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DESIGN QUANTIFICATION

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ABSTRACT
Introduction of new products are vital to companies, however costly and fail at an alarming rate. There is therefore a tremendous need for early predicting both consumer acceptance and the financial potential of a concept. This presents an opportunity for establishing internal metrics to evaluate the relative strength of proposed product concepts. The following interviews with designers and engineers assist in defining the challenge and research questions. Can concepts, design and a product's overall external performance be quantified? If so, can a chain of connections link concept quality to external performance? Frameworks for designers' verbal concept arguments are explored and the Concept Aspect Model is constructed for evaluating concepts. To evaluate a final product's design quality, the Design Quality Criteria is aggregated from literature and design awards. In the marketplace, external performance metrics for products are identified for general public awareness and investor's expectations. An assessment of the current decision-process is made, which in conjunction with the first findings provides insight into an impact and roadmap. In conclusion, five aspects of concept arguments are found to correlate with the identified key external success metrics.

Keywords: Evidence based, design quality evaluation, decision-making, design argumentation analysis, Concept Aspect Profile, design awards, web-citations, web-links, web awareness, public awareness, investor's expectation, stock price.

1 INTRODUCTION - PROJECT FRAMING

1.1 Motivation, Context and Framing
With a 35 to 41 percent failure rate in the development of new products [1], there is a tremendous need for metrics that predict product success. Design is the key driver of product success [2] twice as influential as marketing [3]. New products have to be 10 times better than existing products for consumers to switch [4]. Since development cost and potential earnings are closely related to development time and to hitting a closing window of opportunity [1], a good and early decision regarding with which concept to proceed would be extremely valuable.

The early concept phase in the product development process is characterized by limited knowledge concerning a design parameter's importance, its influence and mutual relationships. Concepts from the conceptual phase are evaluated according to pre-established product criteria, which, in rapidly developing markets, may no longer remain relevant [5] and [6]. These criteria often fail to articulate and provide measurement for concepts' various design components. Evaluating, comparing, combining and deciding which concept to choose are currently accomplished using a combination of subjective criteria, intuition and social power. The present situation makes the decision prone to situational mood swings, personal negotiation abilities, temporary corporate politics and context dependent preferences [7]. Currently, there is no literature about how design is generally handled in industry; with the natural result that there are gaps in the field. This paper aims to address these gaps.

1.2 Observing Design in Product Development
Conducting informal interviews with professional designers and engineers and reviewing literature on design and engineering related subjects failed to provide insight into more optimal decision-making procedures in the conceptual phase. A structured literature review of business management and psychology, provided additional insights into the pervasive challenge of poor decision-making. The challenge of decision-making permeates all levels of the value chain, from management of processes

and business units to corporate strategy and philosophy. The literature also offered suggestions on how to address the decision challenges though decision-making processes, tools, statistical learning, and computer simulations.

While developing a method to quantify design, I posed the following question: Is it possible to change the way designers think and argue design to fit into a predefined framework? Or, would it be wiser to develop an approach that will utilize their current communication style? Because my experience with people has led me to conclude that it is practically impossible to change their behavior after a certain mindset has emerged, I opted for the latter approach. If the design concept decision-making could be improved and perhaps evaluated through some form of visual pattern recognition framework conducive to the designer's visual thinking style, current design challenges could be reduced or eliminated altogether.

2 PROBLEM AND RESEARCH QUESTIONS

Having established that selection of concepts in the conceptual phase of the product development process is suboptimal today, the question became: Can the concept selection process be improved? This led me to pose the following research questions:

A. Is a framework of aspects identifiable, a Concept Aspect Model (CAP), that exhaustively captures designers' verbal design concept arguments, providing an internal metric? A metric, which correlates with industry-accepted Design Quality Criteria DQC, described in (B)?
B. Does an exhaustive construct of industry accepted Design Quality Criteria (DQC) for products exist that correlates with external product performance metrics? (Such as, general public awareness and investors expectations) Are these criteria indirectly, objectively or subjectively and consistently quantifiable?
C. Do a set of key external success metrics in the marketplace exist for evaluating a products potential? A set which can describe a product's capacity to captivate general public awareness (Web Citations) and its contribution to the company's value (Investors Expectations over time)? Metrics, which correlate to the in (B) described Design Quality Criteria DQC?
D. Contingent on (A), (B) and (C), does a mapping exist, connecting these two internal and two external metrics, such as, the Concept Impact Map? Does it connect the Concept Aspect Model (CAM) to the Design Quality Criteria (DQC) then, from DQC to general awareness (Web Citations) and investor's expectations? (Stock prices.) Contingent on this, the Concept Aspect Model, can provide an indication for a concept's success in the market place.

With the existence of the above-described mapping, what remains is to determine a procedure describing how the model can facilitate learning, aiding designers with further refinement in their concept combination and selection.

3. IDENTIFYING THE CONCEPT ASPECT PROFILE AS AN INTERNAL PERFORMANCE METRIC – RESEARCH QUESTION A

Does an exhaustive construct of aspects exist, Concept Aspect Model (CAM) and does it exhaustively capture designers' verbal design concept arguments, providing an internal concept metric? One, which correlates with industry-accepted Design Quality Criteria (DQC)? To answer this question it is important to understand how concepts are selected in the early concept phase today.

To this end, I initiated a pilot project conducting interviews with designers at a large industrial design company in Los Angeles. Historical data was first collected on 66 projects, feeding into the formulation of interview guides. Interviews were then conducted, collecting further insight on how concepts are created and business opportunities formulated in the conceptual phase.

The main conclusions of this study were that industrial designers argue their design concepts during presentations using story telling. Then, strictly on the gut-feelings of strong personalities, stakeholders down select concepts. Based on these findings, 11 frameworks were proposed for evaluating verbal design arguments. Using expert assessments, the Concept Aspect Model was selected as the best

candidate. It proposed framing concepts as a meeting between a user and an organization, each with its own internal progression of product aspects.

The Concept Aspect Model consists of 13 aspects, collected from user, product and provider characteristics, established in the product development literature. This framework describes the progression of key aspects in the provider development on one side and the user experience of a concept and the context in which the user exists on the other side. The product level aspects, resulting from the concept, reflected 13 perspectives of the resulting product, as perceived and verbally expressed by designers and engineers.

These two strings of aspects meet at the physical interface with the product. Following further development, the method was expanded to include a cultural connection at a second meeting point, where both user and provider belong to a particular culture. See Figure 1.

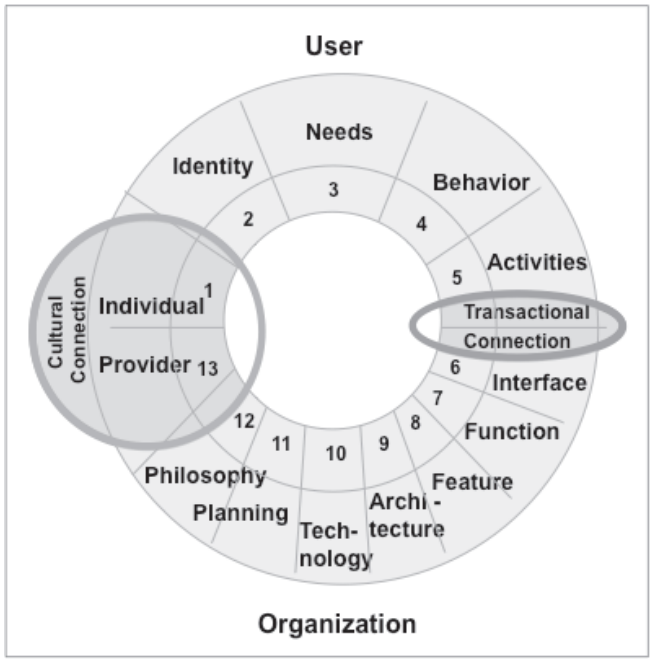

Figure 1. Concept Aspect Model. The model's circular Concept Aspect Profile segmentation, visualizes how users and providers connect at a transactional and cultural point. At the concrete micro level, the user connects to the product through its interface. At an abstract macro level, the user connects to the provider behind the product through their mutual cultural references.

The model was tested in field studies using open-ended semi-structured interview guides and questionnaires. Data on 50 concepts was collected on ongoing projects and coded according to the framework's prescribed aspects. The projects were randomly collected on industry product development projects at leading design companies in conjunction with industry-sponsored student projects at renowned design and engineering schools. Interview subjects were semi-randomly selected (randomly approached, as needed, in the immediate available environment) and all were friendly or neutral towards the interview.

As an initial assessment of the framework's ability to differentiate between concepts, the collected designers' concepts were grouped into broad categories based on industry-recognized characteristics. Concept patterns showed significant differences along predicted aspects, providing first confidence in the framework [8].

4. DEFINITION OF DESIGN QUALITY – RESEARCH QUESTION B

Does a set of industry-accepted Design Quality Criteria (DQC) exist and do these exhaustively capture design quality, providing an internal product design metric? One, which correlates with industry-accepted external product performance metrics? To answer these questions it is important to understand the design process, specifically how concepts are evaluated.

In my experience, designers work with individual, incomplete, inconsistent and changing definitions of design and design quality. An audit of design definitions, historical design movements, and global design awards led to selecting C-K theory as a design perspective. It's mathematically consistent structure based in set theory, treats concepts as vehicles with a distinct set of properties and focuses on the interplay between concept and knowledge, This perspective of design, with its expansion and contraction of properties, lends itself to coding and mapping, opening possibilities for defining metrics for design arguments and establishing connections to external metrics.

The IDEA Awards criteria, together with the Danish Design Prize criteria "structure" and BMW Group's, Chris Bangle's emphasis on philosophy was finally selected as Design Quality Criteria (DQC), following a broad literature and web-search. See Table 1.

Table 1. Design Quality Criteria. Aggregated criteria for concepts from Industrial Design Society of America, Danish Design Center, Bangle Chief Designer, BMW Group.

Strategy	Philosophy	Chris Bangle
	Structure	Danish Design Prize
	Innovation	IDEA
Context	Social/Human	IDEA / Danish Design Prize
	Environmental	IDEA / Danish Design Prize
	Viability	IDEA / Danish Design Prize
Performance	Process	IDEA
	Function	Danish Design Prize
	Expression	IDEA / Danish Design Prize

These criteria exhaustively covered the scope of 17 global product awards, giving credit to their industry applicability. The IDEA award, representing six of the nine criteria, has the advantage of being widely respected and used as quality references in the United States among designers and business people alike. It has published criteria and recorded accessible award winner records dating back to 2000.

It is important to note that these criteria are intended for evaluation of a final product's design and not concepts. Comparing product and concept evaluation criteria however, show that these overlap to a large extent. The main difference between the two is that concept evaluations include emphasis on communicating and realizing various interface aspects.

For this project, I assume that designers and engineers are equally good at translating concepts into products across the examined companies. All rated companies are large American or International corporations, with internal and/or external design teams and decades of product releases. "The law of regression-to-mean" [9] makes similar development skills seem realistic. When evaluating the quality of a final design, this would also reflect the quality of the initial concept.

5 PRODUCT PERFORMANCE EXTERNAL – RESEARCH QUESTION C

Do key external success metrics in the marketplace exist, which can be linked to the Design Quality Criteria as defined by IDEA Award, Danish Design Prize and Chris Bangle, Chief Designer BMW Group's recommendation of philosophy?

5.1 Public awareness

Auditing IDEA winning products' associated web pages, I found IDEA Gold Award winners command roughly a factor five more web citations than Silver Award winners, which then command roughly a factor 10 more web citations than Bronze winners. Non-qualifiers performed slightly below Bronze winner level. Over the following 30-month timeframe this relationship remained consistent, though with a generally decreasing number of Web Citations.

Evaluating the influence of hype, potentially causing a reverse causality due to the publicity of the announced award winners, the web citation count was observed for ninety days following the public announcement. This showed that winner's Web Citation count superiority was inherent in the product offered and not the media hype. See Figure 2.

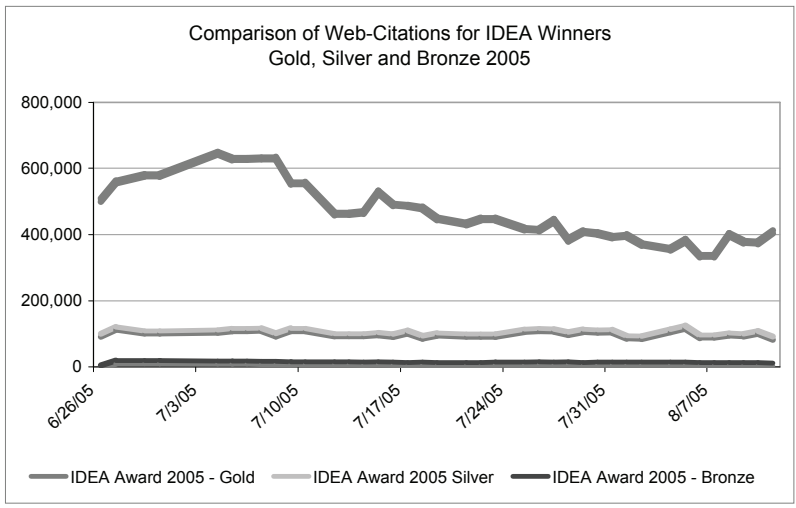

Figure 2. IDEA Award winning products' number of Web Citations over a 7-week time frame. Development in the number of Web Citations with time, measured for Gold, Silver and Bronze IDEA winning products over the period June 26 – August 14. The number of Web Citations increases following the announcement, and then decreases to what appears to be pre-announcement level, followed by steady decline. Over the period observed the distinct difference in the number of Web citations for each level remains.

While investigating if the distribution was likely to be coincidental, award-winning products from the period 2000 to 2007 were recorded for a period of six to 40 months. For five of the eight award announcements observed, the Gold winning products performed better than the Silver and Bronze winners on Web Citations. In one year, Gold and Silver tied and in another, Silver winners out performed Gold. In one year, the number of Gold winners was insufficient for drawing conclusions. Comparing the findings for the winners with the non-qualifying IDEA entries revealed these to have a Web Citation count at a magnitude 10 times lower than the Gold winners for 2005 [10].

5.2 Investor's expectations

The research establishes that products with a high degree of design quality, as measured by the Design Excellence Award (IDEA Award) criteria alone, do poorly the year of award reception. However, the

following year, they exceeded the performance of the prior two years with 16% increase in stock price, versus 14% for S&P500. Observed over a four and a half-year period (2000 – 2005), award-winning product's companies outperformed the S&P500 by 32% (outperforming by approximately 6.5% per year). See Figure 3.

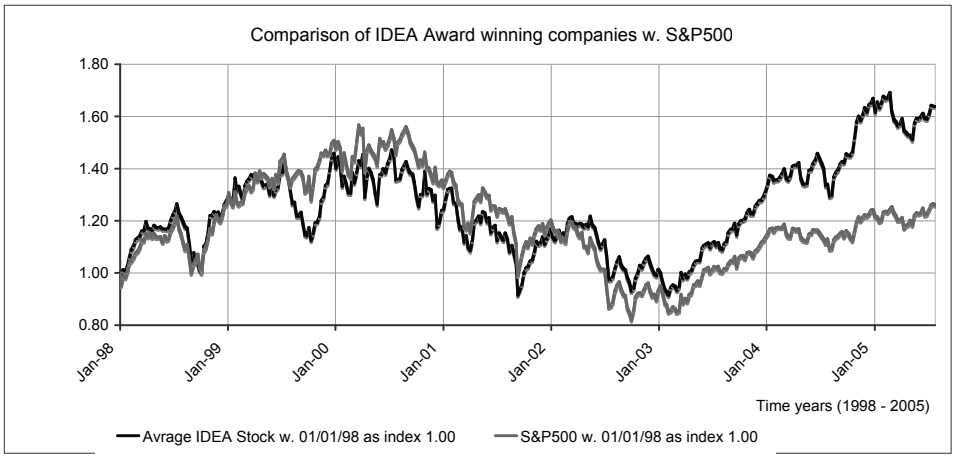

Figure 3. Comparison of S&P500 and stock prices of companies behind IDEA Award winning products in the period 1998 – 2005.

Is Wall Street disposed to award announcement hype? No, since there is no evidence of immediate price change following award announcements. However, a consistent level of design quality, as reflected in steady award reception, is cumulative. Companies winning three to four awards see a yearly stock price increase of 10 percent. While winning four or more awards results in an 18 per cent yearly stock price increase.

Could other factors, co-varying with design, drive this effect? One such well-known factor is Branding. Comparing the top 22 brand performing consumer product companies, according to brand value [11] with their stock prices, showed design and branding to co-vary. Combined, they outperformed any other combinations and design performed better alone than branding alone. This corresponds with previous studies [3].

5.3 Selection of external metrics

In conclusion, as external performance metrics, general awareness (Web Citations) and investor's expectations (stock prices) were used. General awareness was selected due to its trend creation and prediction potential. Investor's expectation was selected due to its ability to capture value creation over time and enable comparison with established financial evaluations [12].

6 HYPOTHESIS DEVELOPMENT – RESEARCH QUESTION D

Contingent on the existence of an internal performance metric for concept quantification, design quality criteria for design quantification of products and relevant external performance metrics, - does a mapping exist connecting these and enabling prediction of a concepts success potential? To answer this question a Concept Impact-Map was constructed, mapping concept quality (CAP_{Arg}) to internal design quality metrics DQC. See Figure 4.

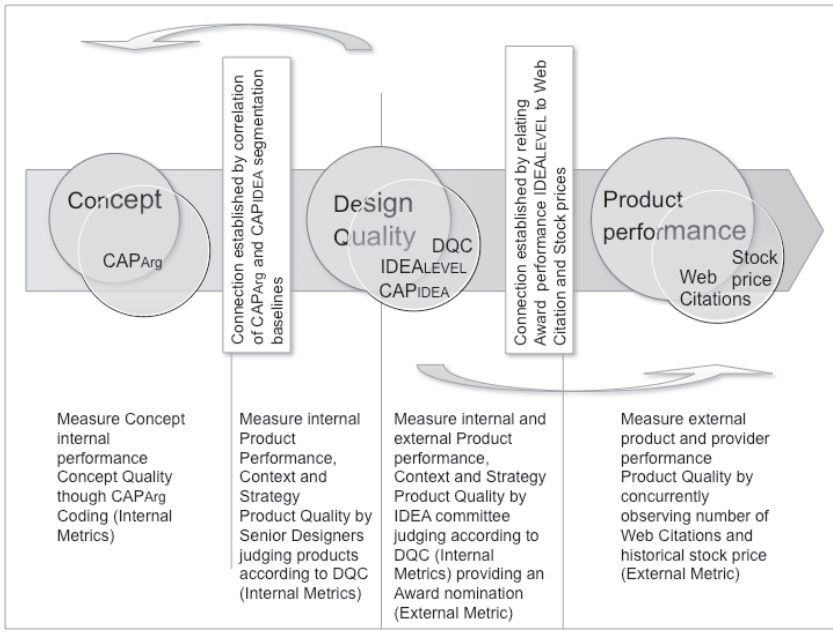

Figure 4. Concept Impact-Map. The construct map internal and external metrics. The baseline for the Concept Aspect Profile (CAPArg) maps to the baseline for the coding of the IDEA Award (CAPIDEA) applications. Though observations of award winners' reception of Web Citations and their respective companies stock price, the IDEA Award classification maps to performance metrics in the market place.

Mapping was realized by identifying a connection from a designer's argumentation for a concept, as captured by the Concept Aspect Profile (CAPArg) to Design Quality Criteria (DQC) as captured by interviews with designers. Then a mapping was made from internal Design Quality Criteria (DQC) to external design quality, as measured by IDEA Award reception (IDEALevel).

7. CONCLUSION

Based on investigation of state-of-the-art in design consulting, literature review, case studies and surveys on the design process, concept generation and selection, the research questions are now answered.

7.1 Answering Research Questions

The research shows:

A. Concepts can be measured – and related to Design Quality Criteria
   The Concept Aspect Profile captures design concept arguments and relates to established Design Quality Criteria for four of the six criteria addressed in the IDEA Award.
   Proven validity of the findings is limited to consumer product concepts, resulting from the conceptual phase year 2005. Differentiation of Design Quality Criteria performance is significant at a $p<0.05$ level. The temporal limit is due to constant evolution of development processes, communication tools and cultural preferences. Further quantitative research is needed to evaluate business area, process and culture's temporal sensitivity.
B. Design Quality Criteria exists
   The nine Design Quality Criteria: Philosophy, Structure, Innovation, Social, Environmental, Process, Function and Expression have been identified and linearly correlated to Concept Quality (CAP), and four of these correlate to the IDEA Award reception criteria.

Proven validity of the findings is limited to consumer products marketed in North America during the year 2005. Differentiation of product quality is for the final product and is significant at a $p<0.05$ level. The temporal limit is due to the constant evolution culture, affecting the Design Quality Criteria. Further quantitative research is needed to evaluate business arena and cultural temporal sensitivity.

C. External awareness and investor expectation's performance metrics
Web Citations can function as a measurement of public awareness and IDEA Award performance is a leading indicator of such performance. The stock price can function as a measurement of a products contribution at a strategic, context and product performance level. IDEA Award performance is a leading indicator of stock price. Stock prices are significant at a $p<0.20$ level and suggest a trend, however, cumulative effect makes IDEA Award reception at four or more, over a seven year period, different from Non-qualifiers at a $p<0.01$ level.

D. Connecting the design concept argument to external metrics
A connection from concept to design and external metrics has successfully been established. Product performance can be predicted and concept arguments optimized along the aspects: "Individual," "Activity," "Function," "Planning" and "Philosophy," thereby improving stock price performance by nine percent.

The Concept Impact Map's three connections, multiply the uncertainties, resulting in a predictability of 71 percent. Conservatively, this is a nine per cent improvement over current methods. Augmenting the prevailing selection process, assuming independency among the two, results in a predictive power of 90 percent.

7.2. Optimal Concept Argument

How does one best communicate the complex profile of an optimal design argument, as opposed to that of a mediocre design argument? Inspired by designers experience with radar-diagrams, the "Golden Fingerprint" was constructed. The fingerprint visualizes an argument resulting in a highest general public awareness and investors' level of expectation, for an examined concept argument. See Figure 5. Utilizing the "Golden Fingerprint," competing concepts can be visualized and provide input as to where to focus further detailing, facilitating comparison for selection and combinations.

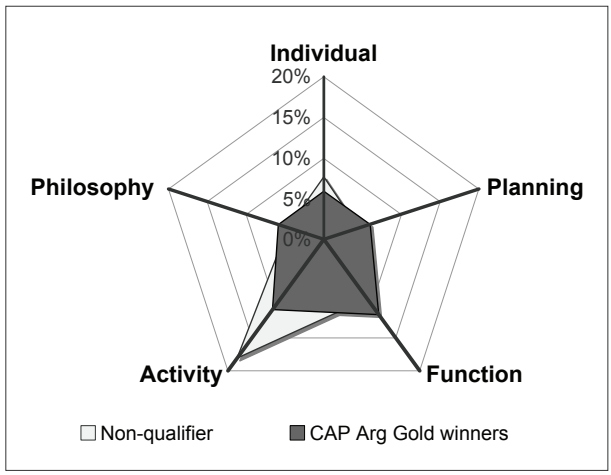

Figure 5. Golden Fingerprint. The two colored areas map the five CAPArg aspects, where the Gold winners and Non-qualifiers varied significantly ($p<0.05$) along the CAPIDEA aspects. These five CAPIDEA aspects translate into CAPArg aspects, using the linear correlation connection between CAPIDEA and CAPArg, thus enabling visual assessment of concepts with high and low degrees of design quality.

Opportunities for further development of the Concept Aspect Model include testing the models general applicability outside the consumer product category and it's possible temporal independency by observing multiple award reception categories and years.

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