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Creativity and constraints
An assessment of four educational timber design-build pavilions

Dan BERGSAGEL*, Laura HANNIGAN, Philip ISAAC

*Director, Scale Rule
White Collar Factory, 1 Old St Yard, London EC1Y 8AF, UK
dan@scalerule.org

Abstract

The future of structural design will rely on creativity. Projects are accompanied by a multitude of constraints, however we are currently ill-equipped to determine which constraints encourage creative design, and which constraints hinder it. This paper proposes a method for evaluating the creativity of project outcomes of four small-scale timber educational design-build projects completed 2015-2017, and determining any impact of project constraints. The projects were completed in three phases: secondary school students producing a concept, young professionals developing it, and unskilled labour assembling the design. Each project had a similar scope and brief, with restrictions on size and material use. However key project constraints, such as programme, budget, equipment and experience were varied between the projects.

Evaluating creativity in a rigorous way is challenging. This paper describes a quantitative approach considering creativity as the product of usefulness and novelty. Targeted questions in relation to the project brief characterise the level of usefulness, and a hierarchical categorization is used to define the level of novelty. The results are correlated with the variation in project constraints to conclude which constraints might be beneficial, detrimental, or neutral to project creativity.

Keywords: Creativity, design constraints, evaluation, survey, taxonomy, education, design-build, timber.

1. Introduction

Structural design is a changing industry, due to developments in technology and the continued fragmentation of built environment roles. It is widely recognised that the industry must react to meet these challenges: in the UK we are exhorted to "Modernise or die" [1]; in the US we are warned that "Structural engineering has operated almost exclusively at the knowledge end of the spectrum. To thrive we must move to the creative end."[2]. If it is accepted that being creative is of value, we must learn how to be better at it.

The concept of spurring creativity by applying constraints has been implemented for millennia, whether through the syllable structure of Haiku, the codification of Greek tragedy, or cooks inventing a recipe from only the chance ingredients available in their kitchen. In the field of structural design there are a multitude of constraints - to better facilitate creative design we need data to inform which constraints are beneficial, detrimental, or neutral to project creativity. Some project constraints are hard to control (such as budget, programme, and site constraints), while some are easier (project brief, the size of the team, and its experience). It is proposed that the impact of different constraints on creativity can be assessed by evaluating the degree of creativity of the outcomes of four similar projects, and correlating these results with project constraints.

2. Project format

An educational design-build format was applied in the creation of four pavilion projects considered (Figure 1). Three distinct phases in this format are identified from concept to completion: (i) student design workshops, (ii) design development and (iii) construction.

Firstly, students aged 14-18 were tasked to produce a concept design for a pavilion over the course of a weekend. Design professionals on hand helped the students develop their concept to a workable solution for presentation to a panel of industry judges where a winning design was selected. Following this, a team of design professionals developed the winning pavilion design from concept to detail, and ultimately through to fabrication and construction.

Figure 1: Four educational timber design-build pavilions
[photos © Erica Choi (A), Sophie Mutevelian (B), Intervention Architecture (C), Richard Winter (D)]

2.1 Variables

While the project format outlined above was adopted for all four pavilions, this paper seeks to interrogate the variables and constraints which existed across the four schemes and correlate these against the creativity of the completed design. Variables across the projects included the number of students who attended the workshops, the number of students in each team, the student to design professional ratio, the design time and the team of design professionals (Table 1).

Table 1: Project constraints and values

Constraint	*Pavilion A*	*Pavilion B*	*Pavilion C*	*Pavilion D*
Number of students at workshop	18	27	35	19
Number of student teams	5	7	9	7
Student/staff ratio	18:5	27:13	35:11	19:14
Budget (materials and logistics only, GBP)	2000	3000	5000	5500
Design time (from workshop to completion, weeks)	2	14	11	14
Size of design team (people)	2	6	7	4
Cumulative experience of design team (years)	6	28	50	31
Assembly time (excluding fabrication, hours)	116	128	80	512
End-of-life design (within hierarchy of waste)	Dispose (5)	Reuse (2)	Reuse (2)	Recycle (3)

3. Evaluating creativity

The concept of creativity is not fundamental and was only adopted, as we might understand it today, during the Renaissance [3]. Definitions of creativity abound, however there is broad consensus that creativity can be defined as "the production of novel, useful products" [4]. The key parameters of *usefulness* and *novelty* as defining the domain of creativity is supported by a comprehensive survey of over 160 definitions [5].

Much work on evaluating creativity has centred on the first part of this definition, *production.* This assesses the process of creativity, and tends to consider the tendency and ability of people to be creative. Evaluating the process of creativity is person-focused (such as the Torrance Test of Creative Thinking), and often attempts to correlate creative performance with aspects of personal development, such as family background, education etc. with the goal to improve teaching.

The construction industry is characterised by multi-disciplinary teams assembled to design and build one-off projects. A client has little agency over the personal development of the members of their team, however they do have agency over the constraints of the project. Thus it is the second part of the definition of creativity which should be evaluated, focusing on *products*. We need to evaluate not just whether a project is creative, but what degree of creative it is. A method for evaluating the degree of creativity has been proposed that considers creativity as the simple product of an assessment of its *usefulness* and its *novelty*, as outlined in equation 1 [6]. To receive the numerical creative value for each product, its usefulness and novelty must first be assessed and converted into a numeric form.

$$\text{Creativity (C)} = \text{Usefulness (U)} \times \text{Novelty (N)} \tag{1}$$

3.1. Usefulness

Evaluating usefulness requires an understanding of the purpose of the product. In the domain of construction, this is concisely described by the project brief. Another facet of usefulness can be a product's rate of use, or a projects ability to serve its brief to a large number of people.

3.2. Novelty

Evaluating novelty is considered more subjective, and consequently more challenging to evaluate reliably. It often relies on expert judges with background knowledge of the product domain, and targeted questions to discuss sub-aspects of a product. To remove bias from selection of the judges and questions it would be advantageous to: evaluate creativity with simple categorizations that experts and lay-people could respond to; and to be able to convert these responses to numerical values simply. In this paper we propose numericizing responses on novelty through the implementation of the Taxonomy of Creative Design [7] - a process which defines different characteristics of a product in a hierarchy. A product could first be assigned to one of the five categories, assigning it to a numeric value range, as indicated in table 2.

Table 2: The Taxonomy of Creative Design [7] with assigned values

Category	*Description*	*Value*
Imitation	Replication of a previous work	1
Variation	Modification of an existing work	2
Combination	Mixture of two or more works	3
Transformation	Translation of a work into another medium or mode	4
Original Creation	The creation of something previously unrecognisable	5

4. Method

A questionnaire was circulated, with 57 respondents answering questions on usefulness, novelty and creativity for each project individually, and relative to each other. The pool of participants consisted largely of engineers and architects who were familiar with the concepts being addressed, though non built environment professionals also responded.

4.1. Questionnaire

The questionnaire first defined usefulness and novelty before asking the participants to assess each pavilion for both. To assess usefulness the questions focused on the pavilion function and brief. For each pavilion, a selection of photos was provided accompanied by the original pavilion design brief. The final section of the questionnaire gave participants the opportunity to rank the pavilions on overall usefulness, novelty, and creativity.

Table 3: Selected assessment questions

Section	*Question*
1. Usefulness (for each pavilion)	How well does the pavilion meet the functional aspect of the brief?
	How well does the pavilion meet the cultural aspect of the brief?
	How many people do you think can interact with the pavilion at one time?
2. Novelty (for each pavilion)	Select the category which best describes the pavilion - imitation, variation, combination, transformation or original creation
3. Overall ranking	Usefulness - rank the pavilions in order of usefulness
	Novelty - rank the pavilions in order of novelty
	Creativity - rank the pavilions in order of creativity

4.2. Evaluation

Creativity is evaluated in two ways from the questionnaire:

(i) By calculating the separate novelty and usefulness of the pavilions from the sum of specific questions in section 1 and 2 of the questionnaire (see Table 3), and defining the creativity value as the product of usefulness and novelty, as described in equation 1.

(ii) By direct comparative ranking of the pavilions in terms of intuitive novelty, usefulness and creativity in Section 3 of the questionnaire (see Table 3).

4.2.1. Creative value of the projects

The creativity values were distributed over the range of available responses from 0-75, with a variable spread in the response range for each pavilion (Figure 2). There was stronger agreement on the creativity value for pavilion A (standard deviation 13.0) in comparison to B, C and D (17.1, 17.4 and 19.1 respectively). It can be seen that the responses are not normally distributed.

The mean has been considered as a single creative value to characterise each project. These values clustered into two pairs: Pavilion B was deemed the most creative with a mean of 43, closely followed by pavilion D with a mean of 42.7; Pavilion A had a mean of 31.1 and Pavilion C a mean of 30.2.

4.2.2. Influence of design profession

The assignment of creative values varied depending on the professional training of the respondent (Figure 3). In three of the four cases (A, B and C) architects tended to assign a lower creative value than engineers, and engineers a lower creativity value than other training backgrounds.

4.2.3. Relationship of creativity value and constraints

The mean creativity values defined in section 4.2.1 were evaluated against the project constraint values as defined in Table 1, using a Pearson product-moment coefficient (*r*) to define the correlation between creativity datasets and constraint datasets (Table 4). It is noted that for a dataset with 4 pairs the degree of freedom is 2. The associated critical value of the Pearson product-moment coefficient for a 90% probability of correlation is r=0.90. Lower values of *r* are associated with less certainty of correlation. The two datasets with the highest probabilities of correlation are shown in Figure 4 (a)-(b).

4.2.4. Creative ranks of the projects

The clustering between the creative value means of pavilion B-D and A-C was less pronounced when the projects were ranked with reference to one another, and reversed in both pairings (Figure 5). Pavilion D was ranked most creative in 49% of responses, while pavilion B was ranked most creative in 42% of responses. Pavilion A was ranked least creative in 67% of responses, while Pavilion C was ranked least creative in only 21% of responses.

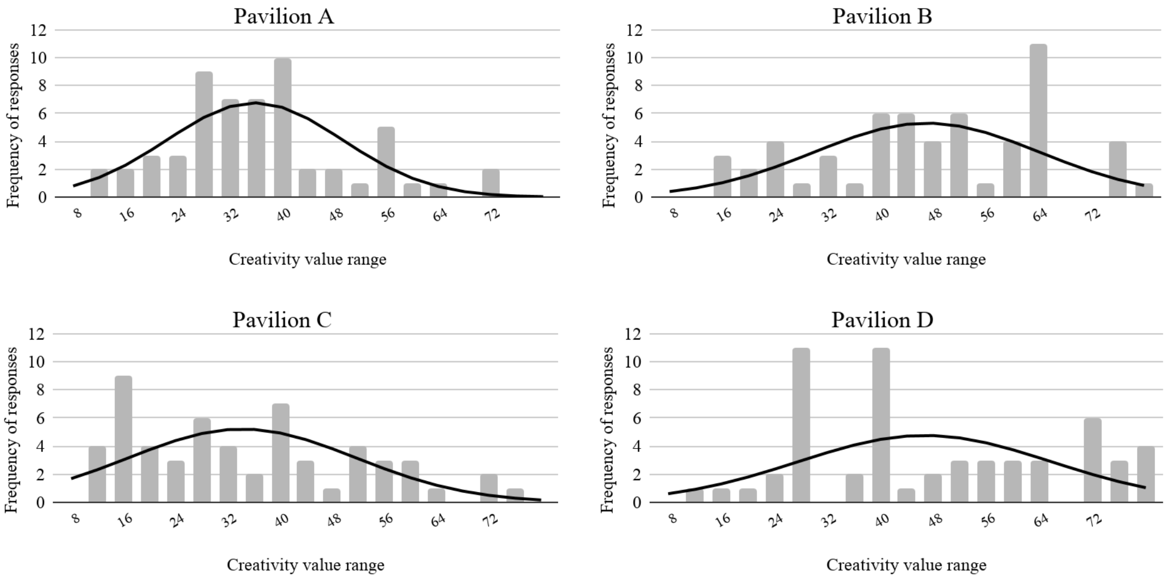

Figure 2 (a)-(d): Histograms of the creativity values, with and reference normal distribution

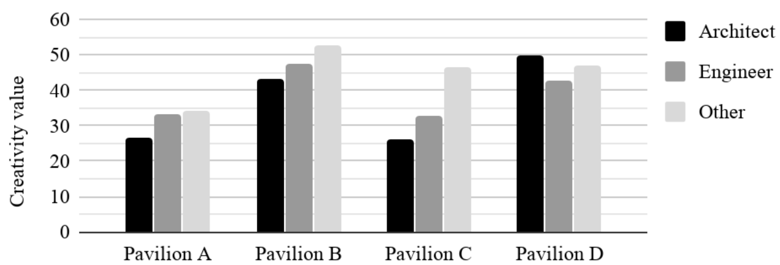

Figure 3: Mean creativity values calculated for professional training groupings

Table 4: Pearson product-moment coefficient (*r*) for project mean creativity values and project constraints

Parameter	*r*
Number of students at workshop	-0.29
Number of student teams	-0.05
Student/staff ratio	**-0.93**
Budget (materials and logistics only)	0.21
Design time (from workshops to completion)	**0.73**
Size of design team	0.09
Cumulative experience of design team	-0.01
Assembly time (excluding fabrication)	0.62
End-of-life (within hierarchy of waste)	-0.37

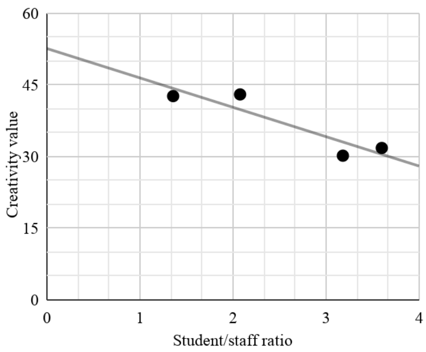

Figure 4(a): Creativity value and student/staff ratio

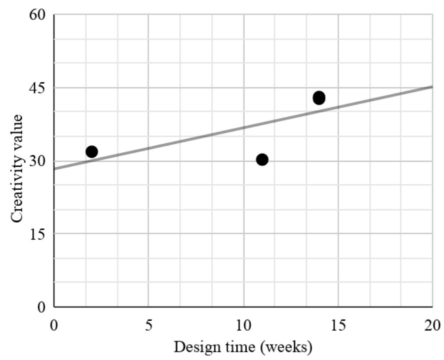

Figure 4(b): Creativity value and design time

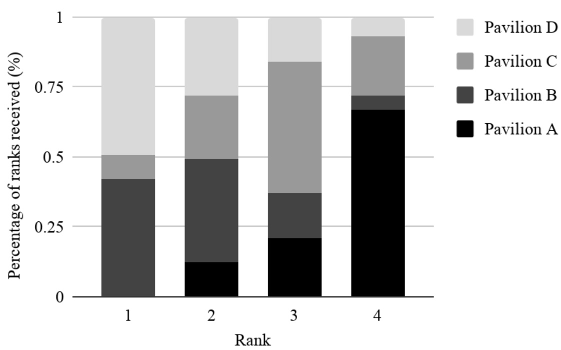

Figure 5: Distribution of comparative creativity rankings

5. Discussion

A significant correlation of r=-0.93 was found between mean creativity values and the student/staff ratio at the initial student concept design workshops, with a higher proportion of tutors providing more creative project outcomes. A lower student/staff ratio may have provided additional discussion time between the students and design professionals to produce concept designs which were well considered, and had more potential for being creatively developed at the later stages. With a higher proportion of tutors there was also the potential for greater rotation of staff amongst the students, allowing for a greater cross pollination of ideas. It is suggested that by applying greater focus on producing considered and diverse initial concept designs we can encourage more creative project outcomes.

While less significant, a correlation of r=0.73 was found between mean creativity values and the number of weeks the project team had available to develop the selected concept design for construction. The trend indicates that more creative project outcomes tend to be produced where additional design time is available. This may be expected given the scope that increased time allows for developing a range of design developments, and for capitalizing on various fabrication and construction techniques.

No significant correlation was found for the other parameters listed in Table 4. Notably this includes the construction budget and the cumulative experience of the project team, which the authors anticipated may have an impact.

5.1 Limitations and further study

5.1.1. Size of the datasets

The significance of any correlations is restricted by the degree of freedom of the data set associated with assessing only four projects. Equally, the range in creativity values shown in Figure 2 (a) - (d) indicates that a larger number of respondents is required to provide more coherent creativity value responses. Further studies could seek responses from a larger group of respondents, as well as increase the number of similar projects being compared.

5.1.2. Familiarity of the projects and reference knowledge

Approximately 50% of the participants were familiar with at least one of the pavilions being assessed, either through direct involvement in the project process, or exposure to the project outcome in the media. These participants may have biases when assessing these pavilions based on additional depth of information when compared to participants who were assessing the projects based on the provided photos alone. Further study could limit the respondents to those who have not experienced any of the pavilions, or provide more in-depth information about the projects during the assessment.

The Taxonomy of Creative Design categorization process requires the respondent to have some reference knowledge of previous works in order to assess a new project. The difference in mean creativity values from respondents of different training backgrounds indicates that this effect could be accounted for in the further studies, however in this paper the creativity weighting was not uniform.

5.1.3. Creativity as the product of usefulness and novelty

The comparison between mean creative values and creativity rankings in Figure 5 indicates that the adopted creativity formula does not fully align with the intuitive creativity rankings. This perhaps indicates that the the relationship between usefulness and novelty is not a simple product, i.e. novelty may contributed more to the overall creativity value of a project than usefulness. It is also noted that while creativity is a valuable asset, the most creative project outcome is not necessarily the most preferred project outcome.

5.1.4. Determining project constraints

This paper has attempted to review the creativity of project outcomes as a function of project constraints, instead of individual creativity of specific contributors. All projects have a large number of constraints, and they are not always easily quantifiable values. By assessing a set of similar projects who had a large number of constraints held equal, we have attempted to evaluate the significance of a smaller number of variables. Further study could assess the influence of multiple constraints together, and further project constraints which have not been considered here.

6. Conclusion

To some there is no simple recipe for creative design: it requires flair, original thinking and courage. However, one person's flair could be another one's fodder. Creativity is at the core of our profession, and will only continue to be ever more pervasive; being able to evaluate and encourage it is logical and desirable. By assessing the creativity of four similar small-scale timber educational design-build projects in terms of usefulness and novelty, a significant correlation was found between the creativity of the project outcome and the student/staff ratio at the concept design workshops, while no significant correlation was found between the creativity of the project outcome and any of the other project constraints, such as budget or experience. It is suggested that by applying greater focus on producing considered and diverse initial concept designs we can encourage more creative project outcomes. Whilst this study consisted of a small sample group of pavilions, the method outlined could be developed and applied on a larger scale which may offer greater insight into a larger range of variables which affect the creativity of project outcomes.

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