INTERNATIONAL DESIGN CONFERENCE - DESIGN 2014
Dubrovnik - Croatia, May 19 - 22, 2014.

CREATIVITY IN TRANSACTIONAL DESIGN PROBLEMS: NON-INTUITIVE FINDINGS OF AN EXPERT STUDY USING SCAMPER

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Keywords: SCAMPER, Transactional systems, Creativity, Concept generation, Design Cognition, Design Methods, Design Problems, Innovation, Cognitive Studies

Abstract

Designers are currently facing design problems that are not uniquely related to physical systems but transactional as well. Transactional processes (services) have had a steady growth during the last three decades and currently add more than 65% of global economic value. This study expands our understanding of designers' interaction with ideation methods. We investigate a heuristic method known as SCAMPER, focusing on a transactional design problem with a relatively large transactional domain expert sample size (n=60). The study shows, unexpectedly, that the SCAMPER method appears to be both a fixating and de-fixating method (at least for the type of problem explored), where design fixation is not shown to be effectively mitigated by the method; yet, despite this finding, a significantly higher novelty production is achieved when compared to a non-assisted scenario.

1. Introduction

An innovative idea can make the difference between success and failure when it comes to developing products or services. To remain competitive, companies seek to develop and deploy innovation processes that enhance designers' abilities to consistently create and evolve new products and services. Some authors have stated that the early stage of development for services is no different than the conceptual design of physical products, but rather that it is at the detailed design phase where the methods diverge [Cagan & Vogel, 2013], therefore, idea generation and development of transactional and physical systems may require similar approaches.

Ideation methods, for the area of services (e.g., transactional processes), have recently become a growing area of research. The Organization for Economic Cooperation and Development (OECD) defines service companies as "retail and wholesale trade; transport and communications; real estate, finance, insurance and business services; education, health and other personal services; public administration; and defense" [OCDE 2010].

The relevance of conducting research studies to analyze idea generation in services lies in the fact that services as an economic activity has increased by 10% compared to products and agriculture during the last three decades. By 2008, services accounted for more than 65% of the economic activity globally, as reported by OECD (OECD, 2010; OECD, 2011), while in the US in 2009 services comprised more than 77% (Chesbrough, 2011; WorldBank, 2011). Based on these figures, assessment and advancement of design approaches for transactional processes are needed, either by morphing existing approaches employed in engineering or architectural domain, or by developing new ones.

A number of newly developed ideation techniques and methods are emerging with supporting cognitive studies. These include intuitive and directed methods [Shah, et al. 2003]. The SCAMPER method is classified by Shah, et al. (2003) as intuitive, and is argued to be an intermediate method because it enables both, idea generation and problem analysis [Chulvi, et al. 2012]. These characteristics make SCAMPER an ideal method to be tested with a transactional problem. In addition, considering the limited number and extent of expert studies in creativity [Dixon & Johnson 2011; Guidon 1990; Kim, et al. 2005; Ozkan & Dogan 2012], the present study seeks to contribute to the understanding of ideation techniques performance in such settings with transactional problems.

Therefore, the research question for the present study is stated as follows:

> *Can a heuristic approach, and specifically, the SCAMPER method, enable transactional domain experts to improve the quantity and novelty of generated ideas while reducing design fixation of solutions generated for transactional design problems?*

1. 1. Semantic Memory Retrieval

Semantic memory refers to the organization accumulation of meaningful information. In cognitive psychological literature, it is often conceptualized as a network with nodal concept representations and associations through categories (Anderson, 1983; Roediger, et al., 2002; Linsey, et al., 2007).

Based on this representation model for semantic memory, a concept node can be easily accessed (recalled) if there is a low number of links traversed to reach it, or if multiple paths that converge to it are activated. Linking new concepts through nodes with a high number of links increases the probability of being retrieved [Anderson 1983; Ball, et al. 2004; Roediger, Marsh, & Lee 2002].

Ideation methods may increase the likelihood of retrieving solutions or ideas that have been previously experienced and stored. Designers may take advantage of the semantic network and, through alternative representations, shorten the distance to access additional relevant concept nodes.

1. 2. SCAMPER Method

SCAMPER [Eberle, 1996] was developed by extending Osborn's (1953) brainstorming recommendations (value of “copious ideation”, the need for incubation, influence of emotions and effort in ideation, guidelines for brainstorming and ways to promote ideation), and convolve them into an extended ideation technique. SCAMPER is an acronym for the following set of categories and actions: (S) Substitute, (C) Combine, (A) Adapt, (M) Modify/Magnify/Minimize, (P) Put to other uses, (E) Eliminate, and (R) Reverse/Rearrange. The method presents the user with a set of possible action operator categories to generate ideas that may be used to develop solutions to a design problem(s). For each operator category, a set of questions suggest reflection and an action (add, modify, etc.). According to Serrat (2010) and Lockton (2012) the stimulus comes from attempting to answer questions that redirect analogical search to solve a problem. For example, if a designer was asked to improve holding/gripping of a cup, he may choose (S) Substitute, which could lead him to replace the handle, and then he will proceed to the triggering questions of substitute category such as: What can be substituted? Can other material be used instead? Other place? From these, he can generate design ideas that replace the handle for a new gripping device made of a different material that would be placed in a different location than existent handle.

Design heuristics, embodied by the operator categories in SCAMPER, find their strength in the fact that similarity relationships may exist with analogies that are retrieved through the operators [Daly, et al. 2012]. From Polya (1945), it is argued that there are no absolute new problems, or that at least a posed design problem may be related to other already solved problems. Polya added that to solve a problem one can always look for similar solved problems, use the results, methods or experience gained solving the problem. He was referring to mathematical problems, but similar arguments apply to general problem solving; hence, SCAMPER presents an approach to problem solving by building on previous results, providing a heuristic to search for solutions.

SCAMPER also has shown its effectiveness in increasing creativity [Mijares-Colmenares, et al. 1993]. There are studies in product-related domains that show the application of SCAMPER resulting in a quantity of novelty results but with a higher utility than those obtained employing directed methods such as TRIZ [Chulvi, et al. 2013]. Studies comparing SCAMPER (sentential stimuli) against images (graphical stimuli) found that the teams using SCAMPER adopted strategies to reframe a given problem, with dedicated efforts to develop generated ideas further [Lopez-Mesa, et al. 2011]

The SCAMPER method was selected due to the capabilities here presented and also for the potential capabilities of being successfully implemented in transactional problems due to evidence of being employed in related service problems such as counseling, where, according to [Gladding, 2011] “Creativity, the ability to foster something novel and useful, is an integral part of counseling.”

2. Research Methodology

To understand the influence that the use of a heuristic method such as SCAMPER has in ideation metrics such as quantity, fixation and novelty when working with in transactional design problems, a set of experiments was conducted with domain knowledge experts in transactional problems from 38 companies (17 product and 21 services) in Mexico and Singapore.

2.1. Experiment Design

The experimental study reported compares a non-assisted scenario (NT) with an assisted scenario using the SCAMPER method (SCA). A relevant transactional design problem was adopted from a previous study [Moreno, et al. 2014] that explored the influence of a design by analogy approach in transactional problems. Domain knowledge participants were selected based on their professional background (transactional related) and the role of transactional processes in their companies. A sample of domain knowledge experts (n=60) in transactional problems from product and service industries was recruited for this experiment, where 26 had an engineering related background and 34 had a non-engineering, economics or business related background. The participants were equally distributed according to gender across the treatment and control groups, with 11 females per group, and the final distribution of participants to the experimental groups was as follows: NT = 36 and SCA = 24. All participants had more than five years of managerial experience, and were immersed in transactional problems due to their roles in their respective companies.

Participants were encouraged to make their best effort to maximize the creativity, novelty and quantity of the solutions they could develop for the given design problem. Participants were requested to generate as many of such solutions over a 15 minute period. Solutions could be presented as a phrase, written description, sketch/diagram, or any other combination that represent best what they wanted to communicate. The experiment was carried out in two phases and participants worked individually during both of them. Figure 1 presents the experimental overview. In phase I, participants were asked to generate solutions using their intuition and past knowledge for a transactional design problem. The problem was introduced in the experiment materials and read out loud.

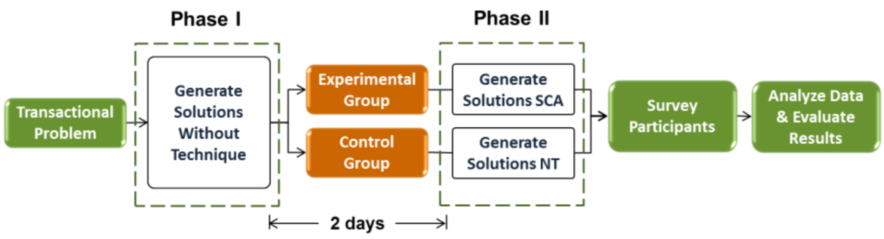

Figure 1. Experiment Overview

The problem given to participants was to “Reduce Overdue Accounts / Unpaid Credits.” This design problem was adopted from a previous study [Moreno, et al. 2014]. There was a two day period in between phases to activate long term memory analogy retrieval, and participants were assigned into a treatment (SCA) or control (NT) group. During phase II NT and CSA worked in separated rooms to maintain independence between treatment conditions.

Before starting phase II, the SCA group was trained in the method for 15 minutes. Participants in both experimental groups were asked in phase II to generate as many solutions as possible to the same design problem introduced in phase I for a 15 minute period. The SCA group was asked to assist their idea generation with the method they were introduced to and the material provided that contained SCAMPER’s triggering questions. To simplify SCAMPER’s application for the allocated ideation time, a subset of categories (letters) of the method (SAMR) were arbitrarily selected, corresponding 33 triggering questions were provided in participant’s material. The SCA group was asked to record their ideas under the category they considered assisted them in creating an idea/solution. The NT group was asked to generate ideas using their intuition and knowledge.

3. Ideation Metrics

Once both experimental phases concluded, all ideas recorded by participants were extracted from the provided materials, and a total of 1,299 ideas were identified. Three ideation metrics, used previously to study ideation in the engineering knowledge domain, were chosen to evaluate the results of the study: (1) quantity of ideation, (2) design fixation, (3) novelty [Girotra, et al. 2010; Linsey, et al. 2011; Linsey, et al. 2012; McAdams & Wood 2002; Moreno, et al. 2014; Oman, et al. 2013; Shah, et al. 2000; Shah, et al. 2003; Srivathsavai, et al. 2010]. We present metric definitions to have robust and comparable results to the previously reported findings in engineering and related knowledge domains.

3.1. Data setup

Participants recorded their ideas by means of bulleted lists, flow or process diagrams, charts, storyboards, or combinations of textual and graphical illustrations. The experimental data were organized and coded for post-experiment analysis. Participants’ recorded ideas were evaluated by two different domain knowledge expert raters (one from a business background and the other from industrial engineering, both with extensive banking experience). The raters independently grouped the recorded solution statements into bins of distinctive ideas resulting in 130 bins generated by the two raters. To validate objectivity of the evaluation, Cohen’s kappa [Von Eye & Mun 2005] was calculated, with a result of 0.78 which is considered an “excellent” level [Robson 2002]. All disagreements were resolved through discussion, resulting in a final total of 127 distinctive bins.

3.2. Quantity of ideation

Some definitions and procedures to calculate quantity of concepts have been developed in the domain of engineering design [Bouchard & Hare 1970; Dean, et al. 2006; Linsey, et al. 2011; Oman, et al. 2013; Shah, et al. 2003]. Following the thought process embedded in these definitions, we defined an “idea” as any form of statement and/or diagram that provides an operational method or solution for the transactional design system to be solved or accomplish the intended goal.

Two primary mathematical representations for quantity of ideas are considered in the study reported here: (1) Quantity of Total ideas (Q_{Total}), and (2) Quantity of Non-Repeated ideas (Q_{NR}). Eq. 1 shows the interrelationship between these quantities:

$$Q_{Total} = \sum all\ ideas\ generated = Q_{NR} + Q_R \quad (1)$$

Quantity of total ideas generated is expressed as the summation of all ideas generated (Eq. 1), at different levels, such as in phase (I, II), across experimental groups (SCA, NT), and per participant. Thus, no specific indices are listed for the summation operator of Eq. 1.

From Eq. 1 we also have an alternative definition for Q_{Total} that breaks it down into two main components: Quantity of Non-Repeated ideas (Q_{NR}) and repeated ideas (Q_R). Quantity of non-repeated ideas (Q_{NR}) corresponds to filtered data, and it takes into account all ideas generated at different levels that were not repeated. A repeated idea occurs when a participant states an idea more than once (usually due to a slight variation or rewording of the idea). A more detailed description and classification on repeated ideas for this study is provided in next section.

3.3. Design Fixation

Jansson and Smith (1991) define design fixation as "a blind adherence to a set of ideas or concepts limiting the output of conceptual design." From this definition, fixation can be identified whenever there is a persistent commitment to a limited (or to a single) exploration of alternatives. Design fixation implies an inability to solve design problems due to: use of a familiar method ignoring new or better ones, self-imposing constraints [Youmans R. J. 2007], or (as in our study) by limiting the space of solutions merely by means of developing variants [Jansson & Smith 1991; Luchins & Luchins, 1959; Luchins & Luchins, 1970]. We build upon the procedure outlined by Linsey (2010) and further developed by Viswanathan (2012) to account for repeated ideas, and propose a metric that relates repeated ideas (variants) in contrast to the total number of ideas developed. Such an approach provides a sense of the intensity of design fixation. An operational design fixation definition is implemented as shown in Eq. 2:

$$Fixation = \frac{Total\ \#\ of\ repeated\ ideas}{Total\ \#\ of\ generated\ ideas} = \frac{Q_R}{Q_{Total}} = \frac{R_W + R_B}{Q_{Total}} \quad (2)$$

There are two different sources for repeated ideas in the study:

- Repeated ideas within a phase (R_W): defined as the summation of all repeated ideas across all participants that have a frequency (F) greater than 1 as shown in Eq. 3.

  $$R_{W_i} = \sum_{j=1}^{b} \sum_{k=1}^{n} F_{ijk} - 1 \quad \forall\ F_{ijk} > 1 \quad (3)$$

  Where F_{ijk}=frequency of repeated ideas for the *ith* phase, *jth* bin, and *kth* participant; *i*=phase number (1, 2); *b*= number of bins (127); *n*= number of participants. A unit is subtracted from F_{ijk} to maintain accountability of the total of ideas generated.

- Repeated ideas between phases (R_B): for bin and participant levels, R_B takes into account all ideas that reappeared in phase II after being generated in phase I.

  $$R_B = \sum_{j=1}^{b} \sum_{k=1}^{n} F_{2jk} \quad \forall\ F_{1jk} > 1\ \ AND\ F_{2jk} > 0 \quad (4)$$

  Where F_{ijk}=frequency of repeated ideas for the *ith* phase, *jth* bin, and *kth* participant; *i*=phase number (1, 2); *b*= number of bins (117); *n*= number of participants.

3.4. Novelty

Novelty provides a measure of the uniqueness or originality of a given solution when contrasted/compared with others in the design space of possible solutions. Some novelty metrics, such as Jansson and Smith's (1991) "Originality", as adapted by Chan (2011), contrasts the non-similar or non-related concepts with respect to the total of concept ideas generated; and the approach proposed by [Sarkar & Chakrabarti, 2007] that requires comparison with previously known ideas. Building upon these definitions, we define a novelty approach that uses only the total quantity of non-repeated (Q_{NR}) ideas, considers phase I as the baseline design space, and the uniquely generated bins of phase II as constituting an expansion of the design space. Our novelty approach is defined as a function of the space composed of all ideas (not bins) that were uniquely generated by a participant in phase II over the participant's total phase II ideas.

$$\text{Novelty}_{j,k} = \frac{\sum_{l=1}^{b} F_{2jkl} \;\; \forall\, F_{1jkl}=0 \text{ and } F_{2jkl}>0}{\sum_{l=1}^{b} F_{2jkl}} \quad (5)$$

Where F_{ijkl}=frequency of ideas for the *ith* phase, *jth* participant, *kth* group, and *lth* bin; *i*=phase number (1, 2); *j*=participant number (1,…, 73); *k*=group (NT, SCA); *b*= number of bins (117)

4. Results

4.1. Statistical data validation

As a means to understand and validate the power of the tests performed, we developed a retrospective power and sample size study. For ANOVA and two-sample t-tests, the sample size, as a function of chosen power, was first evaluated by setting the significance level as α=0.05 (as typically chosen for similar cognitive studies), the power as 0.8 (as typically reasonable value within social science studies), the variance depending on the metric being evaluated, and the minimum difference by using a low and a high value for consideration. Based on this analysis, it is found that for the desired differences, the study's actual sample sizes are sufficient with an 80% power. Using the study's actual sample sizes, power values can be calculated, being higher than 78% for all metrics at a confidence level of 95% for the desired difference in outcome.

To be able to perform sample test comparisons, the normality of data across techniques was evaluated by means of Anderson Darling Normality Test. The experimental study produced data that fitted normal distribution; therefore, statistical analysis such as ANOVA and t-test can be performed.

4.2. Quantity of ideation

Quantity of ideas, Q_{Total} and Q_{NR}, generated by the experimental groups by phase as defined in Section 3.2 are presented in Table 1. Q_{NR} corresponds to filtered data that was used for metric calculations. Q_{Total} has a total of 1,299 ideas, while Q_{NR} has a total of 842 ideas.

Table 1. Quantity of Ideas Generated

	Q_{TOTAL}			Q_{NR}		
Experimental Group	Ph I	Ph II	Total	Ph I	Ph II	Total
NT	327	330	657	282	158	440
SCA	318	324	642	224	178	402
Grand Total	645	654	1,299	506	336	842

For Q_{NR} Phase I ANOVA shows no statistically significant difference in the quantity of ideas generated (F=1.93, *p-value*=0.17), which is to be expected considering that both groups in that phase were within non-assisted scenario. Comparing phase I against phase II for each experimental group, a statistical significant difference is found in the quantity of ideas for the NT group (F=21.87, *p-value*=0.000), due to the reduced quantity of ideas developed during phase II. The SCA group shows no statistical significant difference in the quantity of ideas (F=2.66, *p-value*=0.110).

4.3. Fixation

Applying Section 3.3 definitions for repeated ideas within and between, the distribution over both experimental groups and phases is summarized in Table 2. Examples of repeated ideas were "impose a penalty" and "make credit performance public". "Impose penalty" was a solution idea stated in phase I and then repeated in phase II by the same person. "Make credit performance public" was a solution idea stated by a given participant more than once while working in a single phase. When comparing the results obtained in phase II for both groups, no statistically significant difference is found, i.e., the number of repeated ideas is the same (F=1.46, *p-value*= 0.233). This is not the case for phase I, where a significant difference in the quantity of repeated ideas is found (F=10.16, *p-value*= 0.002). Comparing the SCA group results for both phases, there is no statistical significant difference in the quantity of repeated ideas (F=2.28, *p-value* = 0.138).

Table 2. Repeated Ideas by Experimental Group, Source and Phase

	NT (36)		SCA (24)	
	Ph I	Ph II	Ph I	Ph II
R_W	45	40	94	79
R_B	0	132	0	67
TOTAL	45	172	94	146
Average	1.3	4.8	3.9	6.1

Calculating Fixation by means of Eq. 2, we have the results illustrated in Table 3.

Table 3. Calculation of Fixation (%) by Phases of both Groups

Group	**NT**		**SCA**	
Phase	PhI	PhII	PhI	PhII
Total Repeated	45	172	94	146
Total Generated	327	330	318	324
Fixation (%)	13.8%	52.1%	29.6%	45.1%

ANOVA analysis between phase I fixation results of both the treatment (SCA) and control (NT) groups shows a statistical significant difference in fixation (F=9.01, *p-value*=0.004), which may be due to socio-cultural conditions. Analyzing phase II of both experimental groups shows no statistical significant difference (F=2.15, *p-value*=0.148). Comparing phase I against phase II for both experimental groups, a statistical significant difference is found (SCA: F=13.41, *p-value*=0.001; NT: F=95.34, *p-value*=0.000). These results imply that both the treatment and control groups were fixated, but what is interesting is that in the case of the group that used the SCAMPER method, it appears that the method did not help them to overcome fixation, at least for this type of problem.

4.4. Novelty

A total of 19 bins were uniquely generated in phase II. Four (4) of them were generated by NT group and the remainder 15 to SCA. These 19 bins correspond to a total of 31 non-repeated ideas uniquely generated in phase II (Q_{NR}), which are distributed as NT=9 and SCA=22. Examples of ideas that were stated for the first time in phase II are “Develop tax models where customers can obtain tax benefits when paying their debts” and “Transfer credit to parent company or debtor’s close family member and chase payment or harass new debtors to influence debtor to pay. Table 4 presents the average and standard deviation by participant of the non-repeated ideas uniquely generated in phase II (Q_{NR}) and novelty as defined by Eq. 5.

Table 4. Average and Standard Deviation for Novelty

	NT		SCA	
	Q_{NR}	Novelty	Q_{NR}	Novelty
Average	0.25	4.7%	0.92	12.4%
StDev	0.55	0.11	0.83	0.12

From these results we have that on average one of every four participants developed a novel idea in the NT group and that almost every participant in the SCA group developed a novel idea. To determine if the average and novelty calculated with Eq. 5 per participant is statistically significant, an

ANOVA was performed. There is a statistically significant difference between the total number of ideas generated by both groups (F=13.96, p-value=0.000) and also for the calculated novelty values of both groups (F=6.72, p-value= 0.012).

5. Discussion

To enhance creativity, different factors and methods can be considered simultaneously. We considered the SCAMPER method as an idea generation enabler, because it proposes seven "operators" that suggest possible actions that can be carried out with a given design problem to solve it. The method asks the user to answer formal triggering questions that enables the ability to engage a problem in a different way, and generate variants or improvements for suggested or existing solutions. Posing this set of questions for transactional design problems may allow one to overcome the intangible nature of the problem as well as the typical solutions that are characteristic of such problems. Specifically for the selected metrics analyzed as part of this study, a number of intriguing contributions are apparent.

For quantity, after removing the repeated ideas, when generating ideas in a non-assisted scenario (phase I), both experimental groups performed in an equivalent level. Both groups showed a reduction in their production for phase II when compared to their respective phases I; however, the difference in the NT group was statistically significant, while the difference for the SCA group was not. It is interesting to note that these results may indicate that even though the SCA group had a cognitive load due to learning and applying a new ideation method, the application of the method appears to not restrict the ability to produce a large quantity of ideas as compared to the non-assisted scenario.

Comparing total production Q_{Total} of the NT group with its production excluding repeated ideas Q_{NR} for phase II, the quantity of ideas reduced by half, which might be an indication that the NT group is highly fixated. What seems remarkable is that the quantity of repeated ideas increased almost 4 times for the NT (from 45 to 172) whereas for the SCA group it increased 1.5 times (from 94 to 146), which demonstrates that neither of the methods studied appear to be effective to overcome fixation. However, the intensity of the fixation effect appears to be stronger in the control the group (repeated ideas between NT 132 vs SCA 67).

The novelty results indicate that 79% of the novel bins and 71% of the unique ideas are developed by the SCA experimental group. The calculations of novelty percentages show a statistical significant difference between the NT and SCA groups, indicating a significantly higher SCAMPER result compared to the NT. These novelty results are remarkable and are also not intuitively expected considering fixation results previously presented.

The study results indicate that a large quantity of the participants' time is spent creating repeated, or idea variants. In the case of the NT group there is a tendency to develop small variations to previously generated ideas when alternative categories of ideas are not apparent, while for the SCA group, the repeated ideas correspond to variant, improvements and more refined versions of the ideas with additional exploration of alternative categories of ideas. This behavior may confirm what Michalko (2006) stated in his book about increasing your odds of discovering a novel idea with SCAMPER by generating alternatives of that novel idea.

Two implications can be derived from these results: First, that the cognitive load of SCAMPER may be relatively low and it may increase novelty of participants; second, it is possible that fixation for SCAMPER has a beneficial effect by enabling idea refining while at the same time being prompted with questions that may assist participants to "jump" out of the design space area they are exploring. The conclusion here is that SCAMPER method appears to be a balanced fixating and de-fixating method, at least for the type of problem explored.

6. Implications and Further work

Considering the abstraction level of the transactional problems, the heuristic method here studied shows great potential to significantly improve novelty of solutions and validates the transferability of methods developed in engineering (product/artifact related) domains to transactional (service related) domains. The study results pose new sets of questions to be researched further such as cultural implications when applying ideation methods and the level of fixation that can have a positive impact in the completeness and quality of ideas. Since previous studies have shown that fixation will typically distract from novelty, the counter intuitive result of our study opens a new avenue to be investigated with respect to how much effort a technique should provide a group to enable "staying" around a set of ideas to improve and refine them.

7. Acknowledgements

The authors wish to acknowledge support provided by the ITESM-BMGI Lean Six Sigma Program (http://6sigma.mty.itesm.mx), without whose participants, this study would not have been possible. We wish to acknowledge the SUTD-MIT International Design Centre (IDC) (http://idc.sutd.edu.sg/) for its support and encouragement with this research. Finally, to the Postdoctoral Graduate Fellows program between MIT and SUTD for enabling collaboration from multiple backgrounds and expertise. Any opinions, findings, or recommendations are those of the authors and do not necessarily reflect the views of the sponsors.

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