is done, and how clean and clear it is for presentation to consumers.

A wireframe is simply a series of 2D lines, arcs, and/or circles given a third dimension (termed the Z height). The wireframe is useful as a visualization tool to view the 3D object you want to create. However, viewing a wireframe model in a 3D orientation is extremely ambiguous and unclear. It is really useful only for the internal communication of product data between engineers. A wireframe model can be thought of as a 2-1/2D model. The resulting model is similar to a coat hanger bent it into a 3D shape to represent a product. On the other hand, a surface model is a wireframe with a surface coating that allows you to visualize the object with slightly more understanding. Finally, a solid model is a true 3D model. You use a variety of 3D primitive shapes and extrusions to build up the model into the overall shape you want. The backgrounds of these model types are discussed below.

Wireframe models

A wireframe is the most fundamental type of 3D model. It's a skeletal description of a 3D part, built up from a series of lines, points, and/or arcs. A wireframe model lets you examine the 3D edge characteristics of the part, as they actually exist. You'll find no surfaces in a wireframe model. Because you see the part from all sides, a wireframe provides a visualization method that is a step up from viewing the lines sketched in "true" or "projected" views done in manual drafting. These standard views can be generated after the part is modeled, viewing in 3D helps this process and it gives you a framework on which to place surfaces. Wireframe modeling was adopted by Ford in the mid-'70s and used as the corporate tool up until 1996 when a solid-modeling tool was adopted. Therefore, most vehicle programs that exist today have been developed and documented with wireframe data. The fact that this data is wireframe based and accounts for such a large portion of product data available, is a contributing barrier to utilization of graphic depiction for consumer research and is discussed later in this paper.

Surface Models

Using sculpted surfaces, and some CAD systems use a more general representation called a sculpted surface. Sculpted surfaces are created by one of a family of surface commands that generate parametric surface patches of Coons, Ferguson, or Bezier techniques. You can use a sculpted surface to create a transition between adjacent surface edges. Typical surface types include surfaces of extrusion, surfaces of revolution, ruled surfaces, tabulated cylinders, planes, and swept and lofted surfaces. A surface model is, essentially, a thin 3D "shell" accurately formed in the shape of the part you're going to create. Surface models contain information about the profile edges of the object and the space between those edges. A surface model is created by combining 3D, topologically closed, curved, and flat surface elements to form a shell that encloses the part. Comparing surface to wireframe models, surface models provide more detailed information about the shell or surface of the part you're modeling. In vehicle body panel design, surface models are used for development of any surface that is considered "Class A," which means that it is visible to the customer and contains any sort of nonlinear "styled" surface. These surfaces originate from CAID (computer aided industrial design) software packages and are discussed later. With a shaded model, a surface model can be used to create a faceted model for a shaded rendering.

Solid Models

Solid modeling differs from wireframe and surface modeling in two ways: The information is more complete, and constructing the model is more straightforward. Often, a solid model maintains two principal types of descriptive data: topology data and geometric data. With some CAD systems, as you create a solid model, the system maintains the model's boundary representation, as well as a record of the primitive shapes and operations used to create it. A solid model is also more capable of being rendered and having material and texture mapping applied to the model for photo-realistic renderings. To compare solid models to surface and wireframe models, solid models generate the most information about a part. They also contain enough data to support downstream applications. Wireframe and surface models are more error-prone than solid models. For instance, wireframe models often have dangling edges, and surface models may be missing closures.

CAD solid modeling is now the mainstream development tool within the automotive industry. This latest generation of CAD software provides a model of the product that is fully surfaced and able to be shaded, colored and rendered, and sectioned instantaneously. The product models and assemblies that are created as surface or solids have much greater utility from a visualization or conceptualization standpoint. Although there is more effort and resources required to develop them, they contain a level of visual information that provides a higher level of results from internal and external evaluations. It is important to note at this point that when wireframe modeling was used as a standard corporate tool, there was little use for the resulting visual information outside the engineering community. A wireframe model could really only be confidently interpreted by the technical staff involved in the development. As surface modeling technologies developed, they started to be utilized within the automotive PD community just to model complex surfaces such as exterior body panels or interior trim components. These parts were only partially surfaced; just the outer "skin," This was done to take advantage of CAM technologies for cutter path development, mold flow or aerodynamic CAE analysis. Since, at that time (mid '80s), even a high-end UNIX workstation, which was the standard hardware used, did not have the ability to shade and render these surface at feasible speeds. Therefore, these models offered very little utility as visual aids. That being the case, product data was released entirely as wireframe data. Products were rarely completely surfaced for the visual aspect. The graphics necessary for presentation to a consumer required the redundant task of manually surfacing every part of a wireframe model to close it off, to appear as a solid that could be rendered. This was cost-prohibitive and required extensive computing power. These tasks and limitations have changed in recent years as solid modeling tools having been adopted as corporate CAD methods. CAD packages, such SDRC's IDEAS used at Ford Motor Company, is a feature-based parametric solid modeling environment. Using this tool, designers develop and release all components of the vehicle as a solid model. Therefore, the model that is output is fully surfaced and ready to be further processed to add visualization properties to be used by marketing or other organizations.

3D CAID rendering

Computer-aided industrial design (CAID) is a method of product visualization used primarily for three different purposes at various phases in the PD cycle. Specifically, these correspond to activities of concept, engineering, and design visualization. The 3D models generated by CAID software packages are either NURBS - based (non-uniform rational B-splines) or polygon-based modeling techniques., whereas, all surfaces developed in a CAD modeling environment described earlier are NURBS-based. The distinction of These two model formats are of particular interest to this research and further analysis shows that in order to render or shade for viewing it must be a polygon model with a chosen polygon count, which defines the image quality.

1. Concept visualization

Visualization tools such as *Alias/Wavefront* are used by Ford Corporate design to prove-out vehicle concepts at early in a vehicle program. These NURBS-based models are developed in a software environment in which the model's surfaces are made photorealistic by mathematically mimicking the department cues that the human eye sees in real life, including perspective, shadow overlapping objects, and haziness over distance [9]. These are the characteristics that designers require that an image must possess before they can evaluate it and make a decision on whether it is acceptable from a styling standpoint or appealing to the consumer. This is an indicator of what corporate design management expects from image quality that is used in consumer research.

2. Engineering visualization

This image generation method is essentially a low-resolution visual tie-in to product data management systems. This level of visualization is not necessary for getting a vision of what the concept will look like, but rather to quickly sift through engineering databases of solid models of components and systems to establish a bill of materials or identify part usage [9]. These images are shaded polygon representations of the NURBS models generated from CAD and CAID systems. Figure 5, below, shows the 2000 Ford Explorer. This was the lead truck vehicle program to utilize solid modeling and engineering visualization tools.

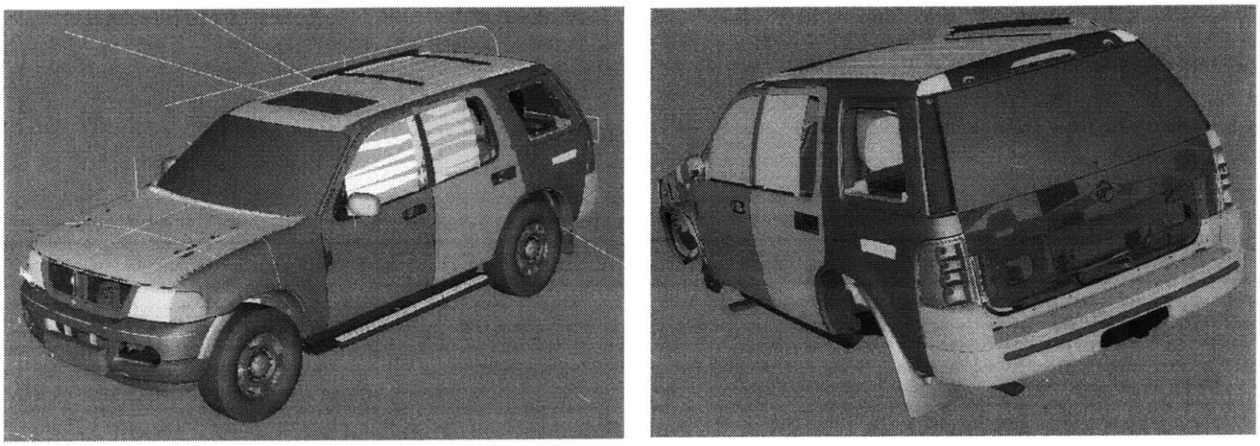


Figure 5 - Engineering Visualization Information / *EAI's Digital Buck*

EAI's *Digital Buck* is utilized within Ford Motor Company's engineering organization to satisfy this visualization need. This database is controlled and populated with data by engineering personnel; the product models begin being added at the onset of detailed design. This is done after styled surfaces have been developed and approved using the previously mentioned concept visualization tools. This surface information, once approved, is moved from CAID to CAD systems, where backside features, flanges and other details are modeled. As this work progresses, parts and assemblies are exported at their current design intent and translated into polygon models by a separate group that is dedicated to populating the Digital Buck database. This activity is significant to this research because the process allows all functions within the PD community visual access to the product at current design intent. This information is served from a central database and is accessible for viewing from PC or UNIX-based platforms using a standard Web browser. Figure 6 depicts the level of detail seen using this type of visualization. Although geometry is clearly defined, many other visual properties and smaller components are not represented. The tool is for engineering analysis. Graphic detail, such as proper color assignments, textures, and level of opaqueness are not shown. Also, material thickness is not added for sheet metal. Many times this results in surfaces visually overlapping when mating conditions are displayed due to inaccuracy of the visualization software.

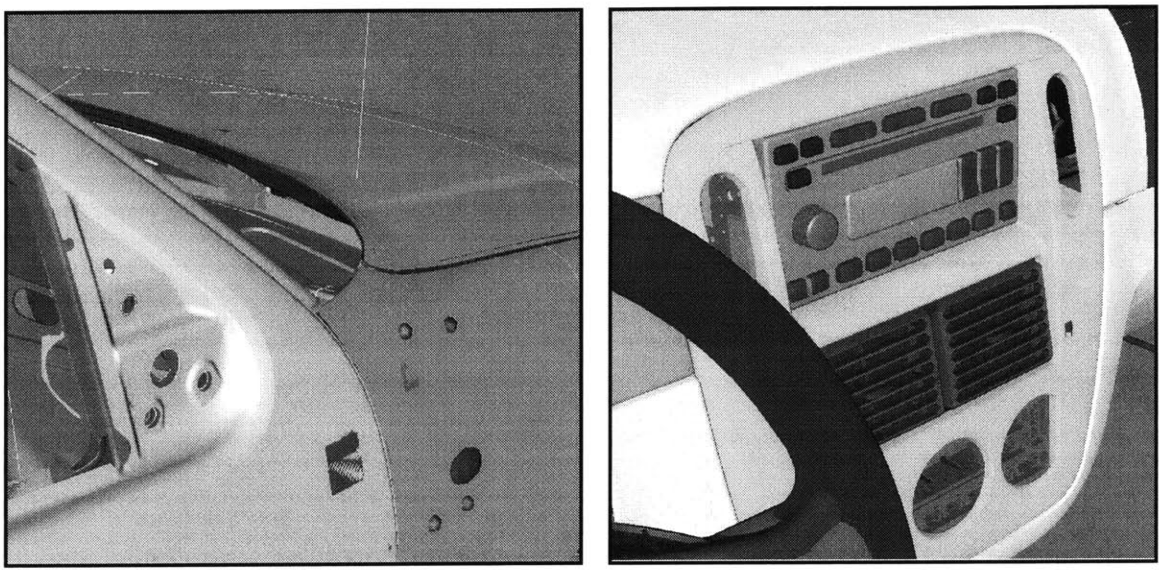


Figure 6 - Engineering Visualization Level of Detail

3. Design visualization

This type of visualization method is what has traditionally been used to date for virtual market research and internal styling evaluations. Design visualization software is used primarily at Ford by importing a CAD or CAID model into an animation and rendering environment software, such as *Maya*, to in order to generate high resolution images. The renderings or animations generated from this effort are used primarily for internal craftsmanship reviews or, occasionally, for external customer "virtual" clinics. The functional group that performs this work is used as a shared resource by all vehicle programs. Therefore, product data must be extracted from several database or software packages to "assemble" the required components or vehicle subsystems necessary for the evaluation. Once assembled, this data needs to be evaluated, refined and cleaned-up (see Figure 7). Often, since the product models are coming from different design groups and CAD packages, the data will be out of vehicle position or orientation. Also, often times smaller components are missing or have not yet been designed.

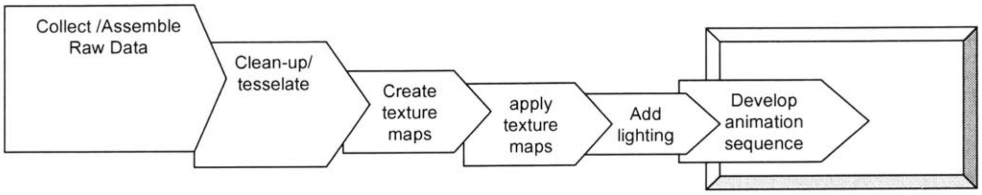


Figure 7 - The Rendering Process

For example, a rear fender of a truck that is used with multiple cab length's may be provided in a vehicle position (3D modeling pace) that is different from what is planned for the animation. This location needs to be measured and the model moved to the right location. Another example is when a rendering or animation is to be developed to show the vehicle exterior body panels and how the margins between mating panels and components, such as headlamps, appear. Often, the understructure, flanging, hinge hardware and other components are not available to realistically "fill" the door or body panel margin. This will result in extra modeling and refinement by the person doing the rendering. This "clean-up" step, along with collecting the data, requires a significant amount of time relative to the rest of the process. The next step is that of translating or tessellation from NURBS-based to polygon-based models. This step is a combination of manual and automated operations. This is the step that determines the trade-off between image quality and required processing power or view manipulation speeds. In this process, the polygonization, or polygon count, is defined.

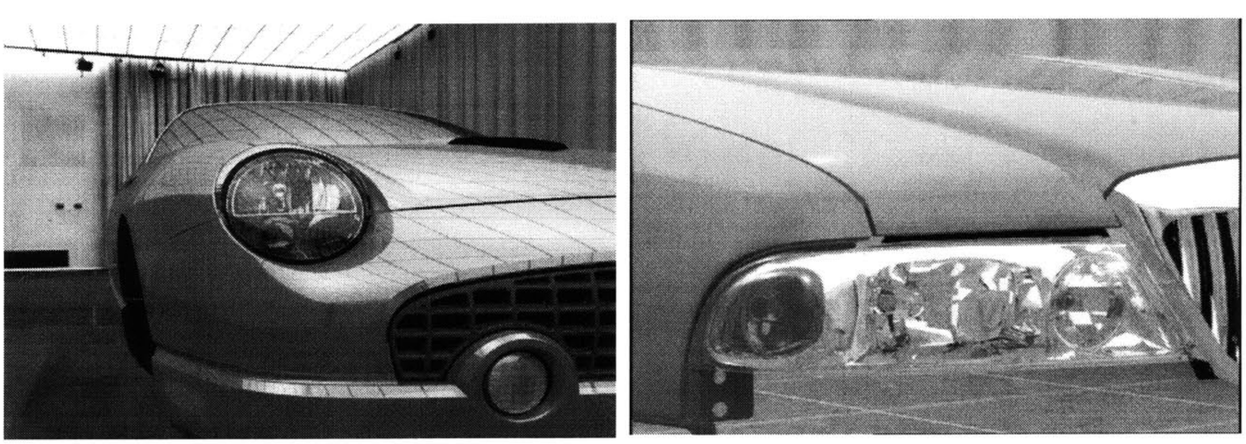


Figure 8 - High Resolution CAID Renderings

The modeler's try to minimize processor requirements by keeping a low polygon count on portions of the vehicle where the lighting or surface styling is irrelevant to the customer, such around a wheel-well opening. The large surfaces that catch reflections and highlights such as hoods and fenders are rendered with a very high polygon count and then are stitched together with the other portions. Figure 8 shows examples of rendering developed for internal craftsmanship reviews. To emulate true reflections and highlights that would be exhibited by a physical model, much time is spent to minimize polygon count in less visible areas to allow for increased counts in others, which reduces data rates and optimizes processing speeds. Once models are defined, the information is sent to an image generator system, which I composed of the following units: an IG host, a geometry processor, a pixel processor and a video processor. The IG host is basically a computer that talks to host computer The IG host also performs database retrieval duties and controls special-purpose hardware. The geometry processor converts 3D polygons into 2D perspective polygons as seen from the current viewpoint. The pixel processor converts the polygons into 2D perspective polygons as seen from the current viewpoint. The pixel processor converts polygons to pixels, and typically requires the most computing power, about 10 GFLOPS. The video processor converts the pixels to video, and sends the video to a display device [10]. Animations output from this process run at approximately 30 frames/sec., using rendered image frames that are, on average, 5 megabytes in size. This means processing hardware must handle 180 megabytes/second to produce an animation that is considered acceptable for a virtual styling review.

Important performance characteristics include:

1. Polygon capacity – Number of polygons that can be generated per second
2. Update rate – The frequency with which the IG calculates a new picture
3. Transportation delay- The lag time or number of frames delay of the IG when a new eyepoint position is received
4. Texture memory – The amount of texture memory on-line
5. Anti-aliasing – The ability to remove jagged edges on a bitmap display

Figure 9 - CAID Technologies for Theme Approval

It is important to clarify that this type of high quality rendering and animation routine is what Ford upper management, including marketing and Corporate Design, use primarily for internal vehicle exterior/interior theme and craftsmanship evaluations, and have done customer styling clinics using these visuals. However, internal use is very limited. Only a small percentage of vehicle programs utilize it regularly and external usage has been mostly as pilots or tests. This limited acceptance results in a reliance on physical prototype reviews that have been proven out over the years. Figure 9 shows a precedence setting use of CAID technologies. In this example, a front-end and rear-end modification was done to a production vehicle without the use of a physical model prove-out or approval within the organization.

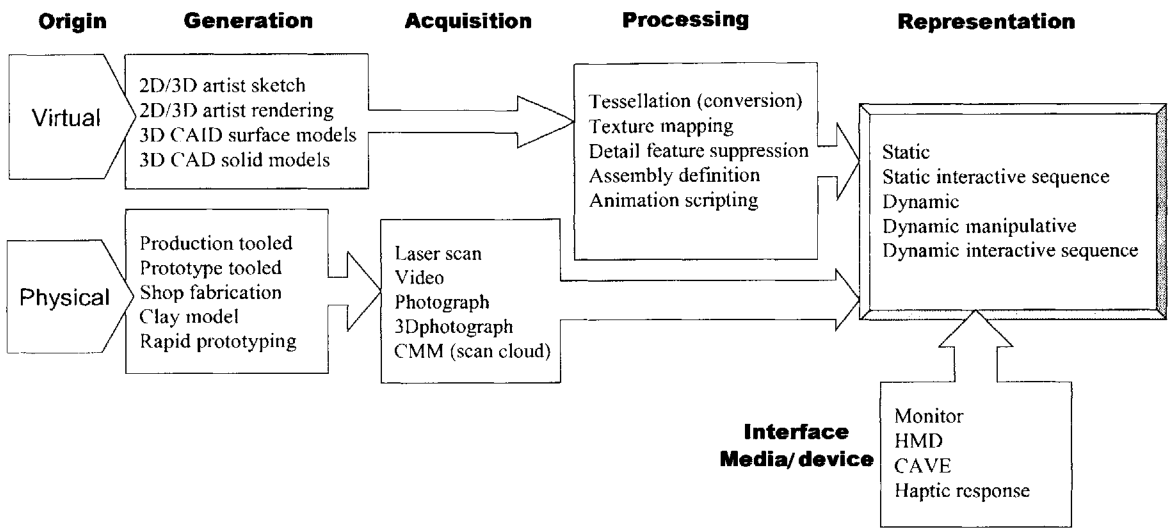


Figure 10 - Product Visualization Methods

Photographic imagery

Photographic imagery is an alternative for capturing visual representations of the product. Static representation can be achieved by traditional photographic methods. Newer technologies such as photogrammetry software such as *EOS's Photomodeler* and 3D optical acquisition software and hardware from *Metacorporation* or *Eyetronics* are now available. These tools allow a physical model of a vehicle to be captured optically and converted to a 3D fully texture-mapped digital model. When Photogrammetry is used, still images are taken from two or more angles of each area of the vehicle that is being captured. These photos are imported into a software package where points are plotted on key points on the vehicle and common points are then referenced, or linked, between photos. When enough points are marked, the software can interpolate camera positions in 3D space and, hence, map the points to a 3D modeling environment, where a wireframe model is constructed and texture-mapped surfaces are taken from the photograph and put on the model. Figure 11 show an example of the output of this process. Here eight photos were taken of a vehicle and mapped to a 3D model. A skilled user would be able to complete this process in as little as 30 hours. The time involved depends on how many points are mapped and accuracy of placement. These points control the level of detail seen in the model, which will decrease as a viewer scales up and examines it closely. Therefore, a model that was generated quickly may be more effective for testing the vehicle proportion attribute than that of craftsmanship (defined earlier).

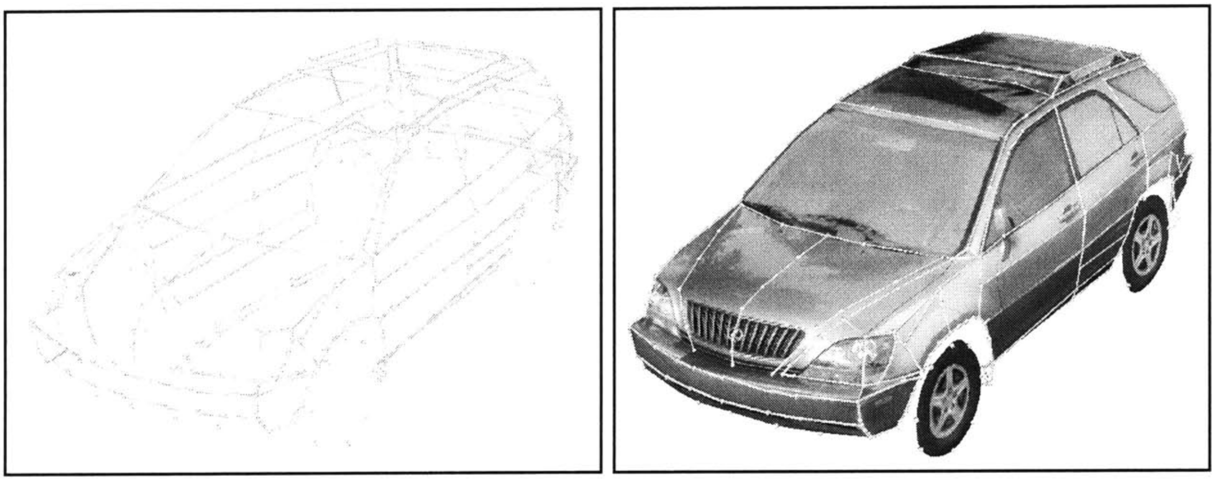


Figure 11 - Example of Photogrammetry

The newer 3D optical acquisition software and hardware mentioned earlier automate this process through the use of a technology that is able to determine the depth and curvature of an object when the photograph is taken. The models generated from photographic imagery can be easily converted into a Web-based model and be interacted with in real-time for use in market research. The image quality of these models does not approach that of the Design visualization rendering techniques mentioned prior in this paper. However, these technologies are expected to advance rapidly and need to be considered as alternatives along with considering what image quality level is needed for accurate consumer feedback and on which attribute (i.e., styling or craftsmanship).

In addition to image quality consideration, the costs and efforts required in the steps of generating the image for viewing are key considerations here. (see Figure 10). Photographic images are of physical origin and require a full-size or reduced scale model to be built. Therefore, the primary costs of these methods are in fabricating this prototype. This cost however will replace costs needed for images generated from virtual origins, such as CAD/CAID model development and processing for rendering and animation.

3.2 Processing – from ideation to the net

Figure 12 depicts roughly where and when visuals could be extracted from the computer-aided design process as a vehicle is styled surfaces and components are being defined during a generic vehicle program development process. This figure shows how a stylist within a corporate design group generates a CAID surface model at rough concept level. It is then passed on for further refinement within an electronic math modeling (EMM) group and subsequently handed off to the engineering community for detailed design, where secondary features are added.

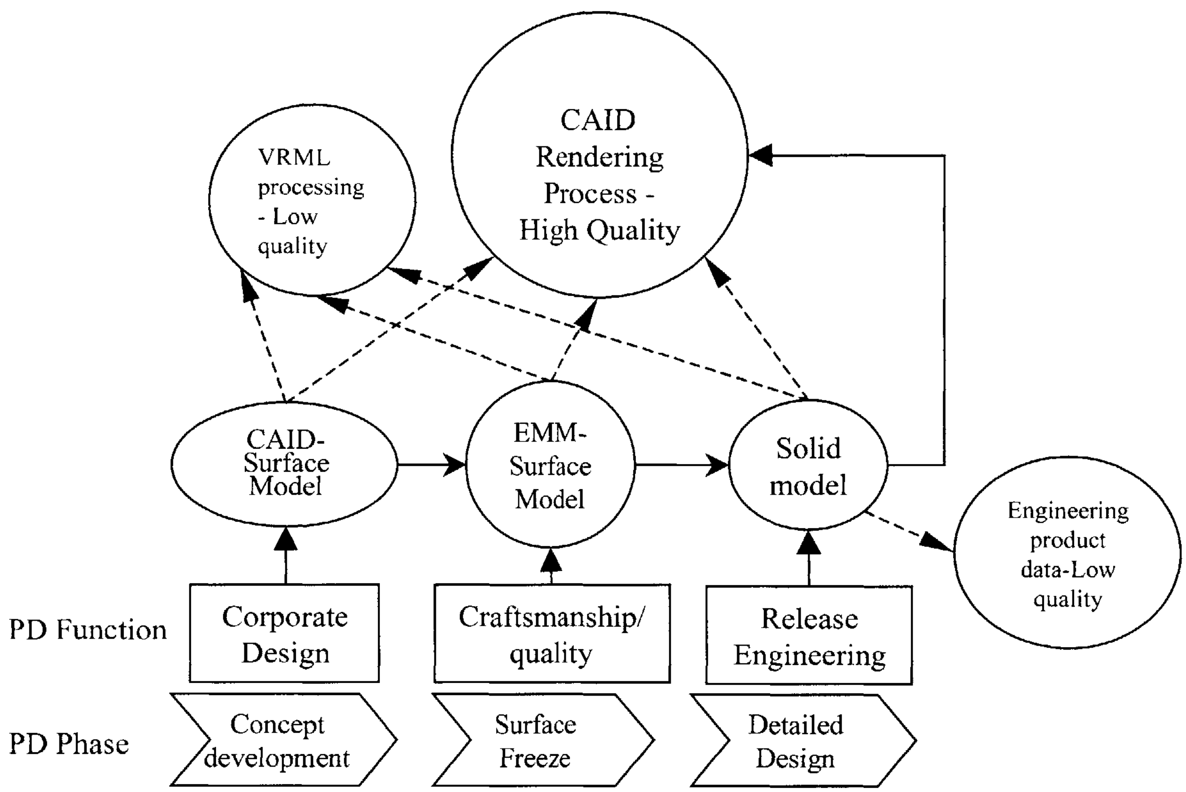


Figure 12 - Product Model Availability For Visual Depiction

At each of these phases, there is an opportunity to extract visuals for market research efforts. The key point of this analysis is that the visuals can be extracted and used in three proposed categories of image generation processing that will support a market research effort (dotted arrows in Figure 12). These categories are described below:

CAID Rendering Process - High Quality

These visuals are yielded by the design visualization technique discussed in section 3.1.2. Here, product data can be extracted at each PD phase, however the designs are at various levels of completion and require much pre-processing to generate a rendering or animation that is considered effective for market research. Currently, this method is not feasible for networking in a Web-based survey due to high processing requirements and limited available bandwidth. These methods are limited to controlled local focus groups where respondents view high definition displays connected to image-generating hardware.

VRML processing - Low quality

VRML visuals can be produced along the same time frame as the CAID rendering process utilizing the same product data. However, this type of processing and image formatting is a low-resolution alternative that permits market research studies to be conducted in a Web-based environment. Limitations of this alternative are examined later.

Engineering product data processing – Low Quality

The visuals drawn from this portion of the PD process are based on design intent, approved product data that is maintained, updated and part of the current mainstream design process. As described in section 3.2.1, the software used to create the 3D models (*EAI's Digital Buck*) takes CAD models and tessellates the data for the purpose of quick viewing over an Intranet used within the PD community. What this means is that product models have already been converted to a VRML type format and are integrated with other product information management systems. The benefits of using this engineering product data for visuals are that the data is readily available and "organized," therefore requiring much less off-line secondary processing. The limitations are that newly designed components are not added to the database until detailed design is underway. Also, the image quality is dependent upon polygonization and bandwidth limitations.

3.3 Visual information within the PD cycle for a vehicle program (what's available and when)

Figure 13 presents a broader view of a vehicle PD process with indicators of when visuals can be extracted. The intention of this analysis is to understand when opportunities for visual depiction come into play and what their origins are, which provides insights into quality and accuracy of the resulting images.

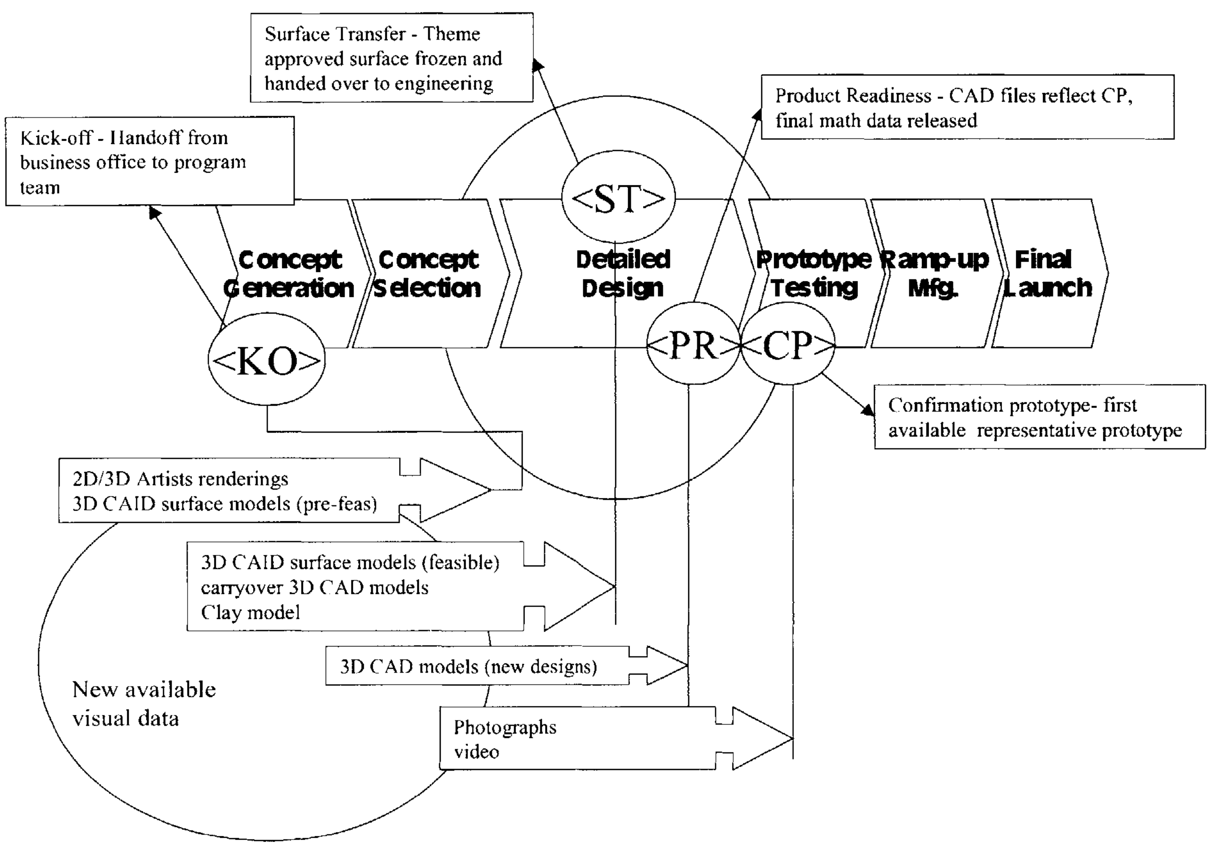


Figure 13 - Product Visualization Methods in the PD Process

Speaking specifically of a typical automotive exterior body panel development cycle, it is standard practice to start hand modeling, or CNC milling, full-scale clay models during the concept selection and refinement phase. This is done between program kick-off<KO> an approved surface transfer <ST> to engineering for detailed design. This reliance on a physical model is very significant to this research. This is the phase at which optimal benefits are realized from the use of visual product depiction in Web-based consumer research. However, even though digital surface (CAID) models are developed initially, costly clay (and fiberglass) models are CNC milled from the digital surface data. These prototypes are then further refined with hand-held carving tools by a team of modelers to add finer detail. These physical models become the "master" model that is maintained and developed as engineering provides manufacturing feasibility input to the studio stylist. As feasibility issues are identified at clay "walkarounds," changes are incorporated by manually modifying the surface of the clay prototype. Once a feasible design is established, the surface is digitized and electronic math models are created for detailed CAD design. Since the physical clay prototype is maintained as the master model, accurate digital models are not readily available to draw upon for visual information. These full-scale clay models are used for theme approval viewing by upper management and customer clinics. It is common to also develop a hand-made painted fiberglass version of the clay model for review at customer clinics. This is done because corporate design management feels the consumer needs to get a better understanding of the exterior styling, which requires that representative surface finishes exhibited show the same highlights, reflections and colors that are given by the materials of the actual product. Most internal styling reviews are executed with a beautified clay model. This process includes attaching real components such as tail lamp and plastic exterior ornamentation and also pressing colored "wallpaper" type sheeting to simulate painted sheet metal surfaces. These efforts demonstrate the cultural reliance on physical prototype reviews for exterior theme evaluation.

3.4 Video Streaming and data compression

This section of the research examines what the status and trend is for compressing data and streaming it over the Internet. It is proposed that implementation of product visualization for market research will have key dependencies on the development of the technological infrastructure for streaming video. Streaming data allows clients to avoid having to download an entire video or animation file. This means that serving a several-minutes-long, high quality rendered animation or live video clip will no longer require a viewer to wait for complete download of the file. There are currently eight primary commercial and 13 research organizations involved in video streaming in various ways. This is clear evidence of the viability and expected growth of this technology.

> *Ideally, video and audio are streamed across the Internet from the server to the client in response to a client request for a Web page containing embedded videos. The client plays the incoming multimedia stream in real time as the data is received. Quite a few video streamers are starting to appear and many pseudo-streaming technologies and other potential solutions are also in the pipeline. Generally, streaming video solutions may work on a closed-loop intranet, but for mass-market Internet use, they are, in many ways, dysfunctional. However current transport protocol, codec and scalability research will eventually make video on the Web a practical reality [11]*

A key characteristic of both commercial products and research demonstrators is the diversity in networks, protocols and compression standards supported. Of particular concern in a mass-market rollout is that of network heterogeneity. To address this codecs or compressions standards (i.e., H.263, MJPEG, MPEG1, MPEG2, MPEG,4) need to be developed and adopted that allows for inherent scalability to work with the wide range of bandwidth that exists today and will remain as broadband networks are implemented.

Standard	Data rate	Applications
H.263	64 kbs	Video conferencing ISDN (dedicated line)
MPEG-1	1 – 1.5mps	VHS quality video 352x288 resolution
MPEG-2	4 - 15 mps	Broadcast quality full-screen videos
MPEG-4	64 kbs	Video conferencing (heterogeneous networks)

Table 2 - Compression Standards

Most commercial video streaming products are optimized for low bandwidth modems and are not designed to scale to higher bandwidth networks. Basically, the video needs to be pre-encoded with the target audience in mind. These product have developed their own proprietary compression standards, utilized the current accepted standard, or implemented a combination of the two. Therefore, compatibility among these products has been limited. H.263 and MPEG-4 (see Table 2) are going to become the defacto standards for video delivery over low bandwidths [11]. But broadband standards such as MPEG-1 and MPEG-2, which are useful for many types of broadcast and CD-ROM applications, are unsuitable for the Internet. Although MPEG-2 has had scalability enhancements, these will not be exploitable until the availability of reasonably priced hardware encoders and decoders, which support scalable MPEG2.

It is important to note that the virtual rendered animations discussed earlier that have been utilized within Ford for craftsmanship evaluations ran at approximately 180mps. This is in line with the compressed data rates of approximately 6-7mps provided by MPEG2. Time required for acceptance of visual depiction quality by Ford's management will be directly impacted by development of these standards.

In summary, compression standards designed for the Internet require greater bandwidth scalability, lower computational complexity, greater resilience to network losses, and lower encode/decode latency for interactive applications. These requirements imply a need for software designed specifically for the diversity and heterogeneity of Internet delivery. There is consensus in the research community that the key to efficient delivery of continuous media over heterogeneous networks is dynamic bandwidth adaption [11]. These formats fall into the category of "Non-DCT" based compression techniques that are intrinsically scalable. Although several of these software CODECs exist, they are still experimental in nature and experience performance problems. Also, all existing video/movie files would need to be recoded in this format also provides resistance to development and widespread usage of a common standard. Video streaming technology advancement is predicted to significantly impact strategies and implementation rates of visually oriented Web-based market research.

3.5 VRML – benefits and limitations

The key to efficient use of CAD models as visual depiction instruments in a web-based environment is a standard language that can emulate a virtual environment with these 3D models at its core. VRML, Virtual Reality Modeling Language, is a recent ISO standard that provides a vehicle for distribution of this information over the Internet and an interactive environment for users viewing the models through a standard Web browser. Using VRML over the Internet has potential to be an excellent tool for sharing virtual models with remote users. Successful utilization of this standard could dramatically accelerate the diffusion of visually oriented market research tools. It is extremely cost effective since the required infrastructure, networked computers, exists everywhere and VRML viewing software is readily available to potential consumers. Today's limitations are dictated primarily by network capabilities such as download times and speed of a user's local computer. To meet today's network limitations, VRML model file need to be minimized, this generally results in sacrificing much of the detail in the product they represent. The VRML model needs to be a polygonal representation of all geometry used. Only these representations allows for fast rendering in real time. Unfortunately, most CAD systems generate models using Constructive Solid Geometry (CSG). This data must be converted to its boundary representation. If the boundary representations of the model are curved surfaces, a polygonal approximation must be derived using a tessellation algorithm, which substitutes the surfaces with a mesh of polygons. The creation of this type of model ends up sacrificing product detail, which dictates level of information conveyed in a visual depiction of a product. This will place limitation on attribute types suitable for virtual market research. In summary, the creation of virtual models for use over the Internet is still a labor intensive and time-consuming process. Even though CAD models already exist for a product, additional efforts are required to obtain an acceptable polygon count for quick rendering with today's network limitations. Fast generation of virtual models, known as fast virtual prototyping, is a topic of ongoing research [27].

4 Product Information Management- Organization and Control

4.1 Transfer of information between functional organizations

In order to get visual data into an Internet-based market research study, this data must move through three key functions; Engineering, Marketing, and the Design studio. Engineering works with the design studio to develop CAD surface models or physical prototypes that reflect feasibility, optimal function and minimal cost.

The marketing organization is responsible for conducting consumer research. Therefore, information is presented to the customer by marketing. This transfer of information results in the marketing organization having a certain amount of control over how the data is presented. Moving from physical to virtual prototyping opens up more considerations on this issue. For example, while a focus group viewing a physical prototype is affected primarily by room lighting conditions, there are many more variables in a computer-based environment, such as image quality, speed, color settings, and size of view screen, etc.

The Process Leadership Division within Ford has several engineering activities involved with the development and deployment of processes that support the advancement of product development systems. Technical staff from one of these particular activities that works with CAD/CAID visualization technologies and their applications provided several insights on how the organizations have reacted to initiatives involving the procurement of visual data. It was discovered that there have been efforts recently that involved computer-based graphical "build your own" vehicle market research studies. Such initiatives were found to be expensive to coordinate and, more importantly, it was very difficult to gather and manage the information required for presentation to consumers. An engineering supervisor of a CAD/CAM visualization group stated:

> *"We focus our work on internal studies. The color and textures from trim and body cladding is irrelevant to a packaging/manufacturing engineer.*

The information that the customer is after is of this type and would result in extensively large models or data sets."

Product visual data is currently considered by many as only fit for engineering studies. Because it lacks the finer details mentioned above, it is not considered by marketing to be "clean" enough for styling evaluations. The visual data currently used for internal studies such as assembly sequence and fit, originate in and is controlled by engineering. Therefore, information on product details such as color grain and textures is absent from the product models and needs to be defined by marketing or corporate design. This type of data is currently not generated and maintained by engineering within mainstream product development modeling processes. This results in a lack of know-how on how to efficiently model these types of visual attributes. Ideally, each functional organization should maintain ownership of the attributes or content that reflects the requirements they own in terms of the customer. This will result in the optimization of the processes required to generate a market research study that is efficient and cost effective.

Another key issue of transferring visual information between organizations is the corresponding shift in power, particularly between the marketing and design organizations. When a corporate design stylist was asked about problems in running a focus group, or clinic, for an exterior styling theme review, the following response was given:

"Power is in information, to clinic a vehicle, the studio must give information and test results over to marketing this (survey questions or visual info) could be presented to the customer in a way that is biased or have skewed the results"

An important observation is that corporate design managers currently experience conflicts in how the information they provide to marketing is presented to the customer. This stems from not having both functions equally involved in the administration of the research. Moving to virtual testing is believed by most to make these issues worse. However, it is theorized that Internet-based virtual studies that follow documented processes that are online with the rest of vehicle development processes could actually remove these control issues experienced today.

4.2 Theme Development Information

Critical to the widespread adoption of different levels of digital imaging is change in corporate culture or level of control that impacts the trust in the customer's ability to articulate their preferences. A low level of trust results in conflict between marketing and the design studio. Design managers often attempt to minimize customer interface until later in a program. When marketing does conduct a research study there is a strong push for very detailed, realistic physical prototypes. It is commonly viewed that virtual prototyping, while it is improving, does not have the ability to convey several key characteristics that give the customer a feeling of "presence". It is of Relevance discuss a technique known as Brand imaging has been gaining acceptance within Ford Motor Company's design studios. The technique possibly demonstrates a reinforcement of internal control, and hence supports a removal of customer feedback during theme concept development. Brand imaging is the translation of words and phrases into images. This information is gathered from customers at focus groups that are viewing the current vehicle that is being redesigned any other vehicle the same class or market segment. For example if a common response from the consumer is that a truck needs to look " tougher", pictures of objects that are considered to represent this phrase such as items from a construction cite, strong materials, certain textures are gathered. These images are then presented to designers by pasting pictures from magazines and other sources to an image board that is viewed to facilitate development of a theme. The pictures pasted on the boards are of any object or scene that is considered to spark the right idea for a design in support of a particular brand. This Process generally results in a couple of theme variations. However, there is one primary theme that is identified internally as representative of the brand. Prototypes are hand-fabricated using either clay or fiberglass panels for review by a focus group. There is a deep reliance in full-scale physical properties to obtain accurate customer feedback at this phase of development.

> *"We have tried using photographs and video in the past to take the place of physical prototypes for use in focus group. We found they were pretty good for 'first choice' in concept selection; however, they were not effective for obtaining feedback on preferred styling cues. They lacked depth and feeling of proportions."*

The statement above, made by a global product-marketing representative, demonstrates the perceived limitations of current levels of graphical detail when used for feedback on vehicle styling.

Even for "first choice" concept selection, most stylists have little confidence in information received from virtual testing. There is general agreement that current Internet visuals lack clarity and true representation of proportions. The communication of proportions is considered critical to studio design managers to gain accurate appreciation and feedback from customers on their theme developments. This, they feel, is necessary to visually understand the theme.

The marketing organization, though hesitant about the effectiveness of Internet visuals, is generally research oriented and is inclined to support virtual concept testing initiatives. However, statements shown below, which were gathered from interviews with marketing representatives of certain vehicle platforms, show the barriers that exist when interfacing with the design studio.

> *"Marketing has to prove to CD [corporate design] that their styling research/results are valid. CD often challenges these. They believe that we will be easily misled by the customer."*

"Exterior design is not worth doing virtually with customer because CD would not believe or buy into it."

"The studio has thrown out or not accepted clinic results because the property was shown to consumers in a room that did not have a 'white' ceiling."

There is a strong belief that the customer must experience the "presence" of the product. Current virtual immersive technologies are believed only to approach this feeling of presence. For example, it was found that stylists often want to move the property outside before they will approve the design because they cannot get a proper feel for the appearance in a confined space. Clearly, this indicates much prove-out of Internet-based visual depiction is needed before acceptance of results in order to benefit from foregoing costs of physical models.

A member of Ford Global Marketing Division stated:

"GM tends to use a lot of consumer research and they end up with very bland vehicle styling. Chrysler takes a different approach, where upper management gives younger stylists more freedom to develop themes, and they rely on less internal/external styling reviews. Therefore, they end up with more stylish products. These, however, appeal to more of a niche market, which will be a smaller segment."

The level of control over utilization of consumer insights is a strategy that is considered to have direct impact on the resultant theme. These strategies, which define the culture of the design community, need to be clearly understood in order to effectively implement virtual product testing. The statements below were made by a vehicle exterior stylist when asked about use the of virtual concept testing for determining consumer styling preferences:

"You need to strike a balance between internal styling control and consumer feedback driven styling design. They can only articulate to an extent, for example, they say, 'Something doesn't look quite right, but I don't know what it is.' This often can be quickly interpreted by a skilled designer as bad proportions."

"The Internet would be more useful for determining what features should be bundled with each other. For example, a 'build your own' type study. These are rational decisions, whereas styling decisions are not."

The above statement demonstrates the mindset and culture that exists throughout most design studios. This indicates, not necessarily a barrier to diffusion of the technologies required for virtual concept testing, but possibly a lack of understanding of what information is required by a customer to articulate needs.

4.3 Managing Product Data

What is key to full utilization of product visualization throughout the product development cycle is total product data integration. This means product data is shared between all functions of a business. The visualization technologies have been developing in the engineering and manufacturing function, and these technologies are now enabling the production of detailed accurate product visuals in shortened time periods. The challenges and barriers that organizations should be addressing are those of standard processes, data formats, and methods of managing historical product data. In brief, the future of CAD/CAID will need to be tied to the future of the rest of the business world. No longer can either engineering, manufacturing, or any area of specialty within a business, remain as a separate entity outside the main data flow, which is becoming the basic necessity of any efficiently run company.

Ford Process Leadership's division management when asked about obtaining visual data from the product development process made the following statement:

"The information useful to engineering is not what the consumer needs to see. That information is modeled much later in the development process or need not be modeled at all (i.e., carpet, graining, textures)."

The statement clearly shows how processes have not been defined for managing this type of information.

- Standard processes
- Data formats
- Managing historical product data

4.4 Building a virtual model database

The Ford Motor Company has only recently implemented 3D solid modeling throughout its design community and supply base. All designs prior to this recent implementation effort were done using wireframe modeling. This earlier generation of CAD modeling is inadequate for use in product visualization for market research, where it must be presented to the customer. There are now only a small handful of vehicle programs (2-3) that have been released with detailed designs done with solid modeling tools. Even these programs still have many subsystems that remain as legacy data because they were "carryover" designs.

4.5 Extending product visualization from engineering to the consumer

The majority of the information used for virtual concept testing will originate and be drawn from engineering and design activities as techniques become mainstream. Diffusion analysis, often applied to new product introduction in a consumer market segment, will directly apply to the diffusion of visualization technologies throughout a large PD community. The potential for rapid diffusion will increase as hardware and software tools advance. Small-scale market research studies will be able to be generated very rapidly by individuals to obtain feedback from customer on attributes at the component or sub-system level. Adoption rates of these tools by the average individual will vary between different functional groups. For example, research evidence has shown that early adopters have a greater ability to deal with abstractions [26]. Since early adopters generally are better at interpreting abstract stimuli, members of the engineering community, for example, will have a better grasp on this type of skill than those in project management or marketing activities. Hence, diffusion may occur more rapidly within engineering or design activities.

To facilitate the adoption of these innovations, it is useful to view changes in this arena in terms of technology diffusion. The diffusion effect is defined as the cumulative increasing degree of influence upon an individual to adopt or reject an innovation, resulting from the activation of peer networks about the innovation in the social system [26]. The product development community should be analyzed to assess and assign adopter categories that would apply to each functional organization. These organizations should be viewed as group members of a social system that will adopt in a particular time sequence based on their level of innovativeness. There is much practical usefulness for change agents if they can identify potential innovators and laggards in their client audience and different strategies with each such sub-audience [26]. Change agents, or diffusion programs, will need to be developed to bring about behavioral change, which will drive innovativeness.

5 Conclusion

5.1 Corporate barriers

Virtual concept-testing methods are currently in the infancy stage. Primary inhibitors are the technological limitations in bandwidth and inefficiencies in generating detailed product models and moving the corresponding large data files throughout an organization. These problems issues and will subside fairly rapidly as technology advances. The true challenge for a large organization will be to simultaneously recognize key organizational and process development barriers and apply the resources needed to develop solutions and, as the technology is advancing, to allow immediate integration into the corporate culture. The companies that are most successful at meeting this challenge will truly be in the "first to market" product development mode, which is key to sustaining leadership in the competitive automotive industry. The following are identified as major organizational and cultural inhibitors of effective virtual concept testing:

Transfer of information between functional organizations

Product information market test methods and results need to be very accessible standardized, and accepted across functional organizations. More specifically, between design and marketing organizations, there needs to be standard methods for running virtual market tests. A key barrier was found to be acceptance and "buy-in" on how a market test was ran and how the results were interpreted using physical properties. This becomes very important as virtual market testing is adopted. Each functional organization may have different expectations that are not communicated effectively. Establishing depiction modes by attribute type will facilitate this. Once a methodology for verification is established, acceptance of the methods and results will occur more easily. Establishment of these methods and eventual incorporation of standard test procedures that are agreed upon at the corporate level will facilitate a mutual "buy-in" between different functional organizations on test results.

Level of trust in customer articulation of preferences

In order to achieve the full advantages of virtual market testing, a clear understanding needs to be established, through experimentation, of what a customer can and cannot articulate. It is theorized, particularly among design studio management, that there is an unjustified reliance on detailed physical prototype evaluations. This has been ingrained in the culture and mindset over the years due the established internal process of full-scale vehicle clay modeling practices. Managers believe the customer needs the same level of information they needed to craft the vehicle theme. This may be the case for some attributes, but not all. Either way, there will be a point of diminishing returns on quality of feedback when depiction methods and level of information and information-control are determined.

Total product data integration

Currently there is much effort to tie information generated during the different phases of product development into a common database. These object-oriented databases are necessary to control and manage the voluminous amounts of data generated by the increasing amount of digital analysis from CAE simulations and other computer-mediated design studies. These efforts need to include virtual market testing methods and processes as part of this initiative. Currently, many virtual marketing testing or internal reviews have been conducted as “off-line” processes. Processes, methods and test results need to be integrated into the mainstream flow of product information in order to be accepted as a mainstream PD process. This assertion will apply at different levels depending on what attribute, subsystem, or component is being tested. At one extreme, several variations of CAD models representing different attribute levels of a styling theme may be linked in an assembly or as object in a database. At another extreme, a data file with historical test results may be linked to a design intent CAD model.

Management of Legacy Product Data

Solid model-based CAD tools are the basis for generating virtual representations of products efficiently enough to make the alternative an effective business case. Solid modeling tools have only recently been introduced as a corporate tool at Ford Motor Company. Therefore, the majority of vehicle program were developed using wireframe CAD packages. How this legacy data is managed will affect the rate of utilization of visuals for representing product. A strategy needs to be developed to efficiently re-master this data and incorporate reused component or subsystem design in new vehicle programs.

5.2 Future Research and predictions

5.2.1 Experimentation Methods – A correlation between visual mode and attribute type

It is the contention of this research that an increase in quality of a product's visual depiction will result in an increased quality of feedback from a respondent. However, this theory should not be misconstrued as meaning visuals that require cutting-edge technologies, and which project the best sense of telepresence, should always be utilized.

Earlier, proportions and craftsmanship were identified as key styling attributes that were best conveyed by an increased level of graphic quality and detail as well as interactivity. This is the case for some key experiential attributes, but not all. Rather, a particular mode should be identified as optimal to get the best feedback. This mode may be unique depending on what attribute is being tested. In other words, a particular attribute may have to be modeled (visually) differently because a customer's desired response will have unique visual requirements driven by the characteristics of that attribute. This will be due to the differing amounts of information provided by the level of media richness and to the varying level of information control offered to the respondent by the interactive visuals presented in this paper. For example, the respondent may lose sight of the questions asked if overloaded with information. Possibly, a reduced level of information control will free up the cognitive resources required to allow a respondent to search for and process the correct information [15].

An example of this can best be demonstrated by the following proposed experiment. This experiment sets forth the establishment of a methodology for teasing apart and categorizing attributes or sub-attributes with their optimal depiction modes. Here, the vehicle exterior styling attribute is examined.

Identify and categorize attributes

The first step is to define the attributes that are candidates for visual representation. These may be either *search* or *experiential* attributes. Once this is established, if necessary, the attribute should be broken down into key sub-attributes. This step is to avoid the issues mentioned prior of bundling various attributes under one depiction mode (DM). Sub-attributes should be identified as key in establishing the proper customer feedback.

For an effective styling evaluation, the following are considered critical in developing an appealing theme and may be best depicted by different visual modes:

- Color Harmony
- Proportions
- Craftsmanship

Obtain rankings of control stimuli

Once target attributes are established, the control stimuli, which will be the physical vehicles, should then be developed. This obviously assumes there is a production vehicle or confirmation prototype available. Since this experimentation is to establish generic depiction mode requirements by attribute, the control stimuli need only be of the same product type for which guidelines are being sought.

In the case of the styling attributes above, a set of control stimuli would be a set of current production or competitor vehicles brought in front of respondents in a focus group setting. Each respondent would be asked to rank a set of six or seven by order of preference in terms of questions asked that elicit responses to the identified attribute. This information will be used to determine accuracy of other depiction modes.

Establish depiction modes

Several different depiction modes should be chosen based on what is available and feasible. The modes should span a range of various levels of media richness and interactivity. Figure 14 provides a diagram of how the experimentation is conducted. In the figure, an example of four depiction modes of five different vehicle brands (or attribute levels) is shown. Each of these depiction modes will be evaluated by an independent respondent base and later correlated to the results from the evaluation of the physical product, or control stimuli.

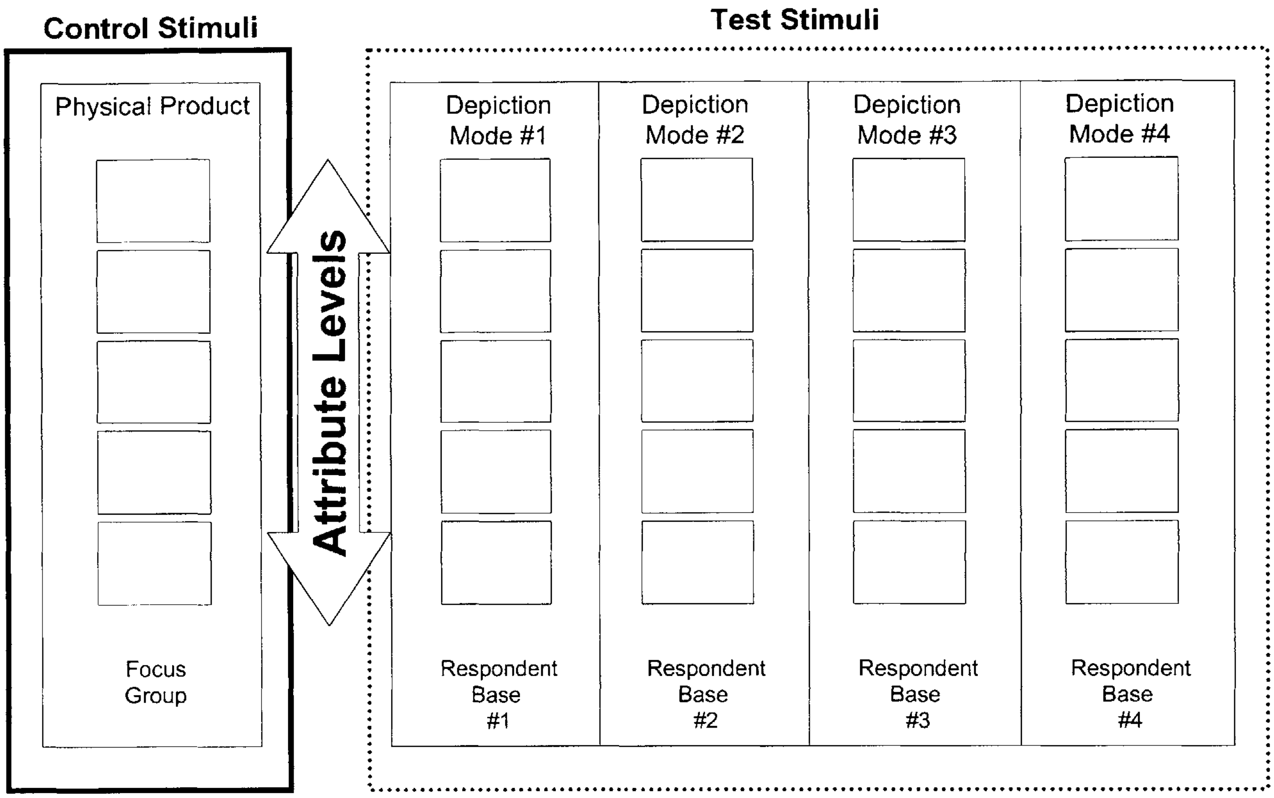


Figure 14 - Visual depiction Mode Experimentation Model

An example of the application of this method to the color harmony attribute is shown in Figure 15. Assuming the experiment is computer-mediated or Internet-based, the images represent what the respondent would be viewing on a monitor. In the figure, 3 depiction modes (DM) are shown. The selected DMs are all static, with varying levels of detail/information. Dynamic or manipulative modes (defined earlier) should also be considered and tested. However, it is doubtful the additional information-control supplied by these modes is required to establish color preferences.

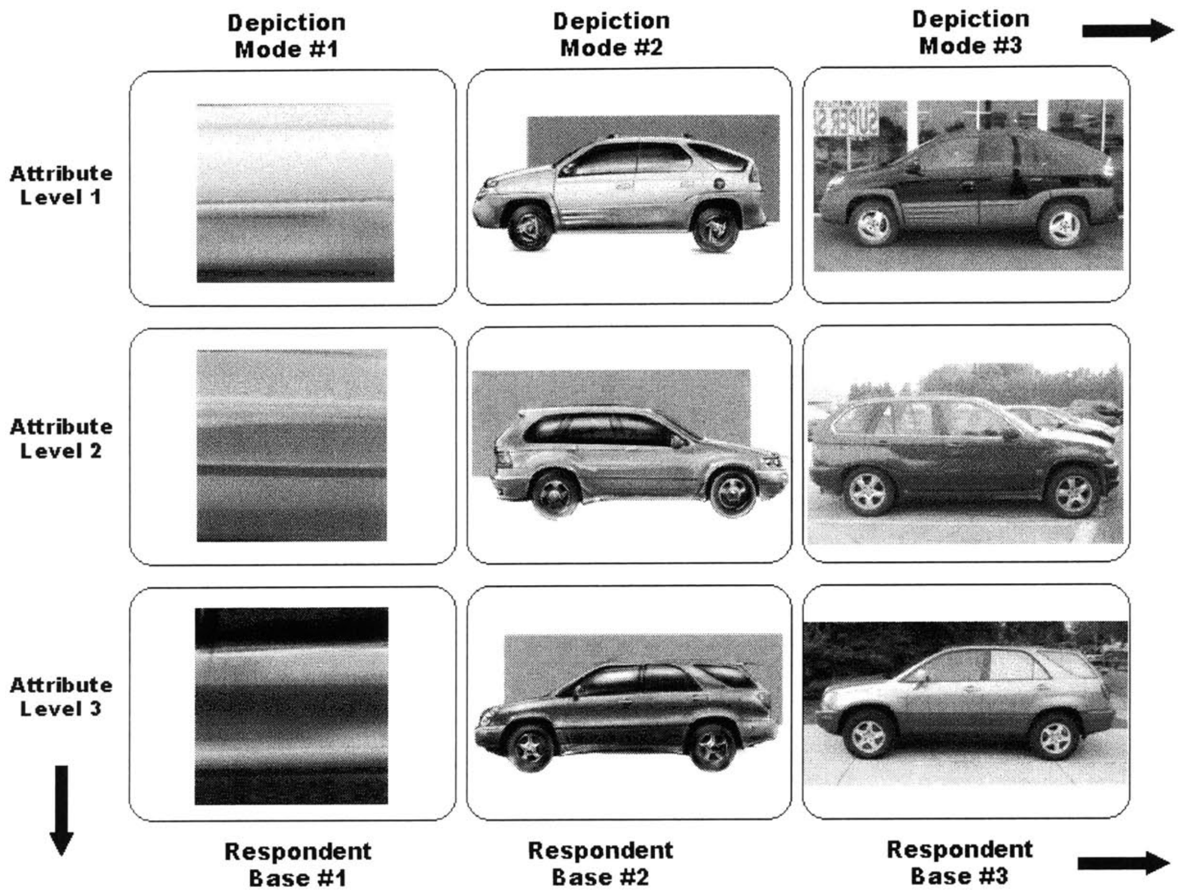


Figure 15 - Example Depiction Modes for *Color Harmony*

Also, three different attribute levels are shown. An actual experiment would include five to seven different color combinations that vary only slightly in color schemes. The three Depiction modes shown are described below:

DM #1 – Static image showing only color combinations

DM #2 – Static image of artist sketch

DM #3 – Static image from photograph, or CAID rendering if virtual representation is required

Figure 16 shows the DMs used for the *proportions* attribute. The figure illustrates only one vehicle, or attribute level. The DMs illustrated span the range of static, dynamic and manipulative image types. Additional modes, with varying levels of interactivity and graphic quality, should also be tested. The ones shown span the range of medias thought to represent the visual requirements of vehicle proportions.

DM #1 – Static 2D Artist's sketch.

DM #2 – Static photograph or photorealistic CAID rendering with modeled environment. Images would be obtained using design visualization methods described earlier.

DM #3 – Dynamic full-motion video or rendered animation in absence of physical model.

DM #4 – Manipulative 3D model using VRML format or comparable representation. Model can be translated, scaled or rotated.

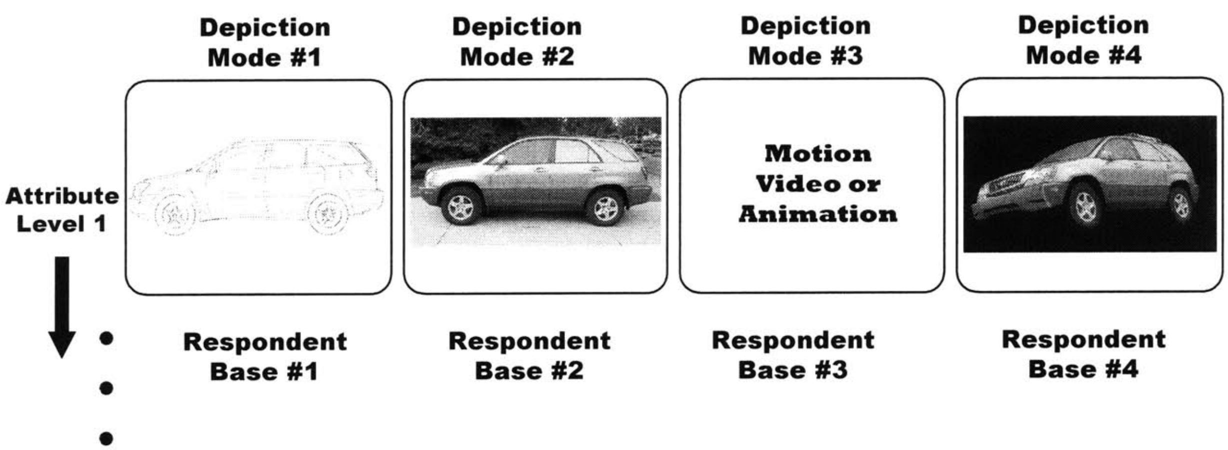


Figure 16 -Example Depiction Modes for *Proportions*

Finally, example depiction modes for evaluating craftsmanship are shown in Figure 17.

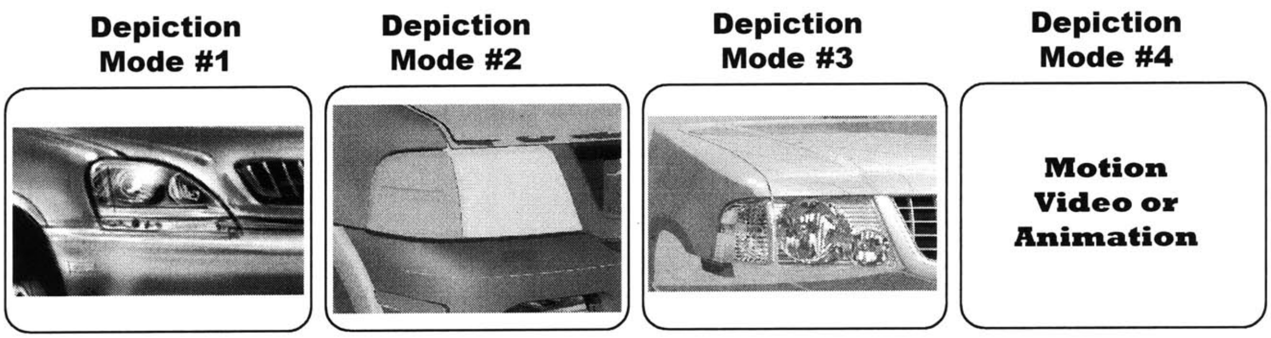
The images shown have varying content. Visuals used in an actual experiment would be consistent in terms of color and styling across modes for each vehicle type (attribute level).

DM #1 – Static artist's sketch

DM #2 – Manipulative 3D model obtained from an engineering visualization database

DM #3 – Manipulative 3D model of obtained from CAID high quality rendering process

DM #4 – Dynamic full-motion video or animation obtained from photographic imagery or Virtual rendered animation techniques



The above are shown at Varying attribute levels

Figure 17 - Example Depiction Modes for *Craftsmanship*

Sources of error:

The primary source of error will be in the relative level of experience respondents have with the interface used. A concentration of experienced respondents in a particular test group will bias results.

Expected Results:

Color Harmony

This attribute is expected to require a low level of information about the actual product. Therefore, simple depictions with a low level of information control or interactivity would probably be more effective in maintaining the focus of the respondent on the color attribute.

Proportions

It is expected that a very high quality, static visual with a representation of the surrounding environment would correlate best with results from an evaluation of a physical vehicle. Dynamic or manipulative representations may confuse the respondent with an overwhelming amount of information.

Craftsmanship

The optimal depiction mode for craftsmanship is expected to be that of highest quality and full manipulation. This requires the highest level of product information and demands the most resources in terms of preparation effort, hardware capability, and bandwidth (for Internet-based research).

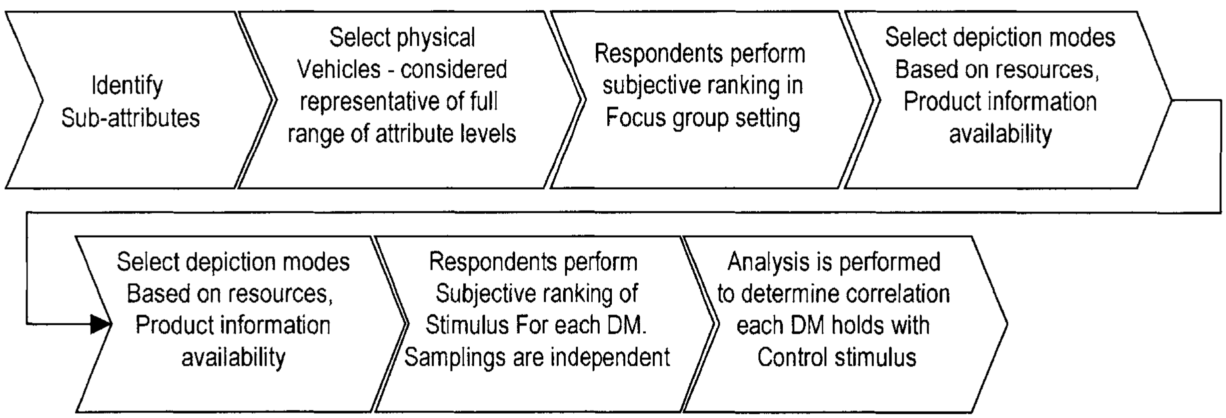


Figure 18 - Visual Depiction Experimentation Flow Diagram

In summary, if correct modes are not identified, there may be significant error introduced resulting in a negative effect on the accuracy of feedback if the wrong depiction modes are utilized. This could happen when aspects, or sub-attributes, of a product characteristic are "bundled" into one market research study with a chosen depiction mode. Therefore, managers need to establish visual requirements for specific attributes through experimentation. Figure 18 represents the general steps recommended to establish these requirements. It was predicted earlier that an increase in media richness and interactivity would result in an increase in the confidence of a respondent's decision in a comparative market study, and a more detailed and creative feedback in a subjective survey. Incorporating survey screens into the methods defined above for establishing depiction modes could easily test these theories. For example, after viewing a set of attribute levels on a computer-mediated study, the images could be replaced by a text screen that surveys the respondent with subjective questions that invoke creative feedback. This survey would be followed by an objective questionnaire that would test memory skills. These surveys would be held consistent between depiction modes and compared to results from surveys done with the physical model.

It is important to state that optimal depiction modes identified from test results should be chosen based on an analysis of diminishing returns. If results for a particular attribute show that a highly detailed, interactive, 3-dimensional depiction mode correlates closest to results from the review of a physical model, then cost and timing should then be considered. A depiction mode of lesser media richness, or interactivity, may provide sufficient results, and at the same time only require information that is readily available and generated from resources that align with the budget of a vehicle program. Clearly, this experimentation will need to be a dynamic methodology, or process, that addresses incremental technological improvements of rapidly changing visualization technologies.

5.2.2 Predicted future trends

It is predicted that, in approximately 5-8 year's time, that most internal vehicle styling evaluations will be done using virtual, rather than physical, modeling. This will be followed by the adoption of external market testing using virtual product depictions rather than physical models, as used in today's vehicle clinics. Acceptance of these methods will need to be achieved internally before the voice of the customer will be trusted as a response to a virtual representation of a vehicle. This time span will be driven primarily by constraints of bandwidth, data-compression limitations, and lack of standards in file formats, browsers and viewers. However, as these constraints are removed, organizational and cultural barriers mentioned earlier will become overriding constraints if they are not developed concurrently with the advancement of enabling technologies.

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