ICoRD '13
International Conference
on
Research into Design
Indian Institute of Technology Madras, Chennai, 7 - 9 January, 2013.

Determining relative quality for the study of creative design output

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Abstract: Design creativity is often defined using the terms "*novel*" and "*appropriate*". Measuring creativity within design outputs then relies on developing metrics for these terms that can be applied to the assessment of designs. By comparing design appropriateness to design quality, this paper develops a systematic method of assessing one element of design creativity. Three perspectives from literature are used; the areas in which quality is manifest, the categories into which quality assessment criteria fall, and how well criteria are achieved. The output of the method is a relative ranking of quality for a set of designs, with detailed understanding of the particular strengths and weaknesses of each. The process of assessment is demonstrated through a case study of twelve similar designs. Through such analysis insight into the influences on quality can be gained, which in turn may allow greater control and optimization of the qualities that design outputs display.

Keyword : Creativity, quality, assessment, design output

1 Introduction

There are a number of existing definitions of creativity within design literature aiming to distill the term into its necessary constituent parts. They also deal with the criteria by which creativity can indirectly be measured [1-3]. Although defined in many ways, amongst the terms most frequently used are "*novelty*", "*appropriateness*" and "*unexpectedness*" [4]. These are used to denote how novel an output is in terms of the field and alternative problem solutions; how suitable an output is as a solution to the specific problem that has been described; and how surprising or unusual a solution is in context of similar solutions that already exist, or the features of the output itself. Through these terms, an output that is creative is defined as a new solution that is recognised as highly and particularly suited to the problem that has been set, likely denoting it as the superior design solution available within the market.

To determine the creative properties of an output it is necessary to identify and assess of these terms. Such a breakdown would allow detailed analysis of aspects that set apart a creative output, in a manner that would give deeper understanding of any specific strengths (particularly novel solutions or particularly appropriate solutions, for example).

Within the literature several examples of methods by which these terms can be assessed exist, such as those developed by Shah [3] and Sarkar [5]. However, perhaps due to the variation in terms used to describe this factor, those methods relating to the term "*appropriateness*" are often variable. As an example, Shah recommends use of the term "*quality*" and subsequent assessment according to a number of methods typically measuring adherence to product specification [3]; while Sarkar [5] recommends the term "*usefulness*", then creating a method assessing an output based on its societal importance and expected in-life use by customers. Further, if taking forward the term "*valuable*" [2, 6] as used in the sense referred to by the field of value engineering, it is necessary to consider not only the benefits of an output, but also a full breakdown of the costs [7]. This task is difficult to complete accurately and robustly at earlier stages in the design process when less information exists, or when considering more subjective criteria [8].

All of these terms refer to the same aspect of creativity [4]. While the potentially difficult and subjective tasks of determining "*value*" and "*usefulness*" do present information on how well an output solves a problem, the focus need only lie on comparison of the output with the specification and requirements that governed its design. Each output must be assessed according to how "*appropriate*" it is as a solution to the problem and its context. For example, while a solution may provide high functionality, it may also be of excessive cost to customer or company, and inappropriate for the problem that it must solve. "*Appropriateness*" can be described as a solution of appropriate quality in context of its problem, assessed through output quality as proposed by Shah [3], using any existing method (such as QFD [9], or decision tables [10]).

However, the work presented in this paper shows that beyond the assessment of quality according to the above methods or otherwise, through detailed categorisation of quality manifest in a design output, significant additional understanding can be gained. This paper aims to present a systematic, hierarchical method to generate criteria and assess quality, in context of what is appropriate to the design problem. This system ensures a link between the specification and additional criteria that also contribute to overall quality of a design output, giving a more complete view than just the design specification. Through consideration of as many criteria as is feasible, including beyond those first specified, a more complete and detailed assessment of quality can occur.

The systematic method presented within this paper has two functions; first to stimulate the identification of criteria which contribute to overall quality, and second to categorise and allow assessment with those criteria in a useful and robust manner. When applied to the assessment of design output, such a method provides a ranking of quality between each, while ensuring that assessment occurs at a high level of detail. These are described in the next two sections; following which the paper then presents a case study demonstrating the proposed process. The purpose of this systematic method is then not only to allow the quality assessment of designs relative to one another, but also to form a significant part of the assessment of the inherent creativity of a design output.

2 The assessment of quality

Through studying the different views on quality within literature, a systematic approach is proposed to identify and deploy a comprehensive set of criteria for quality assessment.

2.1 The hierarchy of quality criteria

As discussed by O'Donnell and Duffy [12] in their work on design performance, both the *design* itself and the *design activity* must be considered. A systematic view of quality criteria in terms of this distinction has been developed, showing separation between criteria that are of quality in different ways. This more detailed view recognises the importance of quality both in context of the design output and of the design development process. For example, a change that greatly saves in manufacture cost without changing design output quality is valuable, but is potentially different to a change that greatly alters design output quality alone. This distinction then ensures all aspects of quality are considered. For the same reason distinction is also created between the design output and its super-system, and the design activity and its super-system; recognising quality both specifically, and induced in the design output and the design activity's environment.

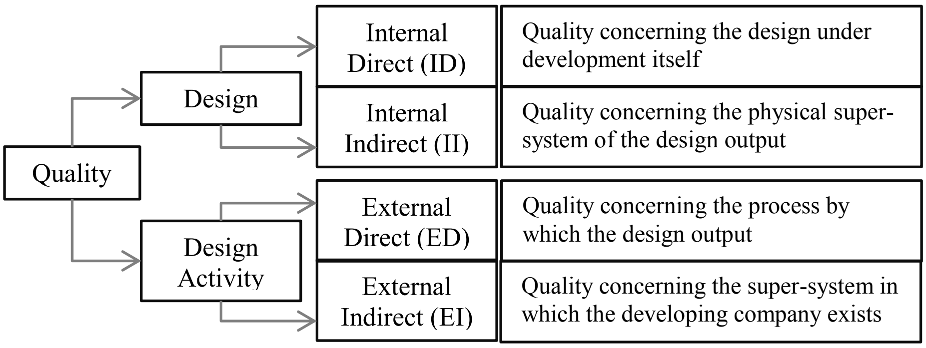


Figure 1 Systematic hierarchy of possible categories for quality criteria

Design quality (referred to as Internal Direct (ID)) – performance characteristics of the design such as speed of operation, precision, range of operation, etc.

Design super-system quality (Internal Indirect (II)) – performance characteristics of the super-system to which the design belongs, as influenced by the design itself. For example, lower design mass may allow the super-system to operate for longer on a single charge, or to operate with higher precision. Here, lower mass does not increase quality of the design itself, but produces additional benefit in the super-system.

Design process quality (External Direct (ED)) – performance characteristics within the development and production of the design, such as in manufacturing (e.g. high use of standard parts, lower manufacture cost) or assembly (e.g. fewer assembly operations).

Design process super-system quality (External Indirect (EI)) – performance characteristics relevant to the company within its super-system, as induced by the design itself. For example, adherence to brand identity or conformance with environmental standards may improve the perceived quality of the company within its market.

Using such a hierarchy, it is possible to describe how a design or feature is of quality. Distinction can be made, for example, between mediocre design performance quality and exceptional manufacturing quality, an important trade-off that may need to be considered. This decomposition is particularly useful in creativity research as it enables assessment of creative quality through the product lifecycle; for example, higher quality in terms of ID is more manifest to the customer. Also of benefit is the equal credence given to high quality in terms of development, which may have little impact on the customer or product use, but is still a valid area of creative product development.

2.2 Specific quality metrics

As the hierarchy provides understanding of the areas that assessment criteria should concern but does not state what they should be, distinct categories of criteria are needed to ensure that all aspects of quality are considered fully.

Much literature addresses the need for categories of assessment by developing criteria from the specification [7, 8, 11, 13]. Within the work presented here, the "eight dimensions of quality" presented by Garvin [11] are used to develop specific criteria:

Performance: a design outputs' primary operating characteristics.

Features: those characteristics that supplement basic functionality.

Reliability: the probability of malfunction or failure within a specified time period.

Conformance: the degree to which an outputs' design meets established standards.

Durability: the amount of use one gets from an output before it deteriorates.

Serviceability: the speed, courtesy, competence and ease of repair.

Aesthetics: How an output looks, feels, sounds, tastes or smells.

Perceived quality: Interpretation of the output through reputation.

By including criteria that relate to each of these "dimensions of quality", a highly detailed and complete assessment of the quality of a design output can be created. Together, the dimensions of quality present a thorough description of all characteristics that contribute to the overall quality of a design output. These characteristics define whether a product is of appropriate quality, and hence a vital part of the interpretation of a product as creative. Particularly important within these categories is the inclusion of those that are more subjective. It is not always possible to judge criteria in a quantifiable manner, due to a lack of detail and information of the design output in question, or because the dimension of quality itself defies numeration. Considering the importance of context and human interpretation given by many to the determination of what is creative [14], such subjective criteria are vital.

It should be noted that although using the hierarchy produces a significant number of prompts for the development of assessment criteria that contribute to overall quality, not all will be relevant to each product or each company. For example, when little to no importance is given to how the company is viewed within the market due to the product, the ED-aesthetics branch of the hierarchy can be omitted. Similarly, some branches of the tree require criteria that are unusual or likely irrelevant in many scenarios (such as aesthetics of manufacture process). However, as with all elements of assessment, the decision of what to include must be made by the company developing the product such that they can ensure all elements are appropriate to their situation are considered. All of the elements that are presented within this work are then pared down on a case-by-case basis.

2.3 Ensuring quality when meeting criteria output

Finally, it is also important to consider not only if a product is achieving each criteria, but also whether it is achieving them *well*. For example, while performance goals of a design output may be met, if the operation is wasteful or time consuming the output is likely not of appropriate quality. Analysis of how well a category is achieved is in this work is described as *performance* in relation to the individual categories of assessment.

Therefore, an output that achieves each category well can be said to achieve them *efficiently* and *effectively* [12, 15]. Each term is then defined as such [12]:

Effectiveness: the degree to which the actual result meets the original goal.

Efficiency: the relationship between what has been gained and level of resource used.

2.4 A combined hierarchy of quality

Quality is then a product of to whom it is manifest, the categories of criteria by which it is judged, and how well the criteria in those categories are achieved. Through these three perspectives, a hierarchy can be created that considers each aspect of design quality, and categorizes in a way that gives highly detailed information of the particular strengths and weaknesses of quality and the stakeholders to whom it concerns (Figure 2). By systematically proceeding through this hierarchy when identifying criteria for assessment and when performing analysis, detailed and complete understanding of design quality can be gained.

2.5 The development of a weighting scale

Clearly, different branches of the hierarchy will have different levels of importance in relation to the overall quality of the design output. To account for this, weightings for each branch must be developed. In this work, weightings have been developed using the Analytic Hierarchy Process (AHP) [16], a widely used, multi-disciplinary method of ranking and assessment developed within the past two decades [17]. Through the use of standard pair-wise comparison [8], AHP produces fair and proportional values of importance for each assessed criteria in relation to every other assessed criteria. The particular strength of this system is the robust manner in which weightings are assigned in relation to the importance of each criterion, rather than the subjective weights attached following ranking used by some other methods.

2.6 Using the hierarchy to assess quality

To use this system for assessment of relative quality, the following steps are completed. This process is demonstrated in the case study.

1) The hierarchy must be formed depending on relevance of each category to the specific design output in question. At this point the assessor must identify all branches of the hierarchy that may bear influence on final quality in the specific case, and omit all those that do not.
2) The hierarchy is populated with as many criteria as is possible by systematically working through each category, adding criteria from the specification and thinking of others that fit.
3) Each selected category is weighted according to the AHP method. This then provides as complete a set of criteria for quality assessment as possible, and places them within a hierarchy that allows easy and detailed analysis.
4) Quality assessment occurs according to the method of Pugh [13]; a datum concept is chosen (using a complete alternative product or the most complete design concept available) and all others are compared to it on a scale of better/worse/same.
5) Ratios are taken of the number of better to worse criteria in each category, multiplying by the appropriate weights during the process.

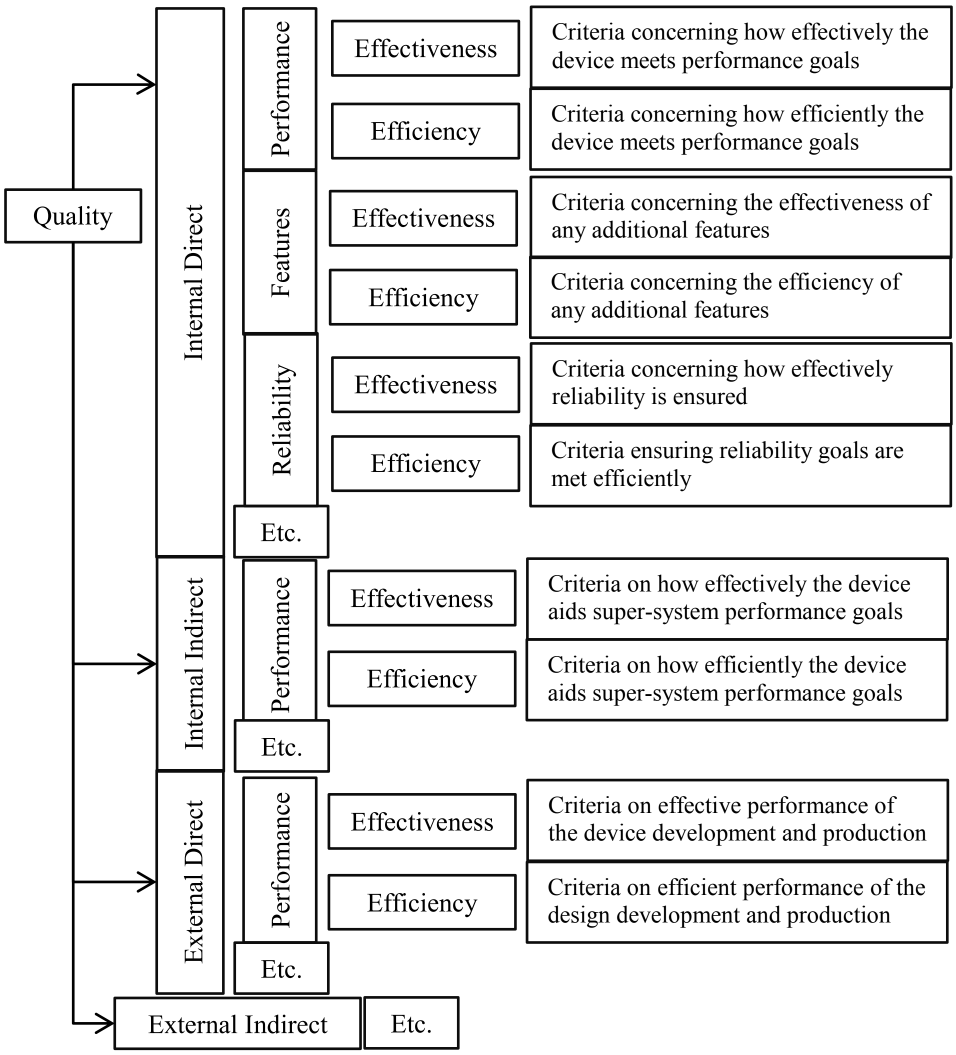


Figure 2 Partial structure of the perspectives of quality used within this work. Complete structure contains all eight "dimensions of quality" under ID, II, ED and EI.

Addition of ratio values then gives a decomposable ranking of all concepts; capable of stating not only which products are of highest quality, but also to whom that quality is of importance, the specific criteria under which that quality falls, and quality of the manner in which those criteria are met.

3 Case Study – Assessment of Quality

An example of the method in use is provided through assessment of 12 designs produced during a previously reported experiment [18], each designed to solve the same problem.

The problem was to design a hanging camera mount to be placed beneath a balloon, with controllable hemi-spherical motion pointing downwards. The design was to accept any amateur camera and be controlled remotely. Designers received identical briefs, and were given 90 minutes to individually produce their design to high a level of detail.

3.1 Assessment

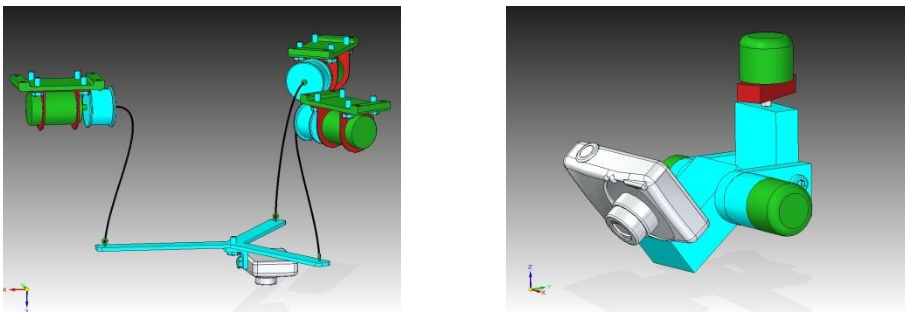
Assessment criteria generation occurred through prompting by the process presented. Each level of the hierarchy in Figure 2 was considered with respect to the design problem in order to prompt the generation of as many criteria (that could be applied to all designs) as possible, and to categorise each in a manner that enhanced understanding. Due to relevance to the brief and the development stage at which the designs were compared, only categories shown in Table 1 could be assessed. In all, 24 criteria were assessed.

Weight was assigned to each category using the AHP method. To judge importance, four engineering assessors (between 7 and 45 years' experience, average 25) were presented with the relevant categories and asked to perform pair-wise comparison between. Comparison achieved a sufficient value of Krippendorff's alpha of *0.74* (a measure of inter-coder reliability), and the resulting weights were averaged (Table 1).

As the experts asked within this study have only a general experience of the output and its context, this work demonstrates only the process and reliability of the weighting process. In reality, weighting would occur through experts with extensive understanding of the design, market, and other important influences. Weighting in reality would likely vary depending on the background of the experts; e.g. should they be heavily involved in manufacturing, then that would likely receive a higher value. Hence, although the weightings presented here represent the opinions of highly experienced engineers and so are valid; those used by a company may vary. It is for the company to decide the importance of each category depending on priority.

3.2 Results

In all, the designs were compared on 24 criteria fitting into these categories. One of the designs (Design F) was selected as a datum, against which all others were compared for each criteria on a better/same/worse scale (as shown for the Internal Direct (performance) criteria within Table 2). Ratios of better scores to worse scores (in relation to the datum) are then taken for each individual category and multiplied by the weight, to produce a final weighted ratio for each design (Table 3). The value for this weighted ratio determines the ranking of quality of designs in relation to the original datum.



Design F (datum) Design B

Figure 3 Example designs produced within the experiment

Table 1 Hierarchy used for assessment of designs (with selected examples from total of 24)

Hierarchy of Quality	Quality metrics	Quality within criteria	Weight	Example criteria
Internal Direct	Performance	Effectiveness	0.179	Range of motion
		Efficiency	0.179	Length of single charge
	Features	Effectiveness	0.0798	Protect Cargo
	Reliability	Effectiveness	0.143	Security of connection
				Etc.
Internal Indirect	Performance	Effectiveness	0.306	Operational mass of balloon
				Etc.
External Direct	Performance	Effectiveness	0.292	Manufacture using existing tooling
External Indirect	Insufficient information for assessment in this case			

Table 2 Comparison with datum for all criteria within Internal Direct (performance) category

Criteria	A	B	C	D	E	F	G	H	I	J	K	L
Range of motion	+	+	0	+	+	Datum	+	-	+	+	-	+
Speed of operation	-	-	-	-	-		-	-	-	-	0	-
Stability in position	+	+	+	+	+		+	+	+	+	+	+
Ease of connection	-	0	-	0	0		-	0	-	-	0	0
Operational range	0	0	0	0	0		0	0	0	0	0	0
Type of control	0	0	0	0	0		0	0	+	0	0	0
Power requirement	0	0	+	0	0		+	0	+	+	+	+
Mass	-	+	-	+	+		+	-	0	+	0	-
Volumetric Size	0	+	0	+	+		+	+	0	+	+	0
Length of single charge	+	+	+	+	+		+	+	+	+	-	+

Table 3 Ratios, weighting and final ranking

Criteria	A	B	C	D	E	F	G	H	I	J	K	L
ID (performance)	3:3	5:1	3:3	5:1	5:1	Datum	6:2	3:3	5:2	6:2	3:2	4:2
ID (features)	1:1	1:0	1:1	1:1	0:0		1:1	0:0	1:1	1:1	0:0	0:0
ID (reliability)	0:0	0:0	0:2	1:1	0:0		0:0	0:0	0:0	1:0	1:0	0:1
II (performance)	0:1	3:1	0:1	3:1	1:0		3:1	2:2	0:0	3:1	0:0	2:2
ED (performance)	0:4	1:3	0:5	1:3	0:4		0:4	0:5	0:4	1:4	1:3	0:5
Overall ratio (decimal)	.44	2.0	.31	1.6	1.2	1.0	1.3	.50	.86	1.5	1.0	.55
Weighted ratio (decimal)	.30	1.6	.21	1.5	.89	1.0	1.1	.44	.61	1.3	.79	.46
Ranking	11	1	12	2	6	5	4	10	8	3	7	9

3.3 Discussion of the results

By this method, each design can be ranked according to the criteria that contribute to its interpretation as of appropriate quality. Extra insight can also be gained; Design F performed poorly in terms of ID criteria, therefore showing a poorer design in itself, but excelled in terms of ED, therefore being more appropriate to company capabilities such as manufacturability and assembly. Conversely, Design L has strong ID performance capabilities, but is particularly poor in terms of manufacturing and assembly.

4 Discussion of the process

While information from ranking aids selection of designs for development, it is for additional information that this method was designed. Many research opportunities result from breaking down the manner in which quality is displayed. Deeper understanding can be gained by comparing how quality appears with designer behaviour, the prescribed design process and brief, and the ways in which designers are creative, for example. Information about these potential relationships will provide a valuable insight into preferable behaviours leading to different forms of output with different forms of quality. This will perhaps allow designers to focus their work to the specific priorities of the company and the brief that they are presented, or will allow greater understanding and optimization of the way in which outputs are developed to maximize their quality in an appropriate manner. Such analysis has begun, and will continue in further work.

5 Conclusions

The aim of this paper has been to present a systematic, hierarchical system to generate criteria and assess quality, in the context of what is appropriate to the design problem.

This is with the goal of allowing assessment of *appropriateness* in design outputs (a fundamental part of the interpretation of creativity) described here as the appearance and recognition in a design output of quality appropriate to the problem that it must solve. Through the categories used, the method also creates deeper understanding about the quality of the design output, which can in turn be used to better inform design decisions, or as a research tool to better understand quality development through the design process.

By assessing through separate perspectives used within multiple fields of literature, this method stimulates the assessment of quality in terms of to whom the design output is of quality, the specific "dimensions" in which its quality is manifest, and how well those dimensions are achieved. Thus, when used to as full an extent as is feasible, this method ensures that all criteria affecting quality are considered.

In assessment, this method uses the well-established process of AHP to determine weights for each category, then assigning these weights to the ratios used for ranking. Weighting is flexible, occurring based on the companies discretion and priorities.

Through the presented example, this assessment method has shown capability in ranking of relative quality of multiple designs, as well as the ability to produce additional information of how that quality appears. Following further validation and comparison of quality with traits of designers and the design process (as will occur in further work), understanding can be gained of the relationships and dependencies of designer, process and quality; information that can then be used to enhance methods of designer support.

Acknowledgments

The work reported in this paper has been undertaken with support from the Engineering and Physical Sciences Research Council (EPSRC) at the Innovative Design & Manufacturing Research Centre (IdMRC) University of Bath.

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