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Design from Discard: A method to reduce uncertainty in upcycling practice

Amaltas Khan & Puneet Tandon: PDPM Indian Institute of Information Technology, Design and Manufacturing, Jabalpur

Abstract

Upcycling is a suitable option for municipal solid waste recovery, especially, in the unorganized waste management scenario(s), where conventional waste recovery options are not efficient. Unlike standardized industrial manufacturing, upcycling is highly dependent on the quantity and quality of discards, and the involved stakeholders. Novel designs are required to suit varying considerations of every new upcycling set-up, and practitioners face uncertainty to parallel handle the variety and develop a design solution. A very few available design education based methods involve and guide design practitioners to handle the challenges in their case-based upcycling practice. However, these research studies are the first attempts to practice upcycling in an academic environment, and the results were limited to concepts and prototypes. This work categorically identifies the vital requirements regarding discard and stakeholders, discuss the theoretical foundation to handle the variety, and develop a practice-based design education method for upcycling practice. We propose a method - Design from Discard, to facilitate the participants to study the characteristics of discards, conceptualize a design as per the identified stakeholder(s), and accordingly develop upcycled designs. The method is explaining with an illustrative case where the design practitioner(s) conceive a new design from contextually discarded metalized film packaging. Finally, findings and research directions are addressed to bring new insights to the effective application of the proposed method as per diverse upcycling requirements.

Key words

upcycling packaging waste; practice-based design method; design from discards

Introduction

Upcycling is an activity that utilises the limited affordance of the *discarded* products to develop a new product (or material) of comparatively better value (McDonough & Braungart, 2013). Upcycling activities have proved to be effective in delaying waste disposal (Singh & Ordoñez, 2016), eliminating the need for new products, enhancing the aesthetic value (Sung & Cooper, 2015; Wilson, 2016), and consuming less energy in material circulation as compared to recycling (Nilakantan & Nutt, 2015). Particularly, in the case of developing and underdeveloped countries, upcycling is a suitable option to *discard* recovery (Slotegraaf, 2012), where the other waste management techniques, such as recycling, biodegradation, landfilling, incineration, etc., are not efficient irrespective of latest technological interventions due to system and service level limitations (Guerrero, Maas, & Hogland, 2012; Hoornweg & Bhada-Tata, 2012).

At the individual level, renowned designers, ordinary individuals, and even marginalised communities with limited knowledge have developed upcycled products (Radjou, Prabhu, & Ahuja, 2012; Sung, Cooper, & Kettley, 2014), creating interest and trends towards upcycling. Along with organisations like TerraCycle in the United States (Li, 2014), organizations like 'Spiral foundation' in Nepal (Spiral Foundation, 2016), 'Taller Re_crear' in Chile (Re_crear, 2016), 'Waste for Life' in Argentina (Baillie & Feinblatt, 2010), and many other initiatives (Hira, 2017), provide substantial evidence on unique models to support *discard* recovery through upcycling. Despite the scope and participation of individual and organizational design interventions, upcycling interventions struggle to handle the contextual challenges in upcycling (Han et al., 2017; Sung, 2015).

Unlike the industrial design process, where standardisation leads to mass production, upcycling is a highly customised activity. Every new upcycled design is highly dependent on the regional waste management sites to consistently supply the unattended *discard*s, to the upcycling setup (Ali, Khairuddin, & Abidin, 2013; Richardson, 2011). Moreover, industrial manufacturing processes cannot be applied to shape and form discarded materials to mass manufacture upcycled goods, and case-specific techniques are developed for each upcycling case (Baillie, Matovic, Thamae, & Vaja, 2011; Han et al., 2017). Other issues such as concerns of the workforce for customised manufacturing (Dissanayake & Sinha, 2015) and applicable regulations for the use of *discarded* materials (Ordoñez & Rahe, 2013) lead to multifaceted considerations for distinct upcycling cases. Collectively, these issues limit novel design interventions in upcycling, irrespective of opportunities present in a sector.

On the other hand, design education institutes have recently attempted to handle the multifaceted considerations in upcycling based cases. Very little research literature is available which demonstrates design research support to handle the contextual challenges in upcycling. Design institutes and universities are engaging design practitioners by means of projects to handle the barriers in creative problem-solving. 'Waste for life' (WFL) (wasteforlife.org) is such a collaborative organization of academic practitioners and ground cooperative partners, which have developed a standard technique and machine to manufacture waste-based composite 'material board' that aids local waste recovery (Baillie & Feinblatt, 2010; Baillie, Matovic, Thamae, & Vaja, 2011). However, an adaptation of the standard practice, such as WFL, is focused on the specific regional opportunities and constraints, and may not be suitable for requirements of varying upcycling initiatives. There is a need for design research support for varying upcycling opportunities and practice that provides novel solutions appropriate for individual contextual settings.

Interestingly, a few of the design institutes have practiced design education as an effective way to incorporate professional knowledge in upcycling based activities, thereby enhancing creativity and creating variety in upcycling. In the few available methods developed by researchers, design practitioners are guided to generate suitable ideas for upcycling. 'From Industrial Waste to Product Design' (W2D) is such a collaborative work of recycling firms, engineering consultancy organisations, along with design researchers in Sweden. Researchers collaborate with recycling industries of highly organised waste management scenarios to collect their non-recyclable waste, and then designers use the *industrial discard*s for upcycling practice (Ordonez, Rexfelt, & Rahe, 2014; Ordoñez, Rexfelt, & Rahe, 2012). Another significant contribution is the 'Design from Waste' (DfW) method developed by researchers for unorganised waste management scenarios in India (Khan & Tandon, 2016). They identified that in their case most of the 'recyclables', in the absence of system level support, end-up in landfills. In their course-based upcycling practice, the practitioners were guided to identify recyclable and unrecyclable *discard*s at municipal waste disposal sites and utilise the limited affordance of *discard*ed materials to conceptualise upcycled products.

The two methods presented here provide a knowledge base for upcycling practice that was much needed to resolve the issues faced by an individual as well as organisational upcycling activities. W2D and DfW are the only methods available that can be 'tested' to varying upcycling opportunities and practice. Further, in a comparative work, both the methods, i.e., W2D and DfW, were compared on their contextual set-up, education set-up, the framework(s) presented to practitioners, and the results obtained (Ordoñez, Khan, Tandon, & Rexfelt, 2016). Some of the valuable insights and research directions of the work include:

1. Planning the product segment according to the prior experience of design practitioners could increase creative problem solving,
2. The duration given to the practitioners for completing the project should be estimated and planned according to their design proficiency,
3. If the practitioners are students of design education, then their learnings should be followed and the upcycling process should be accordingly developed.

The comparative work also concluded that the characteristics of contextual *discard*s and stakeholders are the governing factors to devise a better practice-based education method to *discard* upcycling.

The following are the significant research gaps that have still to be resolved to lead to better-upcycled products:

1. The existing methods agree on the point that ‘discontinuity’ in *discard*s is an integral characteristic, and varying quality of *discard* substantially affects the current upcycling based pedagogy and limits the scope to concepts and prototypes. Moreover, there is a need for clear understanding on how the *discard*s should be handled to result in an upcycled product.
2. The methods had to deal with multiple considerations, e.g., varying quality of *discard* provided by a recycling firm (as in W2D), incorporating marginalised communities for hand-made manufacture (as in DfW) etc., to overcome the limitations in upcycling identified in the individual case.

These two teaching-learning pedagogies are the first practice-based approach to show ‘how’ upcycling can be benefited from the academic practice. However, the current methods merely considered the stakeholder as an important factor, and lack the details on including the requirements of identified stakeholders, e.g., recycling firms, marginalised communities, etc. in their methods. To enhance the quality of outcome, a detailed model of ‘what’ are the multifaceted requirements and ‘how’ to create the final upcycled design according to the identified needs, is essential.

In continuation, one of the fact market, is a must for the acceptability of product in the competitive market (Wang & Hazen, 2016). Moreover, design adaptation with reference to changing user requirements is expected fro ors vital in every design process, i.e., the customer requirements, still has to be explored and implemented in an upcycling process. User expectations, customer influences, etc., regarding an identified m any product for succeeding in market competition. In other words, radically different design responses are required from the design researchers to address the interwoven issues, rather than manipulating the existing methods (Dorst, 2011; Sandberg & Aarikka-Stenroos, 2014).

Accordingly, this article presents a design education based upcycling method—Design from *Discard* (DfD)—that guides and trains the design practitioners to create contextually suitable upcycled products. In the subsequent sections, we first explain the theoretical foundation behind the DfD method, on how the identified research gaps regarding *discard*, manufacturer, and customer, could be resolved by the DfD method. Further, in the method section, the suggested steps of DfD method is elaborated with one of the illustrative case(s). Here, a locally unrecovered *discard*, ‘multi-layered flexible film,' is identified and for a selected region, design practitioners survey relevant sites and stakeholder(s), collect the necessary information, explore the upcycling possibilities, ideate and correlate the design features, and deliver a suitable upcycled product. The manuscript also discusses a unique ‘correlation wheel’ within the DfD method that associate the identified multifaceted requirements together to create an appropriate design. Finally, we discuss the issues related to the conducted steps, the scope of actual application, and further research directions of the DfD method regarding diverse upcycling opportunities.

Theoretical Foundation

It is expected that the DfD method should be efficient to handle the variety of *discard*; and also include various *stakeholders*, i.e., design practitioners, manufacturers, customers, etc. The method should also be capable to understand the personal interests of stakeholders, in the process as well as the outcome. This section proposes the foundation of the existing theories and developed practices, based on the factors that are related to effective participation of designers, exploration of *discard* affordance, and stakeholders' interests, to devise an approach to resolve the identified issues.

Effective Involvement of Participants

Project-based learning is often preferred in an academic environment when practitioners are exposed to actual scenarios and learn from real-world problems (Boss & Krauss, 2014). In the presented literature of DfW and W2D methods, it has been found that the quality of upcycling concepts was highly influenced by the contribution of participant practitioners. However, these approaches did not consider the significant details of engaged participants. It is recommended that such project-based education pedagogies have to be designed by critically considering the strengths and weakness of the individuals to ensure effective participation (Brandt et al., 2013;, Yu, & Chen, 2011; Scheer, Noweski, & Meinel, 2012). In this work, we have selected Master of Design scholars of our institute as the participants. During the initial planning of the coursework, the past education of the participant designers and their professional experience were recorded. Besides, as the practitioners were in the third semester of their two-year master's program, the common coursework in their previous two semesters has also been considered as the recent learnings and knowledge may also influence the practice on the method. This was also taken into account during group formation.

Figure 1 presents the exercise of group formation for the 18 design practitioners enrolled for the task. The group formation was carried out in such a way that individual characteristics such as education, and experience complement each other. The educational backgrounds of practitioners were limited to undergraduate courses in the domains of Mechanical, Electronics, Civil and Computer Engineering as well as Industrial and Product Design. A total of 5 groups were formed to equally balance the strength of each group (Mcmahon & Bhamra, 2016), with three to four members with an engineering background, and one member being exposed to design education.

The scope of growth of participatory design interventions in waste management sector is increasing (Cucuzzella, 2016; Pavlova, 2013), however the existing examples (Lange, Hughes, Rahbar, Matzen & Caldron, 2012; Heidenspass, 2016; Janwani, 2016; Szaky, 2014) are stand-alone practices that involve risk, lack research support, and are therefore difficult to adopt for a larger segment of 'traditionally practising' design practitioners. As an attempt to effectively involve the participants in an unfamiliar sector, the initial stages of DfD method have been designed to first make the practitioners aware about the popular issues, provide visibility to the opportunities available for individual growth and, then motivate them to work on the upcycling process (Wormald, 2011).

GROUP 1	G1, Member 1 (G1M1)	G1M2*	G1M3	G1M4	Education + Experience
Educational Background (Bachelor's Degree)	Mechanical Engineering	Electronics and Communication Engineering	Industrial and Product Design	Computer Science Engineering	Mechanical + Electronics + Product + Computers
Industry Experience	Faculty Advisor (1 y*)	nil	Product Designer (7 m*)	nil	1 y 7m
GROUP 2	G2M1	G2M2	G2M3	G2M4	
Educational Background (Bachelor's Degree)	Mechanical Engineering	Electronics Engineering	Computer Science Engineering	Civil Engineering	Mechanical + Electronics + Computers + Civil
Industry Experience	nil	Freelance Graphic designer (1 y 2 m)	Freelance Designer (7 m)	nil	1 y 9 m
GROUP 3	G3M1	G3M2	G3M3		
Educational Background (Bachelor's Degree)	Mechanical Engineering	Electronics and Communication Engineering,	Leather Design		Mechanical + Electronics + Leather
Industry Experience	Graphic Designer (1 y)	Programmer Analyst (10 m)	Product Designer (1 y)		2 y 10 m
GROUP 4	G4M1	G4M2	G4M3	G4M4	
Educational Background (Bachelor's Degree)	Mechanical Engineering	Electrical and Electronics Engineering	Textile Design	Civil Engineering	Mechanical + Electronics + Textile + Civil
Industry Experience	Nil	Software Engineer (1 y 8 m)	nil	nil	1 y 8 m
GROUP 5	G5M1	G5M2	G5M3		
Educational Background (Bachelor's Degree)	Mechanical and Automation Engineering	Computer Software Engineering	Accessory Design		Mechanical + Computers + Accessory
Industry Experience	nil	nil	Communications Manager (3.3 y)		3 y 3 m
Common courses studied during Master of Design: Semester I: Elements and Principles of Design, Ergonomics for Industrial Design, Art & Aesthetics in Design, Product Design, Visual Design, Design Workshop, Professional Communication Skills; Semester II: Interactive Design, Visual Ergonomics, Videography, Culture and Design, and Sustainable Design					
* G1M1 signifies Group 1, Member 1; 'y' signifies year; 'm' signifies month					

Figure 1. Group formation as per participant education and experience

Opportunity in Discarded Items

Unlike user-centric approach of industrial design methods (Ulrich, 2003), in the upcycling process the practitioner has to primarily deal with the *discard*ed materials that possess discontinuity and limited material characteristics. For understanding the affordance, the *discard*ed material has to be first divided in the form of perceivable entities. Accordingly, the initial phases of the DfD method facilitate the technical study of *discard*ed material followed by a practical exploration. Further, it was identified that a few design methods are inspired from the systems perspective, and divide the challenges into multiple segments till they become perceivable modules (Blizzard & Klotz, 2012; Khan & Tandon, 2015) to generate design concepts. DfD method facilitates processing and splitting of the *discard*ed material into perceivable modules, till they become simple enough to be studied. The process of splitting *discard*s is further elaborated in the upcycling case.

Further, the DfD method facilitates identification of local stakeholder(s), i.e., manufacturers and users, and locally adaptable manufacturing processes to limit the multiple and diverse considerations during the upcycling process (Tremblay, Gutberlet, & Peredo, 2010). Thus, the method assists design practitioners in identifying contextual issues related to the *discard* collection, *artefact* manufacturing, as well as *customer* requirements, and accordingly develop a design that can be circulated in the designated local context.

Stakeholder's Interest

In the present literature, only DfW work has considered and included manufacturing as an important factor, thereby, including marginalised communities in their method for cost-effective manufacturing of hand-made upcycled products. However, such communities will not be present in varying upcycling case(s), especially in the case of upcycling in developed countries. For example, TerraCycle invites and include volunteers (Szaky, 2014; Terracycle, 2016), Spiral foundation train and involve local villagers (Spiral Foundation, 2016), etc., as manufacturers of their designs. In contrast, 'manufacturing communities' (further referred as *artisan*), should be a generic segment to focus upon, to enable acceptance of a method to varying contextual set-ups of manufacturing. Accordingly, the DfD method would guide the design practitioners to identify the capabilities and limitations possessed by a probable *artisan group* based on their education, skills, experience, and motivation.

Customer preferences are one of the principal elements that guide an industrial design process and, also defines the fate of the designed product (Ulrich, 2003). Even though the manufacturing aspects of upcycled design are not comparable to the industrial design processes, yet the success of final upcycled design would be based on customer preferences (Sung, 2015). It has been identified during the literature survey that the number of customer considerations has to be limited to ease out the DfD practice. Norman had suggested that a design feature can be categorised into components that produce technical (function, usability, etc.) and emotional (aesthetics, sense of personalisation, etc.) effects (Norman, 2004). The proposed DfD process does not consider the design of technical requirements, and the novelty of the upcycled design is limited to emotional requirements only. Accordingly, a few of all the identified customer preferences should be taken so as to reduce the number of considerations in creative problem-solving. For the DfD method, the general requirements of regional customers towards the redesign of the existing products were identified, and the technical components were adapted from the relative designs available in the market. Further, the method facilitates the design practitioner to redesign the *artefact* with the emotional features only.

The Method Steps

In the context of design, a problem is said to be complex when the associated designer could not unravel the opportunities related to the identified factors, and, therefore, find it difficult to move to the next phase of problem-solving (Dorst, 2011, 2015). These circumstances occurred during the earlier practice on upcycling, i.e., W2D and DfW, where multifaceted considerations limited the design process and quality of outcome (Ordoñez, Khan, Tandon, & Rexfelt, 2016). For the DfD case too, the *discard*, *artisan*, *artefact* (the final upcycled product) and the *customer* distinct requirements and attributes that have to be meaningfully interconnected to proceed further in the design process. In spite of the fact that the generic industrial design processes cannot be directly applied to upcycling due to lack of inherent knowledge, the hierarchy of steps followed in the proposed upcycled process is inspired from the generic product development process (Ulrich, 2003).

If critically analysed, then for the concept ideation, it is essential that the participant can ‘perceive’ the interconnection between identified attributes (Yilmaz & Seifert, 2011). For example, a food packaging designer has to ‘perceive’ the identified food preservation requirements concerning the affordance of packaging material, to develop an appropriate concept. This interconnection becomes difficult for a practitioner to perceive in the absence of a guiding process (Wong & Siu, 2012), especially when multifaceted considerations are involved. To handle such concerns, the DfD method utilises the fundamental principle of ‘splitting’ the diverse information into comprehensible modules (Blizzard & Klotz, 2012). It is additionally supported by organising the modules in a relative hierarchy, and further analysing the modules in a comparative context. Figure 2 represents the seven-step DfD method, i.e., Draw-Identify-Split-Correlate-Associate-Rectify-Deliver collectively creating the word ‘DISCARD’. The process is briefly presented with the help of Figure 2 to make a clear understanding of how the method steps were derived from the theoretical foundation.

Figure 2. Design from Discard (DfD) method representation

The activities carried out in the individual steps are briefly introduced so as to make the process clear to the practitioners and other stakeholders:

- **Draw**: Design practitioners finalise a material collection site. They identify and collect *discards*, as well as study and analyse the *discard* properties.
- **Identify**: The step involves identification of local individuals and interaction with them to record and analyse their capabilities and limitations as an *artisan*. The step also involves identification of *customers* and *artefact*s of local importance to study their functional and emotional requirements to create new designs.
- **Split**: All the identified requirements of *discards*, *artisan*, *artefact*, and *customer* are categorised into separate groups. *Keywords* are assigned to the grouped requirements.
- **Correlate**: All the *keywords* are arranged in the form of the 'correlation wheel', where *keywords* and their pictorial representations assist the participants to review diverse information.
- **Associate**: The priorities of *customers* (as in the form of *keywords*) are connected with relevant attributes of the *artefact*, *artisan*, and *discard* respectively, creating the association for a concept generation. Similarly, other customer priorities are also connected, and separate concept modules are generated as well as combined to develop the final concept.

- **Rectify**: The generated concepts are cross-checked with the identified *keywords*, attributes, and requirements; the *artefact* is detailed and fabricated.
- **Deliver**: The developed *artefact* and details are handed over to the identified customer and *artisan*, and feedback is collected.

Design from Discard (DfD) Method: A Case Study

The knowledge of upcycling methods, industrial design methods, and stakeholder preferences serve as a foundation to develop the DfD method. The following scenarios are proposed, under which the design practitioners can suitably apply the method.

[Constraint 1]

The primary constraints to the application of DfD method for its successful implementation include fundamental knowledge of elements of design (e.g., point, line, shape, form, texture, colour, pattern, texture, etc.), and principles of composition (e.g., order, balance, hierarchy, etc.). These design fundamentals would assist the design practitioners in connecting the distinct characteristics of *discard*s, *artisan*, *artefact*s, and *customers*, and thus, it is important that practitioners have a prior understanding before practicing the method.

[Constraint 2]

As the method is based on the logical interconnections of distinct elements and attributes of *discard*s, *artisan*, *artefact*s, and *customers*, it is recommended to have a heterogeneous group-based activity to enhance the quality of the outcome. Moreover, the groups should discuss the procedures and the results at every stage to get diverse inputs.

The outskirts of Jabalpur city, in India, are selected as the *discard* collection site. Jabalpur is a densely populated sector and being a major city of the state, it practices a waste management policy and regulations (CPHEEO, 2016). In spite of such installations, the packaging waste disposal is a common issue here and, therefore, motivates the globally comparative platform to initiate the DfD practice. Moreover, a considerable population of Jabalpur is semi-skilled and unskilled individuals, having limited employment options (*Census of India*, 2011; Nandy et al., 2015), and therefore, could participate as manufacturing stakeholders.

[DfD Method Step 1] Draw: Design Intent and Material Knowledge

In DfD method, initially, the practitioners were expected to realise the environmental effects, such as waste generation and accumulation, of industrialisation and consumerism. It is important to create a practical foundation for the participants to drive them effectively towards DfD practice. Various unrecovered materials should be collected from the selected waste disposal site for further off-site exploration. The off-site exploration should include the macro study of the factors that are responsible for the particular waste generation and accumulation. This analysis should be further narrowed down to understand product life stages, e.g., design, manufacturing limitations, production optimisation, transportation efficiency, etc. of the identified *discard*. The documentation of these *discard* characteristics should be focused on the *discard*ed materials, not constrained in any predefined direction, to let the participants come up with unbiased findings.

Figure 3(a) shows the community waste disposal site at Jabalpur, India for the on-site material collection. The participants collectively visited local waste disposal sites and identified *discard*s that were left unattended. The collected *discard*s include light-weight metallised films and multi-layered flexible packaging, poly bags, and laminated paperboard that can be referred in Figure 3(d). Some of the complex items like sanitary pads, degraded paperboard, contaminated cardboards, etc., were not collected due to the risk of health hazards. Figure 4 shows the details of quantitative characteristics identified from the regional database (Indiastat, 2016) and as well as field study. Further, the collected materials were sterilised and sorted to identify the actual quantity of *discard*s generated from a single disposal site each day. The various factors that limit the recovery of collected *discard*s were studied and documented.

Another planned site visit, to a local recycling facility, followed the on-site material collection and off-site material research. The motive of the visit was to explore and ascertain the reason behind the accumulation of identified *discard*s, in spite of the availability of the locally existing material recovery options. In this case, the participating teams visited various end-life locations of the multi-layered packaging systems and services. Figure 3(b) and 3(c), shows the visit to a local scrap recycling unit and scrap vendor garage that was performed to identify the collectibles and discards based on their market value. This stage of the method also created a technical foundation within the participants about the collected *discard*s.

Figure 3. (a) Selected community waste disposal site; (b) Survey of recycling sector; (c) Study of collectibles at scrap vendor garage; (d) Selected discard samples

Characterstics of discards			
Collection		**General**	
Total number of household for each disposal site of ward (Statistical database)	**233**	Combination of material (from outside to inside)	**PET/pigment color/Aluminium film/PET**
Total number of household for each open disposal site (Field Study)	**254**	Density (gm/cc)	**1.4**
Quantity of household solid waste generated in each ward	**720 Kg/day**	Thickness (microns)	**12**
Quantity of total packaging waste (1.21 % of solid waste)	**8.71 Kg/day**	Technical name of material	**Metallized PET**
Total multilayered packaging collected from site (non-contaminated)	**2.12 Kg**	Packaging producers (as mentioned in packaging)	**Various states in India**
Cleaning and Sorting		**Mechanical**	
Total PFP accepted after cleaning and sterelization (percentage/weight in gms)	**57/1208**	Tensile strength (Kg/cm^2)	**1800**
Total percentage of materials selected even after cutting/sorting/rejecting (percentage/weight in gms)	**25.34/530**	Elongation (%)	**70**
		Thermal	
		Shrinkage @ 150 C/30 mins	**2**
		Melting point (Deg C)	**250**

Figure 4. Characteristics of discard explored during the onsite and offsite study

[DfD Method Step 2] Identify: Stakeholder(s) and Scope for Re-purpose

This section of the method assists us to collect the desired information and characteristics about the stakeholders, i.e., *artisan*s and *customers*. The effectiveness of DfD method depends on the involvement of the participants, and therefore, meaningful interaction with the *artisan*s and *customers* is the primary step to engage the design practitioners for gathering insights.

Quantify Artisan's Need

For the multi-layered packaging project, the local 'rag pickers' involved in the unorganised waste management activities were identified as *artisans*, as they were closely related to the present waste management practice. However, the method is not limited to any particular group, and other projects performed by different groups identified different social groups as *artisan*s, e.g., construction site workers, hawkers, etc., for their cases. The manufacturing of designs would involve various processes and may require training during commercial use and, therefore, the information on the capabilities, i.e., physical capability, intellectual capability, literacy, income, prior experience, motivation, external factors, etc., are relevant to determine and measure the performance of the *artisan* group. In this way, one can further manage the workforce, tools, time and other pertinent parameters during organisational application. For this purpose, focus groups, questionnaire, and structured interview techniques can be carried out.

An interaction of practitioners was scheduled with *artisan*s to sensitise and raise awareness about the working and living conditions of the potential *artisan*s. Figure 5 represents the summarised results of the questionnaire carried out by participants on five *artisan* families regarding general information, skills and experience, familiarity with tools and techniques, educational qualification, and motivation to engage in the upcycling process. Besides, the present wages of the *artisan* group is also compared with that of the international standards (International Labour Office, 2014; Labour Bureau, 2010) to measure the economic feasibility of the upcycling case. The questions can be further categorised regarding stages of life-cycle, physical and intellectual capabilities, income, and investment potential, etc., according to the contextual requirements.

These data were further sorted and categorised during the next step.

Quantify Customer's Need

The design practitioners were first expected to identify the product(s) of considerable local demand and select one of them for a redesign. Besides, a certain customer group should also be identified that may be interested in the new intervention on the chosen product. The practitioner should also access their knowledge and experience and then select a product for a redesign. It is also recommended that the product should not have complex functional elements. Further, the chosen product should be studied regarding its functional and emotional elements. To limit the number of constraints, the functional elements should remain constant and, the selected designs should be evaluated within the context of emotional elements only. Additionally, practitioners can explore the locally popular art forms and trends that could be implemented in the redesign to influence customer preferences.

Figure 5 represents the selection and survey of the customer. The undergraduate practitioners of the university were selected as a customer during a discussion of group members for the reason that the DfD process may lead to non-obvious redesigns, and valuable insights can be expected from undergraduate level practitioners since they have a comparatively better intellectual ability. Further, the group members selected the options of existing products such as tote bag, sheet folder, umbrella, and shoe cover, after an interactive session about their background knowledge and the relative feasibility of redesign. Umbrella was finalised for the redesign, and the emotional redesign was limited to 'canopy of umbrella' as the surface characteristics of canopy match with that of the selected multi-layered packaging.

Artisan' characterstics		Customer' characterstics	
General		**General**	
Total subjects surveyed	12 people above 21 years, in 5 families	Total subjects surveyed	27
Present profession of artisans	rag-pickers	Profession of customers	Undergraduate students
Educational Qualification (minimum - maximum)	Uneducated - Grade 5	Educational Qualification (minimum - maximum)	Grade 12
Age group (years)	23-42	Age group (years)	19-21
Sex	9 Male and 3 Female	Sex	18 Male and 9 Female
Skills and Experience		**Redesign details**	
Experience	Various experience related to labour work and ragpicking	Product options selected by participant students based on discard characterstics	Tote bag, Sheet Folder, Umbrella, Shoe cover,
Familiarity with handicraft tools	General tools such as hammer, scissors, adhesives	Selected product for redesign	Umbrella
Motivation		Parts of Umbrella to be borrowed from existing designs	Telescopic Shaft, Rib, Runner, Strecher, crook handle, knob, lock unit
Reason for participation	Financial sufficiency	Part of umbrella for redesign	Canopy
Present daily wage	USD 1 - 1.57		
International standards for daily wage	USD 4-13		
Direct inverstment capability	USD 10 - 14		

Figure 5. Characteristics of artisan and customer identified during the survey

[DfD Method Step 3] Split: Categorise and Abbreviate Information

With reference to a generic product design and development process, the collected information and characteristics on *discard*s and stakeholders have to be converted in the form of *needs* and further into *design features*. In the 'split' step of DfD method, all the collected information should be split, organised and analysed in a relative context till the information is simple to perceive. 'Splitting' for the *discard* affordance, the need for *artisan*, the features of *artefact* and the need of *customer* should be altogether independent of each other. For example, it is highly recommended that the selected *discard*s should be tinkered and if possible, physically split in the form of design elements, like, point, line, shape, form, colour, texture, etc. Moreover, the material has to be split into its compositional elements. Figure 6 represents the split process for a multi-layered packaging project, where subcategory of Design Primitives, consists of a point, line, texture, etc., as abbreviated *keywords*. Similarly, 'split' is performed for other identified requirements of *artisan*, *artefact*, and *customer*.

Further, in the split process, the participants were also required to abbreviate the information(s) into generic 'keyword(s). For example, during 'split' of *discard*s, various techniques that bind the *discard*ed material can be abbreviated as 'joining tools' that can be referred in Figure 6. Such abbreviations support the design practitioners to recall the detailed information as and when required. For the collected multi-layered packaging materials, the splitting of *discard* was based on knowledge of design fundamentals, mechanical and physical properties. Therefore, all the information is first subcategorised as *Design Primitives*, *Mechanical Properties,* and *Physical Properties*. Figure 6 shows that every identified requirement is abbreviated with the *keywords*. The other *keywords* were derived on the basis of critical discussions carried out the practitioners.

Customer' Requirements		Artifact' Qualities		Artisan' Constrains		Discard' Affordance	
Subcategory	Keywords	Subcategory	Keywords	Subcategory	Keywords	Subcategory	Keywords
Priority 1	Personalization	Functional Attributes	Parts (quality)	General Tools	Workbench	Design Primitives	Point
Unique Selling Proposition	Uniqueness		Parts (quantity)		Ruler, Clamps		Line
	Apeal		Compatibility		Spanner		Shape
	Trend		Use-cycle		Wrench, Pliers		Form
Priority 3	Durability		Finishing Quality		Hammer		Texture
Usability / Functionality	Comfort	Aesthetic Attributes	Local Art Form	Cutting Tools	Hand Drill		Pattern
	Usability		Neo-art		Cutting Tools		Space
	Added features		Polygon art	Joining Tools	Punch, Rivet	Mechanical Properties	Flexibiity
	Quality	Contextual Issues	Behaviour		Adhesives		Tempreture Effect
Priority 2	Price Benchmarking		Scenario		Lamination		Elasticity
Purchase Decision	Affordability		Error	Precision Tools	Measurement		Plasticity
	Mental Model		Cognitive		Geometry	Phyical Properties	Optical
			Working conditions	ILO Specification	8 Hours/day		Detoriation
			Weather		INR 250/day		Corrosion
							Electrical

Figure 6. Keywords derived from information collected during stage 1 and stage 2 of DfD method

[DfD Method Step 4] Correlate: Create Significant Relationships

A unique correlation wheel was developed to facilitate the meaningful correlation of *keywords*. As shown in Figure 7, all the identified *keywords* can be categorically arranged on the wheel along with the pictorial representation. The correlation wheel shows the four categories, i.e., *customers, artefacts, artisans,* and *discard*s, and their subcategories based affinity among *keywords*. Since all the *keywords* and a graphic representation were listed on the correlation wheel, it is advisable to begin the task of prioritising the subcategories of customer section. These priorities have to be assigned to a group of *keywords* of customer category, concerning their influence on customer preferences as earlier explored during the questionnaire session of *identify* stage. The practitioners should perceive a feasible way of connecting the *keywords* of customer category with that of *artefact* category only, rather than focusing on developing a tangible solution at that stage. In this way, a connection would be established through most of the *keywords* that would lead to the development of justified concepts in subsequent stages. The correlations can be colour coded for explicit representation of relationships.

Figure 7 provides a clear understanding of the use of correlation wheel that was derived for the case of multilayer packaging project. For some of the *keywords*, a pictorial representation is also illustrated to facilitate better recall of information on artefact characteristics. In this project, the latest trends and local art forms were taken as a priority to influence the customer through aesthetic redesign of the product. Similarly, all the customer *keywords* were prioritised (as shown in

Figure 7 with the labels P1, P2, P3), and connected to the *keywords* of the *artefact*, *artisan*, and *discard*, simultaneously. The practitioners have to consider whether interconnected *keywords* are creating a meaningful feature of the concept. Each relationship (shown in Figure 2 as R1-Rn) represents the conceptualisation of prioritised requirements of the *customer* in an *artefact* using available *artisan* and *discard* characteristics. For example, in Figure 7, the keywords in *customer* section which are named as *personalisation, uniqueness,* and *trend*, are connected to keyword *polygon art* of the *artefact* section, which leads to the hint for practitioner that the *artefact* could fulfil the targeted *customer* preferences if relative keywords are considered and connected from the *artefact* category. The arrow direction shows the dependency of the tail keyword with the head keyword.

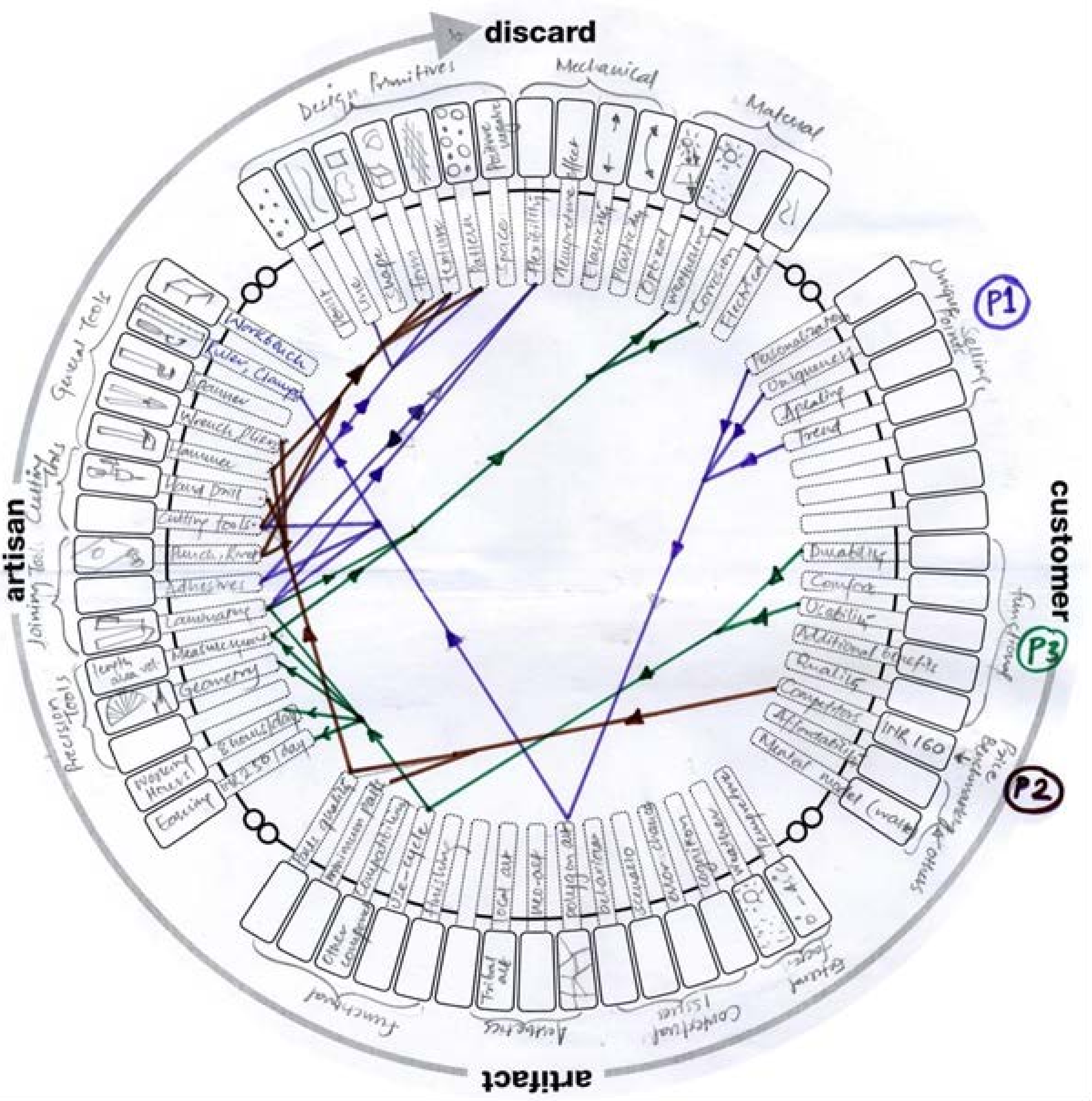

Figure 7. Correlation wheel representing priorities and relationships of keywords

[DfD Method Step 5] Associate: Justify Interconnections and Generate Concept

By the correlate stage, the design practitioners should have a clear understanding of the correlation of *keywords* and how it would lead to a concept feature during conceptualisation. The practitioners should collect all the documented information, *keywords*, relationships, and correlation wheel, and place them in a common workspace. During conceptualisation, the exploratory concepts should satisfy all the *keywords* that have been connected for the identified priorities (shown with the help of colour code in Figure 7 as P1, P2, and P3). This activity of conceptualising relations (referred in Figure 2 as R1, R2, R3… Rk) leads to the first visible representation to fulfil requirements of *customer*, *artefact*, *artisan*, and *discard* information. The participant teams should develop independent *concept modules* for all these *relations* and then should try to merge these *concept modules* in the form of concepts (referred in Figure 2 as C1 and C2).

Figure 8(b) represents the process performed by the practitioner groups, to explore the final form and functionality of the concepts. For testing the manufacturing feasibility of the concept, the participants used various tools, e.g., general tools, precision tools, measurement tools, cutting and splitting tools, adhesion and joining tools that were identified during the *Identify* step of the process that can be referred in Figure 8(a).

Figure 8. (a) Tools identified for manufacturing; (b) Practitioners fabricating the selected concept

[DfD Method Step 6] Rectify: Test and Detail the Concept

During the evaluative research of a product design process, a concept prototype has to be tested in the actual context of use to overcome its shortcomings, before the design is detailed (Ulrich, 2003). However, mere comparing the prototype with identified issues is not sufficient and, therefore, prototyping and testing have to be performed as well. In the DfD method, *Rectify* step has been introduced to simulate the actual conditions, and to explore the overlooked issues in the selected concept. An exciting activity is developed to recognise the hidden issue(s). The design teams developing different projects may be further advised to exchange their final prototypes and train the other teams to manufacture the design as *artisan*s and use the products as *customers* to obtain different insights that might have been overlooked by the team that had developed the product.

During the redesign project, initially, the practitioners performed a cross-check and found the concept prototype C2 satisfying the most of the documented requirements. Different teams exchanged their information, assuming the other team as the actual *artisan*s. The other design teams perceived themselves as the imitating *artisan*s, and adapted to the *artisans*' conditions, i.e., physical, intellectual, and financial conditions, as identified earlier during *Identify* stage. The actual design team trained the imitating *artisan*s, with the upcycling activity. A few unique insights were collected when practitioners were imitating the manufacturing activity as *artisan*s that were not perceived initially by the actual design team. Similarly, some issues regarding product usability were also identified. The observed problems were related to the finishing quality and improper usability. Further, a discussion based interaction between all five groups, which was performed to cooperatively rectify the newly identified issues that were missed by the 'individual' design teams. Finally, the concept was detailed, and a final upcycled design was developed.

[DfD Method Step 7] Deliver and Feedback

To further justify the developed prototypes on the identified requirements, a pilot study of *customers* and *artisan*s was performed. First, the upcycled design was analysed for the final cost and technical performance. The *artefact* was handed over to the actual *artisan* with the intended training, tools and techniques and process details, and the insights were documented. Further, an in-house session with the potential *customers* (as identified during the early stage) was organised to collect valuable insights on the final design.

Figure 9(a) and 9(b) shows the redesign of the umbrella made out of defined metallised packaging film that was shown to *customers* for feedback. The *customers* were asked questions concerning the aesthetic and usability features of the final redesign. The *customers* were also provided the upcycled umbrella for practical exploration. As shown in Figure 10, all the other practitioner groups selected different *discard*s, follow the DfD method and were able to create diverse redesigns.

Figure 9. Umbrella made up of metallised packaging discards

Figure 11 represents the reflection of the final design of concerning practitioners (collectively for each group), *discard*s, *artisan*s, *customers*, and *artefact*s. At this stage of the method development, the success can be measured with respect to confidence in achieving the intended objectives. The primary objective of this project was to propose an upcycling-based method that considers the contextual issues regarding *discard*, *artefact*, *artisan*, and *customer*, and reduce uncertainty, and provide quantitative and qualitative measures to result in a final product.

Figure 10. (a) Fruit Basket made of Tetra Pak by Group 2; (b) Stick for security guards made of perfume bottles by Group 3; (c) Utility basket made of Tetra Pak by Group 4; (d) Sound amplifier made of laminated paperboard by Group 5

Design Practitioners	Discard	Artisan	Customer	Artifact
Twelve weeks is the total duration taken by Group 1 to complete the project	A total of 42 grams of discards were used in each umbrella redesign	All the identified 12 artisan participated in the feedback study	All the identified 27 customers participated in the feedback study	Additional 40 microns PP (polypropylene) (108 grams by weight) is used as base material in canopy
All the five projects were completed in the scheduled time, expect 1 week lag for 2 groups G2 and G5	12 umbrella canopy can be manufactured/MSW disposal site/day	58%, i.e. 7 artisans were able to develop the design with the selected tools	Usability aspects of redesign was accepted by 81% (22 subjects)	Total weight of redesign increased by 27% as compared to 210 grams of the selected umbrella
Selection of discards and stakeholders substantially affected efforts put-up and time-taken	About 77% of the collected discards is wasted in cleaning and sorting	2 hours 20 minutes is the time taken by artisans to manufacture the design	Aesthetic aspects of redesign was accepted by only 11% (3 subjects)	The canopy redesign stood fit against sunlight and, is found waterproof during test
Engaging students directly is hazardous and better ideas are required for safe discard collection		3-4 umbrella can be manufactured in an 8 hour workday		Opening and closing of canopy demands effort as the thickness of canopy is increased
		USD 14.53 is the total cost of tools and additional used to manufacture the redesigns		

Figure 11. Reflections of the final up-cycled design with respect to identified multifaceted considerations

Findings and Discussion

This research work has presented a method Design from *Discard* (DfD), that guide design practitioners to handle multifaceted considerations, and accordingly, deliver an upcycled design. To propose a design research considering the elaborated multifaceted aspects is challenging yet vital requirement to commercialise upcycling practice. The existing works in literature have proved that upcycling through design education is an effective way to boost upcycling practice. However, they lack methodological details to reduce the uncertainty and to lead to a final product.

The few available ‘initial’ methods provide a foundation to practice DfD methods, such as the inspirations from generic design process for upcycling, the effect of participant’s prior experience, and manufacturing considerations. The DfD method further attempts to resolve the issues that limit the existing methods to lead to a final design. The most important issues being the handling of ‘discontinuity’ in *discard*s, limiting uncertainty in creative problem solving, and incorporating the needs of the *customer* and *stakeholders*. In the theoretical foundation, we justified the need for a detailed process that provides quantitative and qualitative parameters to ensure the progression of step by step process.

The project-based coursework initiated a comparison of education and experience of the group members to create heterogeneous groups. One of the important aspects of DfD method is to motivate the design practitioners towards the actual waste management conditions to result in their active participation in the process. We can say that the practitioners are the connection between the DfD method, *discard*s, and stakeholders. Thus, this method indirectly attempts to propose an ecosystem to propagate the idea of collaborative upcycling for a widespread outcome. The enthusiasm of the practitioners during initial steps of 'Draw' and 'Split' was visible and positively affected their participation in the process. The later steps of 'Rectify' and 'Deliver' demonstrate the applicability of the solution for the identified needs, and also shows the involvement of the practitioners in the DfD process to deliver the outcome. Each week of the coursework was appropriately scheduled, and participant groups were able to complete the project in the defined time. However, two groups G2 and G5 had three members, were lagging behind and were given one-week extra time for completion. The quantitative and qualitative measure regarding practitioners can be studied and implemented in future works.

The participants collect the materials directly from the waste disposal sites in the proposed work. It involves health hazards, and some of the practitioners did not find the interaction hygienic. Further, the method also includes an additional step where the practitioners sterilise the collected materials and sort it. However, the demonstrated activities serve as a way to sensitise the practitioners with actual issues in material recovery that can be referred for future works. In further improvement for hygienic waste collection and sorting, there can be an incentive-based direct collection of household waste material (see for example Janwani, 2016; TerraCycle, 2016), in accordance and suitability with local service and system. Presently, the quality and quantity of the material have been explored by the practitioners with an engineering background in each group. However, there is a vital need of database on material properties to ensure the desired performance of *discard*s in an upcycled design.

Regarding the manufacturing stakeholders, the DfD method provides flexibility to identify local communities that can act as an *artisan*. The method is successfully applied to other cases as well (refer figure 10), where the participants selected varying *discard*s, and *artisan*s to develop other design solutions. However, we found it difficult to train the identified *artisan* community, during the 'Deliver' step and most of the *artisan*s were unable to reproduce the designs with the desired level of precision. The method is currently practiced through variable practice sessions to enhance the quality of outcomes during manufacturing. Moreover, additional studies can be performed to analyse the opportunities and constraints with *artisan*s to practice the upcycling for their living. The effect of *artisan*'s skills, prior experience, physical ability and the financial requirement in the upcycling process, is another important and exciting domain to study to steer upcycling practice for employment generation.

In the presented illustrative case, other than the technical details of materials, the practitioners have to test the various *affordance*, i.e., design attributes, physical properties, flexibility, etc., of the collected material during the 'Split' step. In a few of our cases, mere characterisation of material affordances in the predefined arrangement hindered creative exploration. We identified that for effective exploration practitioners have to individually tinker with the *discard*s to understand the physical behaviour. This activity of tinkering with the material is crucial, and ample freedom should be given to study and record the material affordance. There are many tools and methods of material affordance exploration which can be introduced to facilitate material exploration. For instance, Expressive Sensorial Atlas (Rognoli, 2010), and Material Driven Design (MDD) (Karana, Barati, Rognoli, Der Laan, & Zeeuw, 2015; Pedgley, Rognoli, & Karana, 2016) facilitate material sensorial understanding with respect to technical properties and therefore, can enhance the application of *discard*ed materials.

Particular attention was given to abbreviate information for the correlation wheel, where the information gathered during *Draw* and *Identify* stage were converted into *keywords* with minimum infographics. The unique 'correlation wheel' has come out to be a useful tool to handle multifaceted considerations. However, the correlation wheel was confusing for some of the participants and sometimes, they found themselves deviated from the actual motive of *prioritising* and creating *relationships*. Another set of practices on utility and detailing of correlation wheel, and maybe a measure of the effectiveness of the wheel can be significant research works.

The DfD method suggests a sequence of steps (Draw-Identify-Split-Correlate-Associate- Rectify-Deliver) to be conducted during the design process. For the illustrated redesign projects, the practitioners were advised to choose functionally simple products that have a considerable market acceptance. We identified that the suitability and acceptability of the upcycled solutions highly depend on the nature of the project, e.g., time concerns, team size, team expertise, material quality, the requirement of the stakeholders, etc. For example, in a few cases, the *discard* is collected from a comparatively organised waste stream, where the scope for material affordance was increased. Similarly, in one of the cases, the identified *artisan* was capable of relatively greater capital investment on initial setup, and accordingly, practitioners had more flexibility to incorporate better features, e.g., technology adaptation, trend, material finish, etc., that in turn increased the acceptance of the product for the customer. We predict that in a further application, the resulting solutions from the DfD method will create new knowledge of material and stakeholders.

The motivation behind the work is to propose a general upcycling intervention model that can be utilised by various intellectual groups to contribute to mass *discard* recovery in the form of upcycled goods. The success of this motive is a future concern and is dependent on the practice and improvisation of method and acceptability of upcycled solutions to the *stakeholders*. This work is limited to proposing the action steps for the DfD method and shows that how uncertainty in upcycling can be limited and solutions with defined performance parameters can be achieved.

As shown in Figure 11, the resulting upcycling design was shown to the customers and artisans during feedback sessions. The usability aspects of the design were accepted by 81 % of the participants, however, the aesthetic aspects of the redesign were accepted by 11% of the subjects. This means that further improvements are required regarding aesthetic quality, detailing, and finishing of the outcome. However, this work provides answers to the prevalent uncertainty related aspects related to upcycling with the support of an academic setting. The work also established a teaching-learning pedagogy for upcycling practice in institutions, where, practitioners can collaborate with stakeholders in unique ways to upcycle discards. Application of DfD method to other context, materials, stakeholders, etc., would bring new insights and help to refine the method for the overall (i.e., people, planet, and profit) sustainability perspective.

Upcycling has the potential to compete for the quality industrial design, nonetheless, in the absence of inclusive design research, assistive technology, and capital investment, upcycling-based initiatives struggle to initiate and perform efficiently. The present literature and the DfD method shown here are the initial attempts to support upcycling through design education. It is evident that the upcycling and, the related system and services should be evolved with time to result in visible changes. For example, currently for the presented case, *discard* collection is performed at the municipal solid waste sites, that could be further enhanced to invite packaging and recycling industries to aid take-back loops. Numerous in-depth technical tests regarding the business model, sales, and promotion, as required to standardise further operations and procedures for developing a marketable upcycled product. Additionally, the method might provide a broad range of opportunities to step-up a local upcycling based enterprise, resulting in individual and organisational upcycling initiatives.

Conclusion

This paper presents a novel method to support the design practitioners in resolving challenges to upcycling. We have presented a design method entitled Design from *Discard* (DfD), which assist the design practitioners in exploring opportunities with *discarded materials* and *stakeholder(s),* and accordingly, develop a suitable design solution. The DfD method comprises of seven main steps, namely: Draw, Identify, Split, Correlate, Associate, Rectify, and Deliver, collectively the acronym 'DISCARD'. The elaborated case represents our first attempt to resolve the issue of uncertainty of *discard*s, and hindrance in upcycling that is because of multifaceted consideration prevalent in the existing literature. The method is demonstrated by an illustrative case of 'redesigning an umbrella' with *discard*ed 'metallised packaging film' suitable with characteristics for the identified *artisan* and *customer*.

The upcycled designs possess the details regarding the *discard* and *stakeholders*, limit the uncertainty in the design process, and provide a measure of the effectiveness of the final upcycled design, which has not been identified in the examples of the existing literature. The usability aspects of the final design are satisfactory. However, the aesthetic aspects of the final design are not acceptable to the identified customer. Also, the participants' intellect, experience and skill set, are few of the defining parameters based on which the effectiveness of the final design can be ensured. Application of DfD method to other context, materials, stakeholders, etc. would bring new insights and aid to refine the method for the, people, planet, and profit sustainability perspective.

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