Product Concept Metrics: a Preliminary Study

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ABSTRACT

Metrics for product concept evaluation and screening is a relatively unstudied topic of product development. Having a clearly documented set of metrics for concept screening decisions is a prerequisite for an educated and traceable decision making process. Measuring product concepts and comparing the results of pervious products and their success rates to the metrics documented for their screening provides a basis on which to improve the efficiency of product development work. In this study a list of product concept screening metrics, or issues if you please, is put forth. This list is priorized according to the importance of the metrics. The relative importance of the metrics is determined for a number of different groups, including academia and industry, along with geographical samples from Finland and the USA. Furthermore a brief study on published product concepts is presented to show that some of these metrics are indeed researched by companies and to determine the information that companies seek to obtain by publishing product concepts. Finally the realtion of the results of these studies is discussed in terms of their implications to the management of research and development in corporations.

1. INTRODUCTION

Producing product concepts allows for organizing the often 'fuzzy front end' of product development. Currently many companies do not have a process for providing or presenting product ideas or concepts. Even fewer have a procedure for evaluating the concepts in batches to allow for comparison and an informed decision on the resourcing of new product ideas. Studies have shown that companies currently favor evolutionary or incrementally improved products to new product or technology development [Christensen 2000]. A study by Mayers and Marquis found that only 21% of successful products were technology push products [Mayers and Marquis 1969]. These results suggest that the screening process and the information needed for making decisions on product concepts is not normally present in the R&D functions most commonly producing the product concepts. A solution to this problem is a list of metrics that need to be evaluated for the screening and selection of the product concept that is to receive the resources to proceed.

A standard set of selected metrics provides a checklist of issues to verify before the presentation of the product concept for the go / no-go decision. A standard way of presenting product concepts ensures that in addition to a product concept description the necessary metrics are presented in a way that facilitates an educated and fair selection process. A standard way of presenting product concepts also supports the view often promoted by literature[Pahl and Beitz, 1988] [Ulrich and Eppinger, 1995] that it is advisable to produce a number of product concepts to compare and choose from. However, a standard presentation of the product concept does not require a number of concepts to be analyzed at a given time as it also allows for a retrospective comparison of the current product concept with past ones. Conversely the standard metrics used in the decision would provide a back drop for future concepts to be compared to.

Christensen shows in his study of the disk drive industry a dialogue between a manager and employees presenting two different product ideas: one a market driven evolutionary product the other a technology driven product. [Christensen 2000]

A marketer presents a market driven evolutionary product idea that he came up with.

> "Who's going to buy it?"

> "Well, there's a whole segment in the workstation industry - they buy over $600 million in drives each year - that we've just never been able to reach because our capacity points just don't reach that high. I think this product just might get us there."
> "Have you run this idea past any potential customers?"
> Yeah, I was in California last week. They all said they wanted prototypes as soon as they could get them. There's a design window opening up in nine months. They've been working with their current supplier [competitor X] to get something ready, but someone we just hired from competitor X said they're having lots of trouble meeting the specs. I really think we can do it."
> "But does engineering think we can do it?"
> "They say it'll be a stretch, but you know them. They always say that."
> "What kind of margins are we looking at up there?"
> "That's what really excites me about this. If we can build it in our current factory, given the price per megabyte competitor X has been getting, I think we can get close to 35 percent."

An engineer presents a technology based low-end product idea he has come up with.

> "Who's going to buy it?"
> "Well, I'm not sure, but there's got to be a market out there somewhere for it. People are always wanting things smaller and less expensive. I could see them using it in fax machines, printers maybe."
> "Have you run this idea past any potential customers?"
> "Yeah, when I was at the last trade show I sketched the idea out for one of our current customers. He said he was interested, but couldn't see how they could really use it. Today you really need 270 MB to run everything, and there's just no way we could get that kind of capacity in this thing - at least not for a while. His response doesn't surprise me really."
> "How about the guys who make fax machines? What do they think?"
> "Well, they say they don't know. Again, it's an intriguing idea, but they already have their product plans pretty well set, and none of them use disk drives."
> "You think we could make money on this project?"
> "Well, I think so, but that depends on how we could price it, of course."

The conclusion Christensen draws is that there is an inherent drive toward higher performance products. This may be true, but as shown in the discussion extract above the technology push product concept lacks the standard data the manager wants to make a go ahead decision. Thus the clear identification of the metrics used for the evaluation of product concepts is a necessity.

1.1 Literature on Product Concept Metrics

Metrics for product concept analysis and screening in literature by authors such as Pahl and Beitz, Ulrich and Eppinger, Pugh and Ullman are not well discussed as the metrics they put forth are often targeted at later stages of product development. Cooper introduces a questionnaire for product screening and a list of metrics and his work can be regarded as a benchmark for the studies presented in this paper.

Pahl and Beitz present a set of criteria for making a decision on launching a product program (Table 1). They categorize the issues to be considered in three groups and give an importance coefficient to each of these groups. The issues for analysis, however, are not easily adapted into a standard method of product concept analysis, screening, and presentation. Only groups of attributes are valued in terms of their importance and there is no specific testing whether the attributes indeed are the ones that most importantly need to be evaluated.

Table 1. Pahl & Beitz's Criteria for Planning a Product Program

Company Objectives	Sufficient profit Large turnover Fast growth of market Large market share Leveraging short term market opportunities Large benefits and superior quality to the end user	weight >50%
Company Strengths	Good know-how Appropriate enlargement of product or project portfolio Strong marketing position Small need of investment Small sourcing problems Good opportunities for rationalizing	weight >30%
Business Environment	Small number of overlapping products Little competition Favorable patenting opportunities Small number of legal constraints	weight >20%

Adapted from [Pahl and Beitz 1986]

Elsewhere in their work Pahl and Beitz introduce methods to perform a preliminary selection of product ideas and an evaluation method of further developed concepts. At the earlier phase they do not list what metrics should be used but they say that a concept that proceeds to the next phase should fulfill the following criteria: the concept must be compatible with the overall task (A); it must meet the specification demands (B); it must be realizable (C); and it must stay within the given budget (D). In addition they mention that often a concept should also incorporate direct safety measures or have good ergonomic conditions (E) or be developable using company's own know-how, procedures etc (F). If a concept does not meet criteria A and B the other criteria does not have to be considered at all. Also E and F are looked upon only if a concept has passed the criteria C and D.

Pahl and Beitz recognize the importance of cost analysis at the later stage of concept evaluation but they emphasize that also other selection criteria ie technical and market analysis are important. They present a model where they stress the importance of formulating the metrics to fulfill the following criteria: the metrics should cover all decision-relevant requirements and constraints; metrics should be self-contained and not depend on other metrics; and the metrics should be presented in an unambiguous quantitative, when possible, or qualitative way. The different levels of importance of each evaluation criterion can be taken into account by assigning weighing factors. Then an evaluation matrix is formed and the concepts are scored to find out the best alternatives. [Pahl and Beitz, 1988]

Ulrich and Eppinger introduce methods to screen and score concept variations. The first is better suited for early stages of development and the latter for later stage when more detailed information is available. The screening method is based on Pugh's concept evaluation method. The criteria are mostly technical and based on customers' needs, but they point out that cost and ease of manufacturing can not be left out either. According to Ulrich and Eppinger it is important to present the evaluation metrics at the same level of detail for reasonable evaluation. They also accentuate the importance of graphical presentations. Just as Pahl and Beitz Ulrich and Eppinger also use weighing factors and evaluation matrices to select the best concepts for further development. [Pugh, 1996] [Ulrich and Eppinger, 1995]

Ullman presents four methods of evaluation that should all be used together. He classifies the methods to absolute and relative methods depending on whether the concept is evaluated individually or compared to others. Absolute methods include Feasibility judgement, Technology readiness assessment, and Go/no go screening. Decision matrix method is a relative evaluation method. Feasibility judgement is based on ranking the concepts to "not feasible", "might work if something changes", and "worth considering" according to the designer's "gut feel". This considers the functionality of the concept. In the second method, Technology readiness assessment, the technologies used in each concept are graded by the maturity of the technology. In the third evaluation method, Go/no go screening, customer requirements are transformed to questions answerable with either yes, no, or maybe. Go/no go statements are made after each answer and if a concept has many no go's it is rejected. In case of a few no go's the concept can be modified to have more positive statements. This method takes customer needs into account. The fourth method is the Pugh's concept evaluation method, where engineering details of each concept are compared to a "benchmark" concept. Also Ullman stresses the importance of showing all concepts at the same level of detail. Ullman does not list any metrics but the four methods include some criteria. [Ulman, 1992]

The decision matrices in all selection methods required detailed numerical information that is not available at the earlier concept selection phase. Ullman's first three methods could be applied also in the beginning of the concepting phase but all three Ullman's methods are absolute methods ie concepts are evaluated individually and not compared to other concepts. To choose the best concepts for further development, a comparison of concepts is also needed. This comparison is included in Ulrich and Eppinger's and Ullman's decision matrix methods but neither one of the books lists what metrics should be compared. Pahl and Beitz as well as Ulrich and Eppinger give some criteria for the attributes to evaluate but neither lists anything specific.

A more comprehensive list of new product screening metrics is put forth by Cooper, in the form of a new product screening questionnaire and screening model. He identifies eight categories of metrics that need to be evaluated, as shown in Table 2. The questionnaire asks a number of detailed questions on each of these categories. The shortcoming of the method, however, is that there is no prioritization for the different categories or specific metrics related questions. The validity and importance of the metrics that Cooper proposes is evaluated in the studies presented in this paper. Also the existence of industry or company specific metrics is studied to amend the list compiled by Cooper. [Cooper, 1986]

Table 2. Cooper's Categories of New Product Screening Metrics

Product advantage	Technical issues that differentiate the product from the competition and make it profitable for the company
Economic advantage of the product to the end user	How the product is better than its alternatives for its user.
Corporate Synergy	How does the product fit with the company overall.
Technological synergy	Does the product leverage current technical capabilities of the company.
Project newness to the firm	Does the product require learning in the company. (I.e. Competence development aspects) and does it open new market opportunities.
Market need, size and growth	What customer needs are addressed, the number of potential customers and the growth rate of this customer group.
Market competitiveness	Why will the customer choose this product over others.
Projects scope	How much resources are needed and how much of the current corporate structures are effected.

Adapted from [Cooper 1986]

It seems that a clear specification of metrics remains understudied. Our aim is to find out the most important metrics to enable the definition of product concepts so that the necessary data for the selection of the most promising ones is prepared and availble during the selection process.

1.2 Definitions of Key Terminology

To be able to discuss the subject of measuring product concepts, a few key definitions need to be clarified. In this paper the terms of *product idea*, *product concept* and *metric* are understood as follows:

Product Idea- A product idea is a largely undefined identification of a possible product. A product idea often only resides as a vision in its conceiver's mind expressed with only a few attributes. For example through definitions such as "a mobile phone with features for the disabled" or "a palm computer with constant Internet access". The attributes of the definition are often voiced through an device with some similar attributes to define the 'ball park' the product would be in and a user or technology related attribute that differentiates the product idea from the product mentioned. There can be several attributes that define the idea but most often these are limited to two or three. The attributes can be viewed as intersecting groups A to N, shown in equation 1, and the intersection defines the bounds of the product idea (P) as shown in Figure 1.

$$P = A \cap B \cap \cdots \cap N \qquad [1]$$

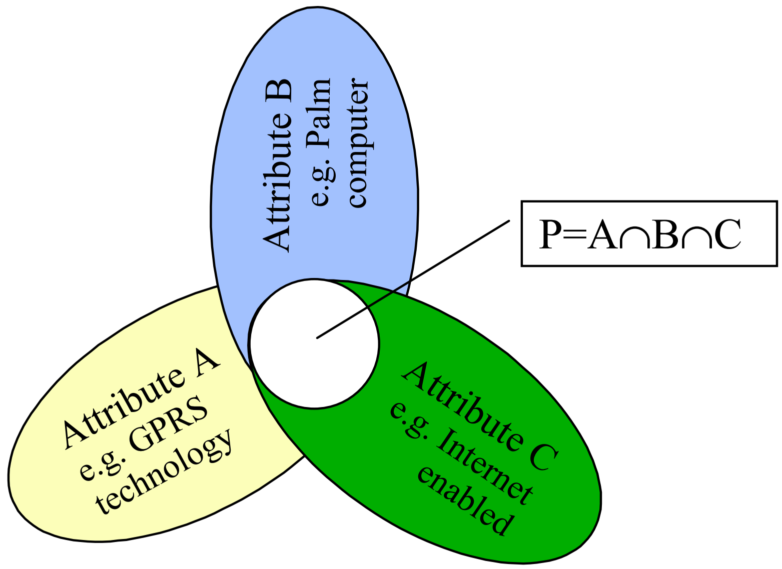

Figure 1. The intersection of attribute groups defines the product idea.

Product concept- A product concept is understood to be the description of a product idea that has been evaluated or is in the process of being evaluated enough to allow the decision of starting actual product development. A product concept provides ontology to product ideas through a standard presentation of a selected set of metrics.

Metric- A product concept metric is a definable quantitative or qualitative attribute that can be used for the evaluation or screening of product concepts.

Product concept evaluation requires both quantitative and qualitative metrics. In literature metrics are often only quantitative. Such a definition of a metric is given by Moody et al. [Moody et al., 1997] Moody's definition disregards the qualitative issues that are a key to assessing product concepts. The value statement for a metric, which describes the desirable values for it, cannot easily be molded into the definition of all qualitative metrics. However, this may not be as problematic as one would assume. Due to the nature of product concept screening decisions being instrumental in the implementation of corporate strategy, the required value statements for qualitative metrics for product concept screening can be drawn from the company's statements of vision and strategic intent. Definitions such as Moody's definition are not broad enough for product concept measurement, thus the broader definition provided above is used in this paper.

1.3 Hypotheses

As a basis of these studies it was hypothesized that, a number of metrics for product concept evaluation can be identified and prioritized in terms of their importance. These metrics are both quantitative and qualitative in nature, regardless of the difficulty in comparing qualitative metrics and setting value statements for them. It is also hypothesized that metrics for product concepts can be grouped into several categories, these are; Universal metrics that industries need to follow for most of their products, metrics that are industry specific, and company specific metrics. The prioritization of metrics should be done separately for these groups to allow for industry and company specific priorities need to be determined at an appropriate level. For example a company might want to refocus their strategy due to a shift in its focus market. This refocusing may change the prioritization of company specific metrics. If the company moves into a new industry sector as a result of it refocusing of strategy the results of this study's prioritization of the new sectors industry related metrics helps in finding the right order of importance of metrics in the new segment. The volatility of the metrics in terms of their prioritization also becomes larger as one moves from the more universal metrics to industry and company specific metrics. Indeed, the company specific metrics are reprioritized to attack short-term market opportunities or by a shift in strategy.

In addition to these hypotheses, information on the metrics companies want to find clarification to with publishing product concepts and what other drivers there are to publish product concepts, was researched in a brief second study also reported in this paper.

2. STUDY TO PRIORITIZE METRICS, ISSUES, AND TOPICS FOR PRODUCT CONCEPT EVALUATION

The aims of this study are to identify and prioritize the metrics, according to their importance, that best can be best used for the analysis and screening of product concept. The aim is also to provide material for making a questionnaire for a further more detailed global study on the valuation of product concept evaluation metrics. A second aim is to see if differences in valuation can be found between different groups. This is done to evaluate if universal, industry, and company specific metrics can be identified. The study was done during the spring of 2001.

2.1 Method of study

The structured brainstorming was performed by a number of selected groups of professors and researchers at MIT Center for Innovation and Product Development (CIPD), at Helsinki University of Technology (HUT) Laboratory of Machine Design, and company representatives. The groups were asked to list metrics that they find important in selecting concepts to pursue. Additional information was gathered by interviewing managers who actually perform concept selection at their companies to get their view of the main metrics they would like to have for the decision.

The structured brainstorming method used was a variant of the 'Tuplatiimi' method developed by Innotiimi Inc. in Finland. The basic process of brainstorming was divided into three basic steps. Firstly a short presentation of the idea of the study, a definition of the term product concept and a brief 'mindsetter' presentation with pictures of published product concepts was done to focus thinking on the topic. Secondly the groups were asked to jot down their ideas on the candidates for product concept metrics, first individually then discuss then in teams of two and propose a set of about five metrics for each team. Thirdly the importance of the brainstormed metrics was voted upon individually. In the vote everyone was asked to identify the three most important metrics in rank of their importance (the most important one was given three votes the second two and the third important metric one vote).

The following views of the sample were produced: The whole sample, Industry USA vs. Industry Finland, Industry vs. Academia, and Finland vs. USA.

The results were calculated to give an equal weight to all the groups in the analysis. This allowed the formation of a combined result without giving any group more emphasis than the others. However, this did cause the answers of individuals in smaller groups to have larger significance than individuals in small groups.

Groups for the analysis were formed by combining the results from different brainstorming sessions and interviews by calculating a score (S) for each metric to eliminate the effect of the sizes of the different groups. The score (S), equation 2, is a percentage of the votes of the session the metric in question received.

$$S = \frac{v}{V} \cdot 100 \qquad [2]$$

Additional groups for the analysis and compilation of graphs were produced by combining the scores (S) of the smaller groups according to equation 3. The sum of the induvidual scores from equation 2 were is the total score (S_{tot}) used to produce the graphs.

$$S_{tot} = \sum_{l}^{n=k} S_n \qquad \text{(k to l are the groups which are summed)} \qquad [3]$$

The graphs for the different groups show the relative importance of the metrics within that group as the absolute number of votes the metric got in the vote (v). In cases were the graph was compiled from a number of groups the absolute number of votes was replaced by the sum of the scores ($v = S_{tot}$). The cumulative importance of the metrics (C) is calculated as percentage of the sum of all the votes that were given to the metric in question and the metrics that were valued more important than it and the total number of votes given in the brainstorm session (V), equation 4.

$$C = \frac{\sum_{j}^{n=i} v_n}{V} \cdot 100 \qquad \text{(i= the most important metric and j= this metric)} \qquad [4]$$

2.2 Results

The number of people in this study was 40 of which 38 were in the brainstorming sessions and 2 were interviewed. 26 Metrics of product concepting were identified in this study. The detailed definitions for the metrics identified are shown in Appendix 1. Figure 2 shows the overall results of the study with the combined valuation of all the metrics compiled from the whole data set. Figure 3. shows the valuations of metrics in industry in the U.S. and in Finland. Figure 4. shows the prioritization of metrics between academia and industry. Figure 5. shows the prioritization of the concept evaluation metrics in Finland and the U.S.A.

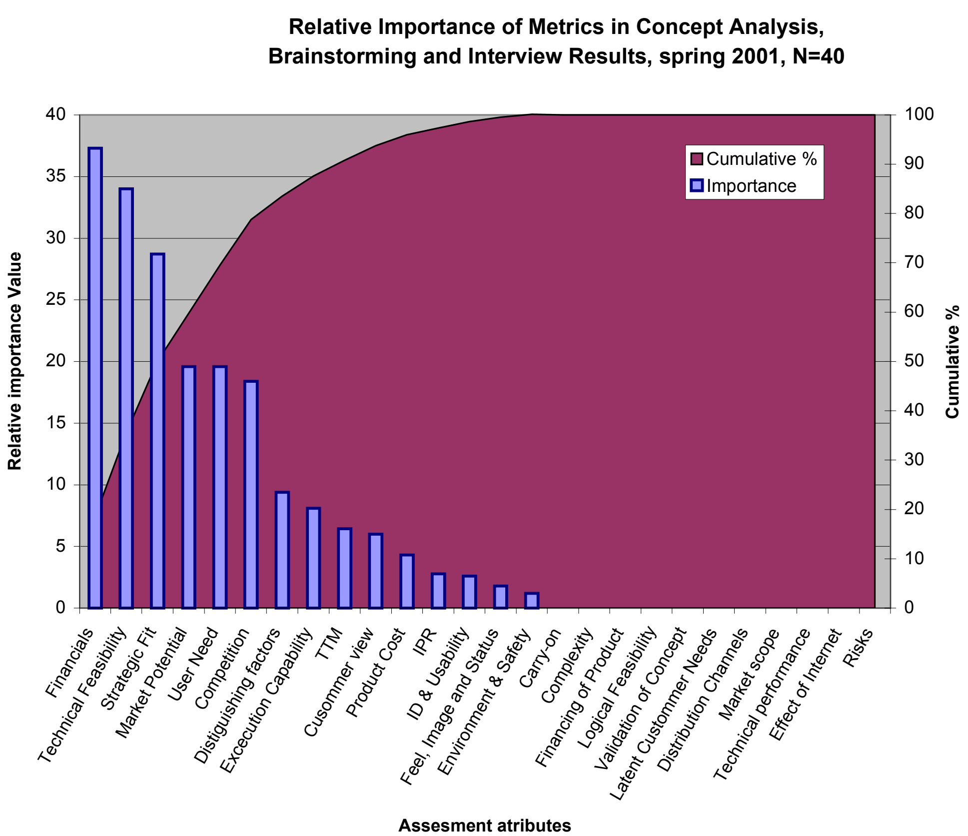

Figure 2. Relative importance of the metrics identified in the study.

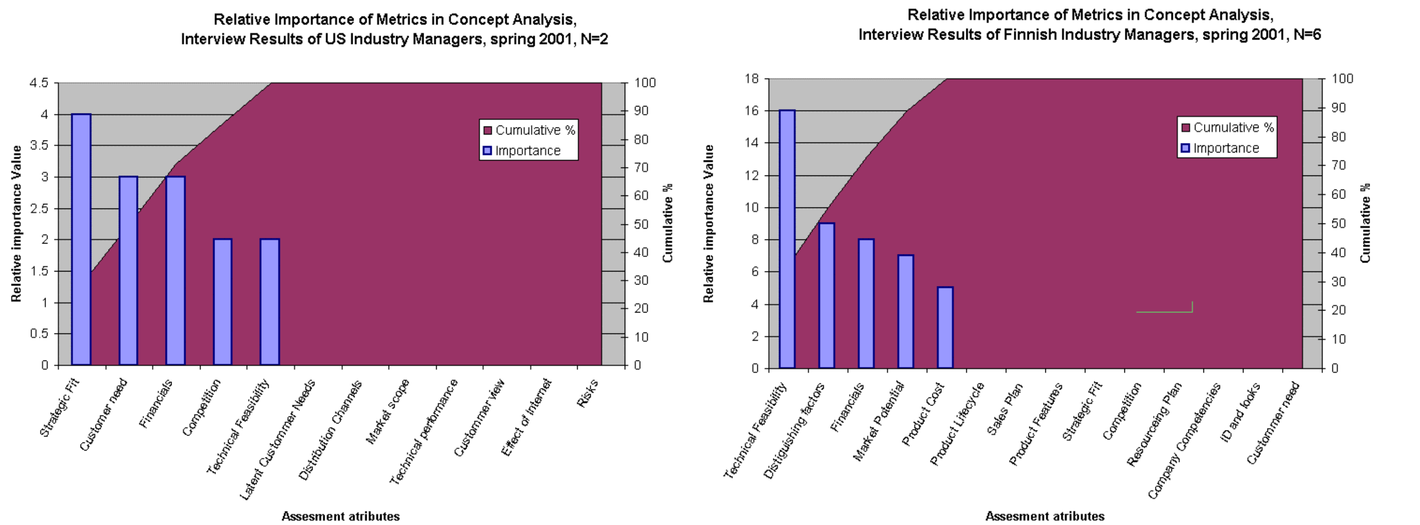

Figure 3. Importance of product concept evaluation metrics in U.S. and Finnish industry

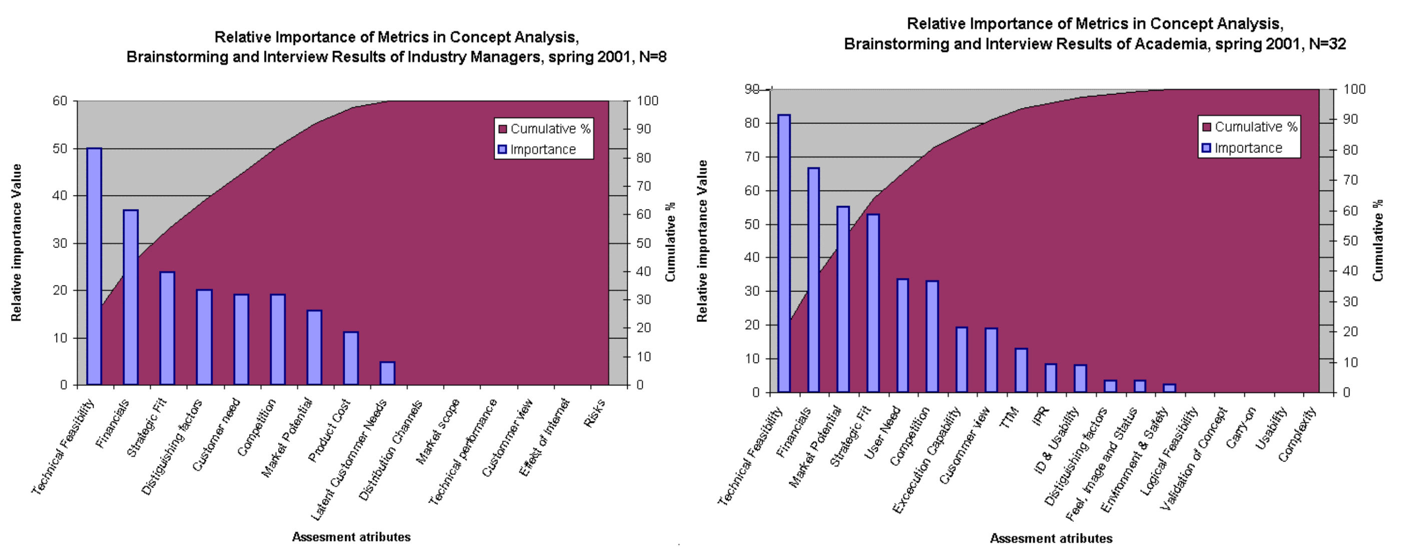

Figure 4. Importance of product concept evaluation metrics as viewed by industry and academia.

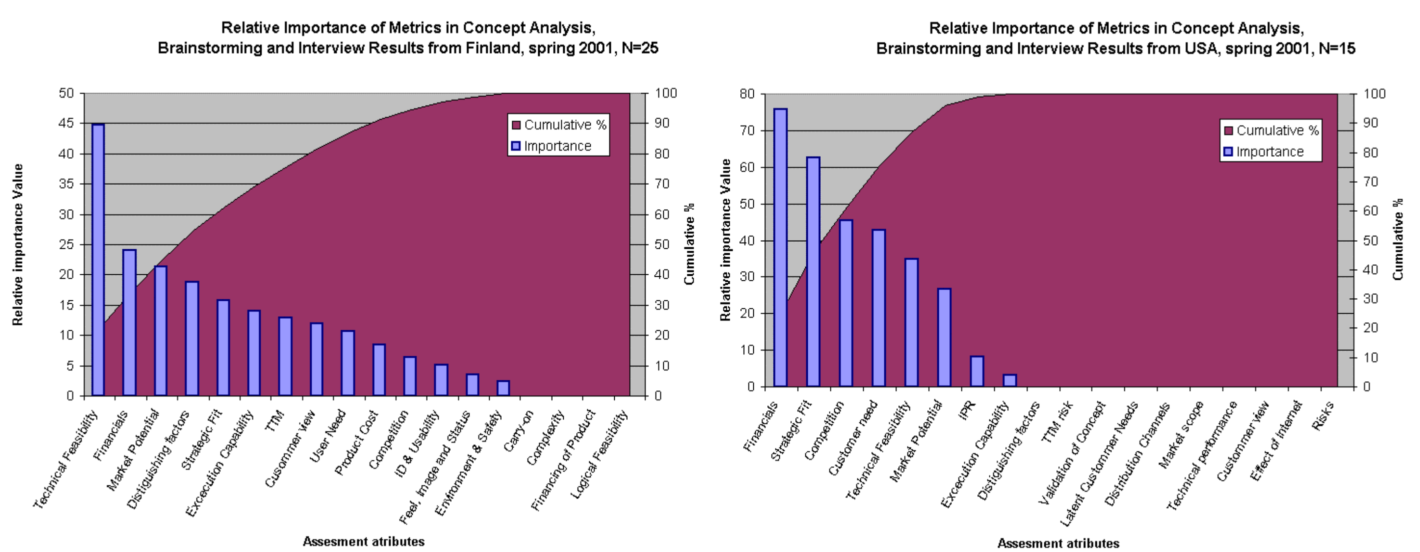

Figure 5. Importance of concept evaluation metrics in Finland and the U.S.A.

The metrics valued most highly by the whole sample and the different groups is shown in Table 3.

Table 3, Top Five Metrics of the Different Groups in the Study

All groups, N=40	Industry, N=8	Academia, N=32	Industry U.S.A., N=2	Industry Finland, N=6
Financials	Technical Feasibility	Technical Feasibility	Strategic Fit	Technical Feasibility
Technical Feasibility	Financials	Financials	Customer need	Distinguishing Factors
Strategic Fit	Strategic Fit	Market Potential	Financials	Financials
Market Potential	Distinguishing Factors	Strategic Fit	Competition	Market Potential
User Need	Customer need	User Need	Technical Feasibility	Product Cost

HUT Faculty, N=7	MIT Faculty, N=8	HUT Students, N=13	MIT Students, N=5
Technical Feasibility	Financials	Technical Feasibility	Financials
Market Potential	Customer need	Strategic Fit	Market Potential
Customer need	Competition	TTM	Strategic Fit
ID & Usability	Strategic Fit	Financials	Technical Feasibility
Execution Capability	Technical Feasibility	Execution Capability	Competition

USA, N=15	Finland, N=25
Financials	Technical Feasibility
Strategic Fit	Financials
Competition	Market Potential
Customer need	Distinguishing Factors
Technical Feasibility	Strategic Fit

3. STUDY OF PUBLISHED PRODUCT CONCEPTS

Corporations publish product concepts to get an understanding of public reactions to certain types of products. The publishing of product concepts is also often a part of the corporate marketing and branding strategy. Companies tend to define their published product concepts by giving information on some of the metrics identified in the previous study, to then be able to learn more about customer and market preferences in terms of other metrics. The objective was to identify the metrics companies develop and are willing to publish and the metrics on which feedback is sought.

3.1 Method of study

The study of published product concepts was made by collecting and analyzing information about published product concepts. The data were collected in the form of photographs of product concepts, handouts, and publicity material and data based on conversations with company representatives. In many cases some information (metrics) on the proposed concepts is provided or can be directly seen or deduced from the product concept artifacts. This information is compared to the metrics identified in the brainstorming study to identify what metrics are and are not published and what data companies are looking for by publishing the product concepts. The published product concepts and their metrics were collected at trade shows (CeBit 98, 99, 00, 01 and Telecom 99), the Internet and through publications (magazines and company publications and press information).

3.2 Results

The number of product concepts analyzed was 81 in total. The analysis identified 14 of the studied metrics (listed in Appendix 1) in the published concepts. Of these 35 were to be mostly for image purposes and 12 for R&D purposes. The rest were for both. The main objective seemed to be to collect customer feedback and testimonials for either marketing or R&D purposes, though some published concep products were intended mainly as attention grabbers.

The statistically significant metrics that were the cause of investigation in the products and the metrics that were published are shown in table 4. The analysis was done by counting the frequence of each metric being identified and by categorising concepts according to whether a metric was disclosed or investigated by the company. If a metric was identified to disclosed in a published product concept it was annotated by the value 1 and metrics that were investigated were annotated with a value of 2. The averages of these are also shown in the table.

Table 4, The Most often Investigated and Published Metrics in Product Concepts Published by Companies (in order of frequency)

Published Metric	Metric Subject of Investigation
Distiguishing Factors (78 /1.08)	Customer Testimonial (69/2.00)
Industrial Design (67/1.07)	User Need (66/1.68)
Technical Feasibility (42/1.07)	Market Potential (63/1.98)
Usability (42/1.33)	Customer (62/1.87)
Feel, Image and Status (31/1.00)	Strategic Fit (41/1.02)
Technical Performance (30/1.07)	Latent Customer Need (33/1.66)
Execution Capability (19/1.00)	Sales Argument (23/1.52)

The first number following name of metric shows the number of times the metric was identified in data set and the second number the average of the data set on wheather the metric was published or investigated (1= published, 2 = investigated).

4. DISCUSSION

The studies presented here effectively raise more questions than they were able to solve. However, some conclusions can be drawn from the results based on the original hypotheses along with some discussion of the management impacts of using a set of product concept metrics for evaluation of product concepts.

It was shown that a number of metrics for concept evaluation can, indeed, be identified and prioritized and the metrics can also be grouped into several categories i.e. country, industry, or company specific metrics as hypothesized. Country spesific lists were shown in results but more data is needed for better results. Also company and industry specific lists require more information before a list can be compiled.

According to our results it seems that financials, technical feasibility, strategy, and customer or market related issues are among the top five in each category analyzed. These can be considered universal metrics that should be evaluated no matter what region, industry, company etc.

Finnish industry managers seem to give more value to the product and its functionality whereas US managers stress more financials matters. But since the sample was so small (N_{US}=2 and N_{FIN}=8) the results can only be seen as suggestive. Further study is needed for more comprehensive results.

There was suprisingly little difference between the valuations of industry vs academia. Both consider technical feasibility and financials to be the two most important metrics for concept evalution. More distinction could be made by splitting the top five into more detailed metrices.

There were clear regional diffenreces in the prioritization. Finnish give more value to technical issues whereas Americans hold financial issues more important. This verifies the predicted result based on cultural differences.

All results are only indicative and more data is needed for more accurate results.

Based on the work and formulating the list of metrics it was found that value statements can be given for quantitative metrics but are hard to give for qualitative ones. Value statements are importan because they determine the prferential direction of development. However, experience has shown that corporate strategies determine the value statements for qualitative metrics, solving the problem of including them in the metrics definition. Product concepting, concept evaluation and screening are in an iteration loop with the corporate strategy forcing the assessment of the strategies every time concepts are screened. Linking strategy to the value statement of qualitative product concept metrics gives a reasonably good image of what are preferential values of metrics to the concept creation process, provided the strategy is properly communicated. This linkage allows also for rapid changes in the specific implementation of the strategies according to e.g. competitive situation (a certain type of product is expected now or now we need a new premium product to bolster brand image) or a specifically identified business need (such as a drive to diversification). An additional benefit of the product concepting and screening process is that it facilitates corporete stratedy implementation. This hopefully helps create a more agile company with a clear vision what it can do and what it wants to do along with a number of strategies implemented as the reasoning for the selection of future products.

Creating product concepts and comparing them with each other and possible benchmark products or product concept using a set of metrics is a way to bring visibility and accountability to product selection. Documentation of the metrics for product concepts also allows revisiting the metrics of product concepts after they have been developed into products, and assessing the effect of the metrics on product success. Such reflection is a key to ongoing improvement in the efficiency of product concept selection. By defining a set of metrics that must be produced for product concepting it is also possible to focus work done in the concept stage on the issues seen important, leaving other less important issues for development later on in the product creation process.

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REFERENCES

Christensen C., "The Innovator's Dilemma," Harper Collins, N.Y., 2000.

Cooper R., "Winning at New Products" Addison-Wesley, 1986.

Mayers S., Marquis D., "Successful Industrial Innovations," National Science Foundation NSF 69-17,1969.

Moody J., Chapman W., Van Voorhees F., Bahill, A., "Metrics and Case Studies for Evaluating Engineering Designs," Prentice Hall, 1997.

Pahl G., Beitz W., "Engineering Design, A Systematic Approach", The Design Council, London, 1988. ISBN 951-817-468-7.

Pugh, S. "Creating Innovative Products using total design," Clausing D., and Andrade D. (eds.). Reading, Massachusetts, USA. Addison-Wesley Publishing company. 1996. pp. 544. ISBN 0-201-63485-6.

Ullman, D. The Mechanical Design Process. McGraw-Hill, Inc. 1992. pp. 337. ISBN 0-07-065739-4.

Ulrich K., Eppinger S., "Product Design and Development", McGraw-Hill, Singapore, 1995. ISBN 0-07-113742-4.

APPENDIX 1

Names and definitions of product concept metrics identified in the study.

Competition	List of competitors to this product their selected market segments, product features and prices
Customer	Who is the customer? Target segment for the product
Product scope	Is the product global, regional or national
Legal issues	What are the legal and regulatory requirements for the product
Market Potential	What is the size of the market, what are the adoption rates, %of product users in population, and prediction for segment growth
TTM	Time To Market, Is there a market window for this product, what is it and can we make it
Product cost structure	What is the target price of the product, what is its cost structure. (i.e. Cost of HW, SW, parts, marketing, sales, take-back etc.
Revenue per customer	How much profit per customer can we make with this product
Time to profit	how long will it take to cover development expenses of this product
Strategic fit	Does the product fit current company strategy (product-, technology-, sales-, service strategy etc.)
Execution capability	Is there resources for making this product (R&D, Manufacturing, supply chain, money) Can we get them?
Existing in-house competence	Is there an in-house competence that we can leverage for this new product
Carry-on	Are there components, know-how or learning's in making this product that are seen useful in future product generations and is there something from previous products that needs to be used.
Environment & Safety	Preliminary LCA and lifecycle plans. What are the safety issues to be considered
Distribution Channels	What are the distribution channels of the product
Outsourcing	Supply channels and what is done in house and what outsourced
Internet	How does this product utilize the internet and E-business.
Risks	What are the business risks involving this product
User need	What user need is being addressed by the product
Sales Argument	What is the argument we can use to sell this product to the customer

Customer testimonial	What do prospective customer think of this product
Distinguishing factors	What are the distinguishing factor of the product How is it better than competition, Why does a customer choose it
Industrial design	What is the role of ID and what will the product look like
Usability	What are the ergonomic and ease of use features and innovations of this product
Feel, Image and Status	What is the feel, image and status of the product in terms of the customer
Complexity	What is the level of complexity of the product for the user, does he need training in handling the product
Latent customer needs	What latent customer needs can be addressed to provide the product to fulfill even unrecognized customer needs
Technical feasibility	Is the needed technology available, what are the key technologies.
IPR	Who has the necessary patents, can they be licensed or designed around
Technical performance	How does the product technology compare with state of the art technology and benchmark products
Reliability	What is the reliability target of the product and how can it be reached