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New Mind Development Makes Issues in Home Fabrication of 3D Printing

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Abstract

Despite the existence of a multiplicity of changeable and erratic desires for product design, 3D printer makers often mull about maintaining their market-leading positions. As the household 3D printer market segment has boomed over the recent years, an interesting question arises here whether it is really a good idea to have home fabrication on the basis of a theory that 'satisfaction' through the visual form printed by the 3D printer cannot remain the same forever, and lead the prosumers to change the last printed form by frequently printing another design to overcome the satisfaction. This immediately dismisses the last printed form creating a lot of waste/scrap. Here, we have arrived at the hypothesis that 'it is not possible to obtain waste/pollution requirements in the future by sending a 3D printer to every house without having a proper solution'. In order to understand this phenomenon, first of all, the research paper tries to prove it through literature review; then mathematical argument supports the findings. In the end, all these arrive at a recommendation. To meet the requirements of a sustainable society in the future we need re-manufacturing which is just operated by prosumer.

Keywords

Erratic Desires, Non-Static Design, Individual Freedom, Car Design, 3D Printer Waste.

Introduction

What Overproduction always produces an abundance of waste/pollution through inefficient processes. Many people talk about being non-professional in production these days, such as futurologist Alvin Toffler in his book, *The Third Wave* in 1980, talks about the concept that the consumers would take on producer roles in mass customization (Toffler, 1980). As a matter of fact, we see how prosumption has become an important topic in literature in recent years.

Nowadays, as customers are generally interested in achieving high product utilization, a convergence of technologies and industries, rapidly emerging and changing Product Development Process, using the ubiquitous potential of consumers, increasingly sophisticated and demanding costumers; it has changed many aspects of the design world. This has been influenced by directions in the domain of presumption (Zwick & Denegri Knott, 2009). Consumers and companies are now partners in constituting new era of post-modern, when *Postmodern society* thinking in demassification has resulted in 3D printer idea which persuades the 3D printer makers to shift the industry with its mass-production to the household-production level operated by prosumers, with its fundamental shift in Product Development Process through the participatory design (Darmody, 2009). These companies recognized this new collaborative design reality since mass customization as a relatively new concept described consumers' ability to design their own unique product using modern technology (Morris, 2009). This will achieve superior organizational performance by the way of increased prosumer involvement and satisfaction. By placing this, companies allow consumers to engage in the design process that is newly liberated, although not sustainable. As the creation of a form through a sustainable technique is as important as the efficiency aspects of a product, therefore this research helps in achieving the essential design goals of value creation for futuristic sustainable design, since it is clear on the wide range that the fixed design — printed by prosumer or made by the factory— is tiresome for the users and affects the product longevity — as access to prosumers' desires affects their behavior—. Therefore, enabling them to change design of products every day can give individual freedom, and lead them to incessant printing whenever they get tired of their personalized designs.

Now, this newfound spirit of collaboration is fostered by increasing the number of printer makers; Companies think about maintaining their markets in the leading positions in a competitive global market where the annual growth is approximately 170% to date from 2008 (Li et al., 2017). The amount of personal 3D printers has surpassed industrial printers by several scales in terms of growth rate and quantity (Wohlers, 2014). Besides this, according to statistics collected by 3D Hubs over 10,000 printers; the main application field of personal 3D printers are for Fashion/Art, DIY/Hobby, Prototype, Gadget, Scale model and Household (3D Hubs, 2017). This new idea appeals to satisfy the prosumer, but it is not fit for its intended purpose forever since innovation must take care of many factors. In the past, the lifespan value of a product had not been measured, whereas nowadays, human will consider the waste and pollution as negative effects of 3D printers (Jaafarnia et al., 2021).

This research tries to put this home fabrication under the spotlight. For this purpose, a hypothesis of this research indicates that since the design of a product cannot be fixed forever — it can only answer to the desires of consumers within the duration of a specific time, owing to consumer's erratic desires— (Jaafarnia, 2017); therefore, prosumers cannot stand on the fixed printed form and lead a change in the form by frequently printing another design, which is not possible for removing waste and pollution in the future simply by home fabrication. This privileged sustainability position is created keeping the following question in mind. Is it really a good enough idea to have home fabrication without having a solution for its WP? In order to understand this phenomenon, extensive research can be employed to find out the answers, although as a device, a 3D printer is a good achievement, which allows prosumers to make their required products such as masks at home in the time of shortage in COVID pandemic. However, this paper reports initial work of identifying research literature to show inconveniences of 3D printers.

For this, first, we undertake an overview on Product Development Process and its disposal position, and then research focuses on household 3D printers and points out their disadvantages at the end through mathematical argument eventually the research explains the issue and predict the future waste/pollution.

Waste and Pollution

Waste leads to pollution and in the current times it has become one of the plaguing concerns of the world. For our convenience, the two words Waste/Pollution have been shortened into WP in our research. According to different definitions, *Waste* is any kind of property — such as substance, food, air, soil, energy, water, every kind of resource, product, and mental/physical health of human resources— that lose the quality and become useless, discarded or unusable after primary use; finally, in environments, these unwanted properties become pollution which is useless for the society and sometimes even harmful.

Design Overview

An overview of the product design history is closely showing the processes of disposal. Our discussion is broadly related to every kind of product but here we dig just through car design overview. This can be cited in the case of car design in the year 1885, Benz had begun to think about making a gasoline vehicle through engineering (Figure 1). They however did not pay attention to consumers' visual desires and their effect on longevity (Jaafarnia, 2019).

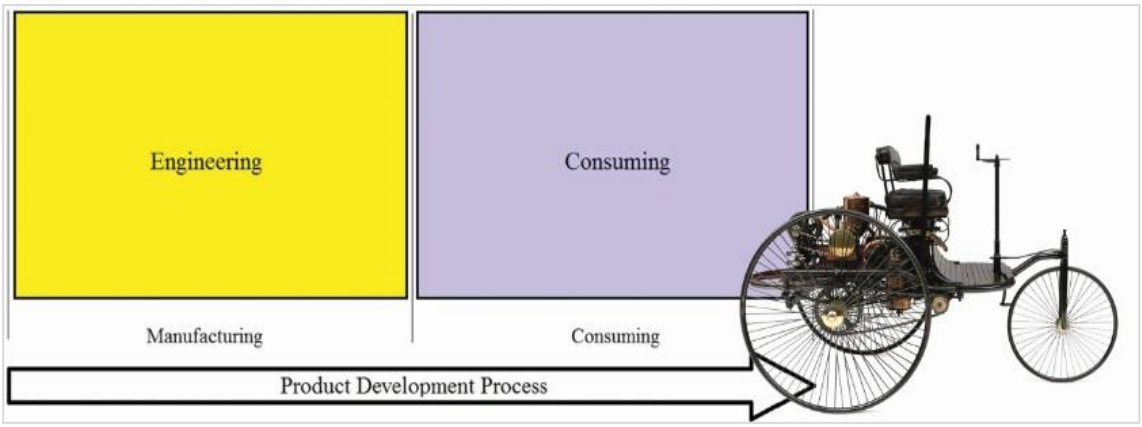

Figure 1: *Product development process in invention era.*

Because of a competitive environment, they started to modify its artistic forms and began marketing it to consumers who were thought to be a ready market for buying cars (Figure 2). During that time contemporary issues of disposal were non-existent (Burdek, 2005).

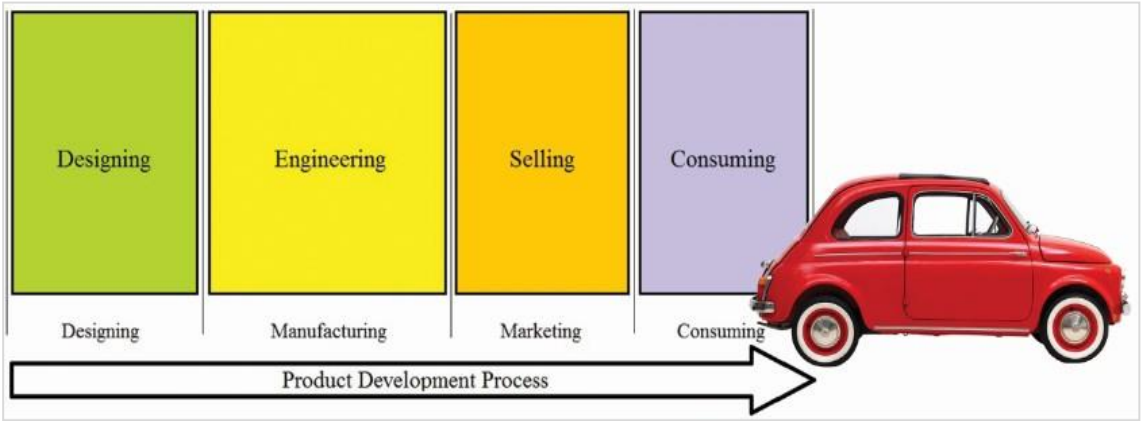

Figure 2: *Product development process in the last century.*

Nowadays, industrial companies are concentrating on services; following new ways designed to add value to the product through consumer orientation. These services were also connected to product manufacturing that slightly affected longevity (Chaturvedi, 1997). However, for better results, designers and engineers must be active in the entire Product Development Process — show in Figure 3— (Buxton, 2007).

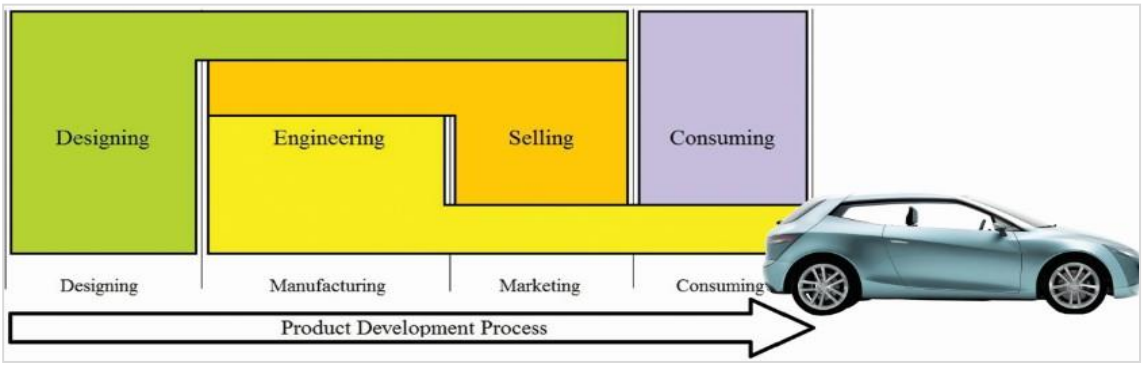

Figure 3: *Product development process in the current decade.*

According to philosophers thinking, form is in the mind, not in material, and since the mind transforms frequently every day, the quality of desire follows suit (Jaafarnia, 2017). *Smart Fortwo* (Figure 4) is an exemplar, which demonstrates the first changeable car form in 1998. Here designer's put forward several choices in front of prosumers, allowing them to compose some design elements all by themselves, according to their desires (DK, 2011). However, this idea cannot be considered phenomenal since the number of choices is limited.

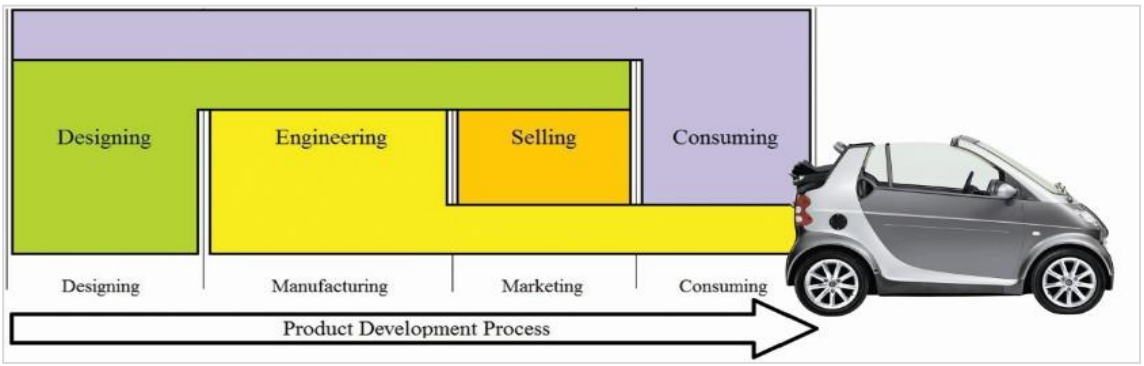

Figure 4: *Product development process for prosumers.*

But now, 3D printers have provided prosumers to print their own designs liberally (Figure 5). Although it is joyful for prosumers, the result is a solid fixed and non-changeable form which will be tiresome for its prosumer and go to landfill soon.

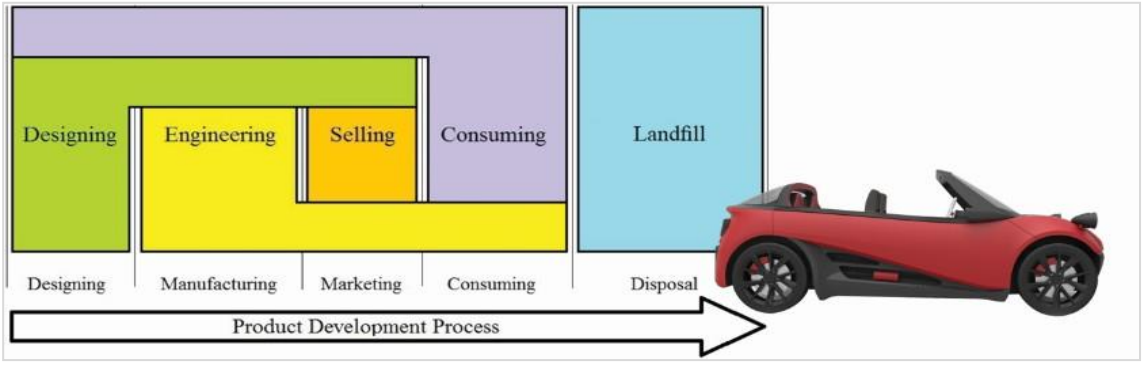

Figure 5: *Product development process for prosumers use printer.*

Ontologically participatory designing implies a radically different understanding of design as prosumer practices and postmodern product designs than those generally we did; it also implies different ways of understanding how prosumers, as postmodern designers *are* and how they come to be who they are in the postmodern world. The ontological aspect of the study of this kind of creativity is connected with the identification of the essential nature of the participatory design (Jaafarnia, 2017). In most studies, the nature of fun is directly defined as participating in making. When we make our things we enjoy. Fun is often stated simply as a justification for the transformative effect of making. William Shakespeare says *Things won are done, joy's soul lies in the doing*. People's perceptions of fun are distinguished as sociability characterized by making things by ourselves (McManus & Furnham, 2010). In making, fun is not derived from external motivations, but from *intrinsic fulfillment of meaningful work*. Fredricks et al. (2004) mentioned that making is a construct often closely associated with fun. This helps us understand the fun and the significance of efforts attempting to elucidate it.

Researchers found that enjoyment comes from the process of designing; a feeling of contentment comes when prosumers complete the process of product design. However, sources of enjoyment and pleasure are in materializing things and personalizing usefulness of created artifacts. They experience embodied pleasures through the process of selecting, designing, and working with hand, since the enjoyment of making for the adult prosumer comes mainly from the process, with a focus on the end product (Lynn Chu et al., 2017). We lost this enjoyment several centuries back when we found industries. A long time ago, William Morris and Ruskin believed in this issue at the Bauhaus that only handmade things create beauty and they were against all the things that were made by technology and machine. They believed that all people should participate in the creation of works of art, which again finds itself in the new era of postmodernism through presumption. If you want to spend 10 months of the year on the road, what do you want? In India, most consumers buy trucks without a cabin, and they design the cabin and make it with help of a carpenter because the design of company on their trucks is not acceptable for them which they want to spend their time on. Even the manufacturer cannot produce trucks with many designs to satisfy their consumers.

Figure 6: a. *Indian self-customization of a truck.* ***b.*** *In India companies sell trucks without a cabin.*

These truckers in India, means a kaleidoscope of colors, slogans, bright paints, motifs, typography, some unique couplets, and intricately painted symbols. This truck is not just a way to get around. It's a moving work of art reflecting the character of its driver and a brilliant beacon for new customers, which explores India's spectacular truck art tradition and an age-old folk art form of India that makes journeys through the dusty highways of India, incredible in more ways than one. Indian trucks are not functional but they fit into owners' desires. It is more important that as they design, they enjoy.

Home Fabrication Using 3D Printer

Today research reaffirms that consumers' tastes has totally changed because of the consumers' inclination towards changeable forms. They have adopted a new outlook towards the market for features that can cater to their everyday desires. In this way, 3D printers are in vogue, since they can be summed up as a skill problem-solving device that contemplates the creative aspects of a product form (Niemann et al., 2009).

Prosumers can now print whatever they desire as per their choices. But this creates sustainable issues for the environment waste management which is now a pressing concern. These problems are listed below;

1. *Erratic Desires and Fixed form Effect on Longevity*

In the past, designers tried to find vital desires to satisfy most of the consumers in the target group, but not all. It is frequently seen that many people do not use a transparent protective cover for their mobile phone, instead, they use covers that change the aesthetic value of the phone and keep replacing it frequently to customize it (Jaafarnia et al., 2021). Going by the prosumption meaning of 3D printers, companies are granting freedom to consumers to print as many as they want, since the ideological recruitment of consumers into productive co-creation relationships hinges on accommodating consumers' desire for individual contentment (Zwick et al., 2008). But this makes way for WP.

Human emotions, as Visser (2006) opined, are conscious thoughts reflecting complex interaction of mind and body, therefore, behavior revolves around emotions. The response of prosumers towards a printed form can invite a response of positive emotions/attitudes; but no one can ensure that the desires will remain the same tomorrow and can generate the same positive emotion again, as users get disappointed very fast. Form alone cannot evoke pleasant sentiments for the user sometimes and of course, this will create a negative effect on longevity. Wakefield & Baker believe that emotions are the reason why pleasant-looking things work better (Wakefield & Baker, 1998). According to a study by Niinimaki, a reflective response as an emotional experience creates attachment, and this pleasant aesthetical aging process is important for a product's longevity (Niinimaki, 2010). Such personal and positive relationships with a design evoke feelings of affection, loyalty, and patience and all these are significant factors in the long-term usability and longevity that show how effectively people interact with design (Lidwell et al., 2010). Altogether, printing form that addresses the erratic desires of prosumers are a complex challenge, where prosumers find a new scale for the judgment of beauty leading to numerous prints (Jaafarnia et al., 2021).

2. *Trial-&-Error Method Makes Issue for WP*

It is clear, that the method of Trial-&-Error creates issues for sustainability as it is a repeated attempt that is continued not until reaching success but for development and perfection. It is an instinctive behavior with the simplest possible way of creation (Goldenberg & Mazursky, 2002). However, this approach can be seen as a basic approach, prosumers develop everything by frequent printing and discard the previous print which is a problematic issue. Although in the level of factory production (mass-production) the same technique is used; they do this once for all people. For a better result of all production, prosumers do it just for themselves and create a surprising amount of waste. If we calculate the number of prosumers, the amount could be thousands of times more than that of factory WP (Jaafarnia et al., 2021).

We gauge this issue from the view of Emotional Design. While designing eyewear, if we consider the *touch form* issues — which consumers receive from the expression of form felt from the touch on his/her skin, such as fitness and comfort, along with the perception of the shape, we realize that it is an extremely important part and the entire experience of wearing eyeglasses should be one of *feel good* as opined by Formosa (Formosa, 2007). When we see *User Experience* we realize that prosumers often try to customize eyewear by using different elements like that of tissue paper or tape to impact the form on temples as well as temple tips. This can be termed as the creation of *Desire Lines* that are also done by using the Trial-&-Error method (Jaafarnia et al., 2021).

Car tuning is also a kind of *Desire Line* that shows the method of Trial-&-Error (Figure 7). Nowadays young prosumers are interested in car tuning and they modify the appearance weekly. Since manufacturers design the car for meeting average consumers' desires, tuning has become a popular method to personalize the characteristics of a car based on the consumer's erratic wishes.

Figure 7: a. *A classic example of a 'Desire Line' that cuts through a paved bend in a park and* ***b.*** *Car tuning (Photo by Karinoa Oshima, T. AREA., 2015).*

One knows that the issues of cognition, emotions, and experiences are significantly vital. It can be argued that human reflexes are emotion-oriented (Formosa, 2007), and also perception differs from the design printed just a day before. As it is evident, aesthetic valuation differs every day in minds of the prosumers. Demirbilek and Sener highlight how thoughts can be susceptible to change and the response/reaction to a meaning as reflected by a fixed design could vary depending on everyday changeable desires (Demirbilek & Sener, 2003). To this, Piaget stated that people learn through their experiences and culture, which starts in early childhood and is an ongoing process (Piaget, 1990). Printed products may incite user's emotion in variations so that prosumer react differently to the fixed design of printed forms. Hence desires of prosumers are developing. Therefore, using the method of Trial-&-Error by prosumers is obvious as we cannot request prosumers to stick on just one printed design and stop frequently printing and developing designs.

Have you ever walked on a paved line crossing a park diagonally? *Desire Lines* are the paths people (prosumers) choose to take instead of a path that designers dictate them to take. The path was clearly not designed by the designer, but it is clearly a product of a User Experience. It doesn't matter how beautiful designers have designed the path of the park and determined efficient ways to get from one place to another. It has applications beyond the design of walkways and can be applied broadly to any prosumer's customization on a product, which conveys valuable information and clarifies consumer's erratic desires and behaviors. A *Desire Line* is a way that consumers use that indicates preferred methods of interaction with an object or environment (Myhill, 2004).

It shows that the fixed printed design that seeks to accommodate prosumer's desires cannot lead to all solutions for a long time and try to modify the design again. The frequency of products tuning and printing by prosumers indicates the importance of having consideration on 3D printer and its WP.

3. *New Mind Development Exploration*

This perspective has provided a wide-band understanding of many parameters of personalization, where this exploration can estimate them. For convenience, one can find the nomenclature of the symbols and shortened terms used here in the equations.

This contribution in exploration of reprint decision-making confirms that many parameters of personalization — including the ability to cope with reality, relation to time, expansiveness, risk shift, knowledge, ego, creativity, anxiety level, and authoritarian attitude; each corresponding to different variables of personality— are effective in New Mind Development (NMD) for the prosumer's decision-making process regarding the initiation of a next print. Bezerra et al. (1996) state that these parameters refer to the particularities of the individual.

Table 1: *Symbols and abbreviations used in this research.*

Symbols	Terms and Nomenclature
NMD	*New Mind Development*
F(S)	*The total number of prints occurannually*
S	*Solution*
F	*Number of prints per year*
(f)	*The density of prints per year as a function to have "f" to the prosumer of committing to initiate print*
C(S)	*Is the cost per print of imposing an expected solution*
D	*The damage per print (Damage to victim)*
MC	*Cost of deterring for next initiating print*
$\hat{S}$	*Expected solution which minimizes the social cost function*

We have discussed the relation of frequent reprinting with satisfaction, as prosumers act on the basis of ever-changing states of mind when making the decision to create a new set of prints. This exploration builds a representation of the essential characteristics of prosumer behavior in the decision-making process regarding reprinting.

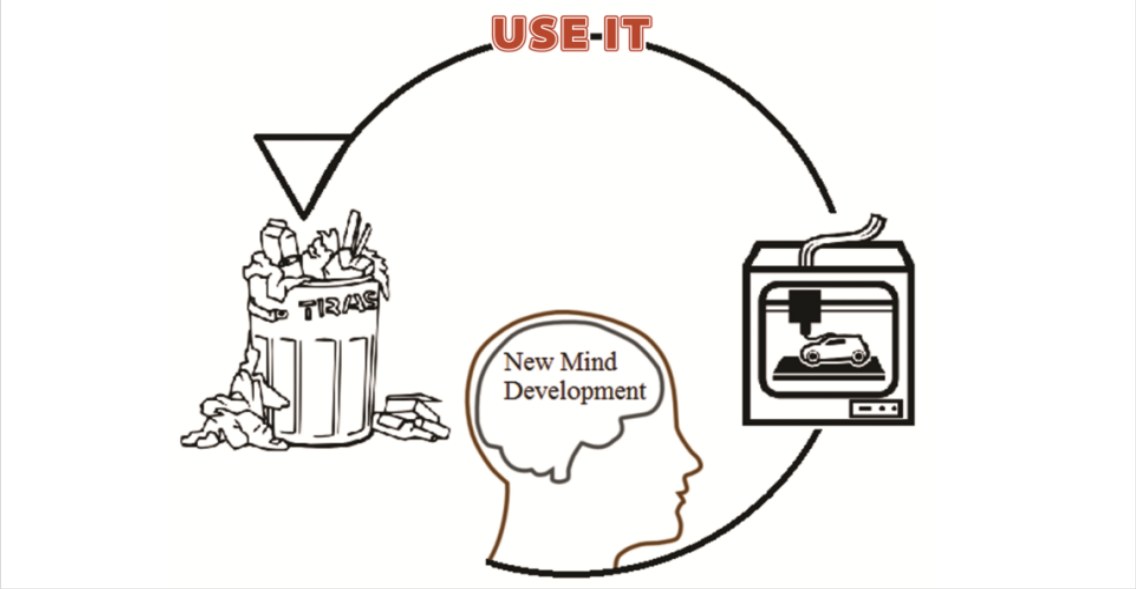

Figure 8: *Decision-making process cycle diagram.*

Passing time helps prosumer to grow level of mind development that leads them to have an NMD which has a significant influence on judgment, leading to the decision of initiating the next print. Always mind development has continued growing progress. It is depending on the mental capability of prosumers how fast they cope with reality, expansiveness, knowledge, ego, risk shift, creativity, anxiety level, and authoritarian attitude the time may increase or decrease. Therefore finding NMD in some prosumers could be shorter or longer. Also depending on the technology and speed of the 3D printer, the speed could be effective on NMD.

We use probability density functions. When the domain is continuous, the definition of probability is specified in terms of probability density functions, which provides a way to measure sets of different possibilities and worlds, defined in terms of an integral probability density function. Here we want to use a model by Friedman (2001) that is offered in the book *Law's Order: An Economic Account* to explore what will happen on environment and ecology if a society increases or decreases the level of solutions against the prosumer's print — regarding sustainable waste management—.

Hence we introduce a simple model for explaining prints of prosumers in a sample society. In this society, we need an expected solution (S) relative to the prosumer's manner for the next initiating print.

The distribution of the prosumer with *f* prints per year is ρ(f). Here, *f* is equal to NMD. The number of prints can be computed by an integral;

$$F(S) = \int_S^{\infty} \rho(f)df$$

We suppose the number of prints *f* can be taken as a continuous parameter which makes sense as the upper limit of the integral; it is a very large number i.e. infinity. The number of prints per year that prosumers have is more than *S*. Since a print will be made only if the initiating is at least as great as the expected solution relative to the prosumer, F(S) is the number of prints that occur annually if the expected solution relative to the prosumer is *S*. C(S) is the cost per print of imposing an expected solution S, using the least costly combination of actual solution and probability. We assume that this does not depend on the number of prints. The damage done per print is *D*. For simplicity, this is assumed to be independent of the number of prints.

We wish to find $\hat{S}$, the expected solution relative to the prosumer which minimizes the social cost function:

$$SC(S) = F(S)[D + C(S)] \text{ \& endash : } \int_S^{\infty} f\rho(f)df$$
$$= \int_S^{\infty} \rho(f)df\,[(D) + C(S)] - \int_S^{\infty} f\rho(f)df$$

The first term on the right hand side is the cost of print, the number of prints multiplied by damage per print plus enforcement of solution cost per print. The second term is the benefit of prints to the prosumers. The integral starts at f = S, because only prints for which benefit is at least equal to expected solution relative to the prosumer will be committed. Setting the derivative of SC(S) with regard to S equal to 0, we have, for S equal to its optimum value;

$$0 = -D\rho(\hat{S}) + d[F(\hat{S})C(\hat{S})]/dS + \hat{S}\rho(\hat{S})$$
$$0 = \rho(\hat{S})[\hat{S} - D] + d[F(\hat{S})C(\hat{S})]/dS$$
$$\frac{1}{\rho(\hat{S})}.d[F(\hat{S})C(\hat{S})]/dS = D - \hat{S}$$

Therefore, for the optimal solution relative to the prosumer's next print:
Net damage = Cost of deterring for next initiating print = Damage to victim - Expected solution relative to the prosumer's next print

Which is: MC = D-S

$$MC = 1/\rho(\hat{S}).d[F(\hat{S})C(\hat{S})]/dS$$

F(S)C(S) is the total cost of imposing an expected solution relative to the prosumer's print of S on F(S) prints. Deterring for next initiating print requires an increase in S of 1/ρ(S).

Then; if $1/\rho(S).d[F(S)C(S)]/dS > 0$, at $S = \hat{S}$, then total enforcement cost increases with increasing solution relative to the prosumer's print, and as can be seen from the equation, the optimal solution relative to the prosumer's print is less than the damage of the prosumer's print (D>S); therefore probably society is facing a great deal of waste, since the solution would be left far behind, and F(S) increases too gradually then we cannot follow the optimal solution relative to the prosumer's print as the number of prints increases faster than we can respond with regulation.

If $1/\rho(S).d[F(S)C(S)]/dS < 0$, at $S = \hat{S}$, then total enforcement cost decreases with increasing solution relative to the prosumer's print, but since the optimal solution relative to the prosumer's print is more than the damage (D<S), the prosumers might display convergent behavior to create more prints; if they believe society has solved the issue of printing waste, for instance, prosumers think society can do recycling of all 3D printed waste. Then they might once again make the private decision of initiating further prints.

Then, whether $1/\rho(S).\,d[F(S)C(S)]/dS < or > 0$, at $S = \hat{S}$, society cannot expect to overcome the tendency to frequent printing, and it, therefore, faces a great deal of waste. The result comes out from here that regarding erratic desires of prosumers this exploration is showing the waste depends purely on to the user which would determine the life span of the product.

Discussion and Recommendation

Quite interestingly these days 3D printer has entered household usage. Research concentration has presented household 3D printer WP above. It is no longer possible to print at home fabrication level to create WP and hence they resort to 3D prints ill-practices that are being followed at a much wiser step.

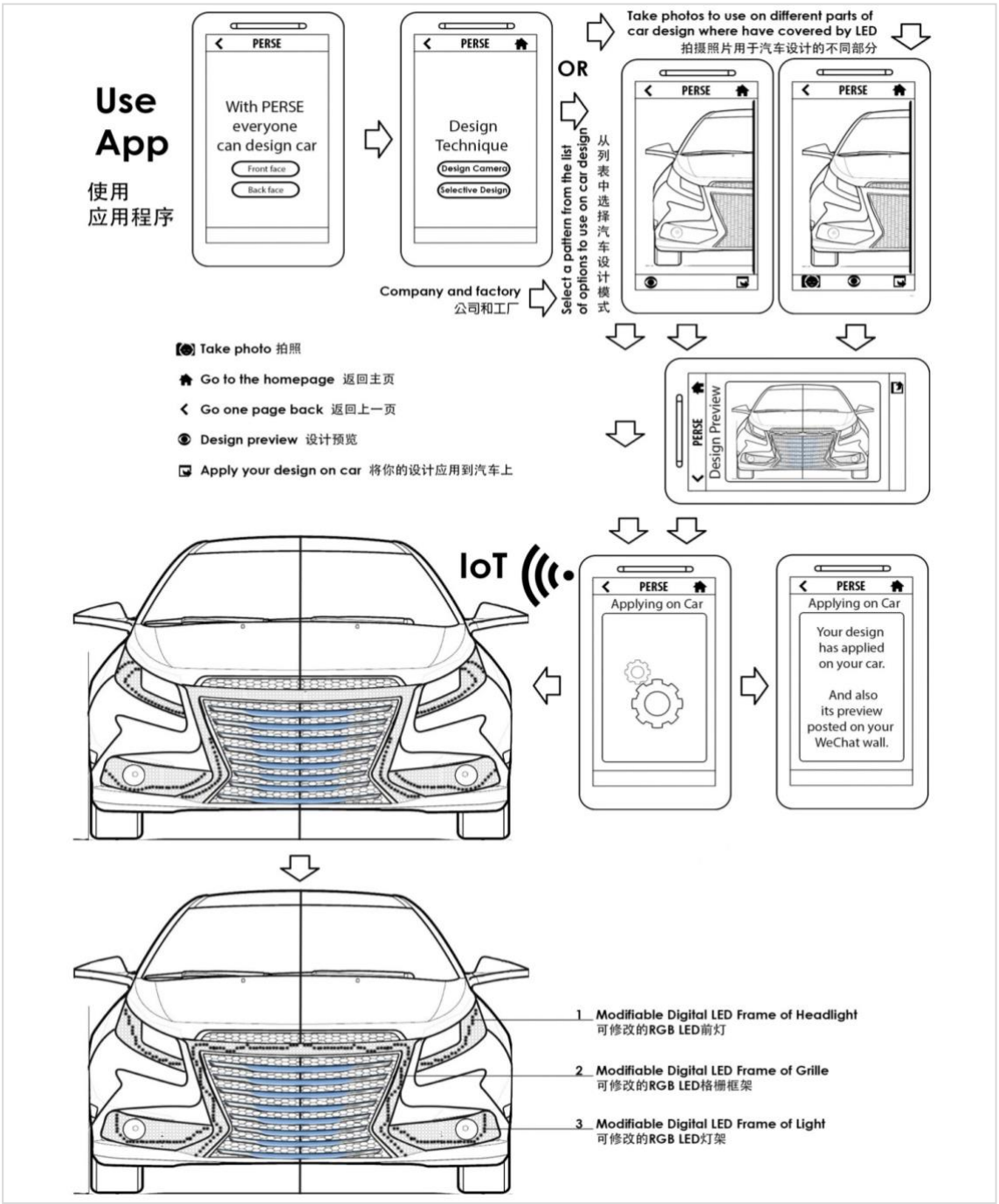

Figure 9: *Prosumers can change the design of his car by himself everyday through his phone App (Jaafarnia, 2016; 2021).*

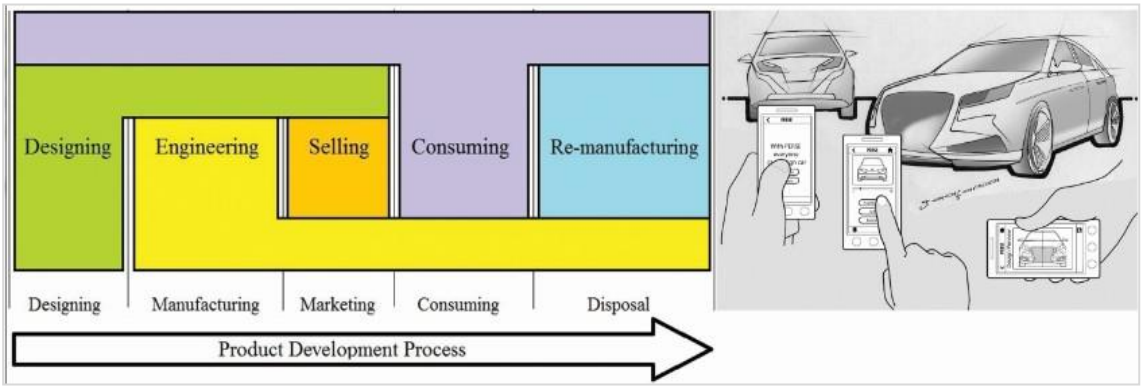

Figure 10: *Product development process for re-manufacturing by prosumers.*

This could compel people to think about the ideological recruitment of prosumers into productive co-design relationships. Participatory design hinges on solving the issue of 3D printer waste and enterprises think about other products that transfer added value activities towards the area of changeable product design form for prosumers which is actually re-manufacturing the product at disposal level by prosumers (Figure 10). This sends the product back to the level of recurrent consumption; and 'watching' their interaction with prosumer affects the longevity since they will take care of their product more and more, and this would easily affect the longevity of the product leading to zero waste.

To set up a direction for the future, the competitive base must be understood in the context of consumers. Therefore, the key to future development truly can be found in understanding the consumer experience and innovating meaningful ways of transforming it. A positive experience depends on the degree to which consumer can control their interactions and get feedback that they want (Prahalad & Sawhney, 2011). In case of customization to improve customer satisfaction and surpass customer expectation in car, unfixed (changeable) form can be controlled by the consumer via APP of the phone to create wide varieties of designs, instead of solid metallic body like steel with fixed color. As we see designers design cars but consumers try to change the design with car tuning, they try to customize the design since the manufacturer cannot do that because of the nature of consumers' desires which is fuzziness.

Conclusion

Household 3D printing is a fast-growing technology that will play a significant role in the critical environment sector. It is hard to imagine that this device can replace home printers in the next few years. However, the tremendous market potential, along with the economic, geopolitical, and other implications of 3D printers, will inevitably draw the attention of a number of issues. This research has been concentrated on this issue and talks about product longevity, waste, disposal and pollution of 3D printed products to explain illogical issues. In this way, disadvantages and mathematical explanations establish the hypothesis that *it is not possible to obtain WP requirements in the future by sending 3D printers to every house without having a proper solution is true*.

Based on the above mentioned results, since the desires of consumers are not fixed, 3D printing home fabrication always faces a risk of mass pollution created by prosumers. Product design cannot be upgraded to a new level of desire to keep up with rapidly changing design and cannot save materials and satisfy the requirements of the environment makes issue for sustainable waste management. Watch out: printed products that are not designed to be upgraded without being designed to be durable, break the logic of sustainability. But this paper shows a way to guarantee the sustainable waste management, where manufacturers must use new technologies to leave a part of the design task as part of consumers' duty. A positive experience depends on the degree to which consumer can control their interactions and get feedback that they want; this is critical to improve the effectiveness of a designed product for different users.

These points show the importance of improving the effectiveness of a designed product for non-fixed individual desires. The benefit of this outcome is that when companies do not need to think about the final form and design as the final design is decided by consumers of the product. Then using demassification helps to cover everyone in post-modern society for better sustainable waste management.

We conclude all together that, if the solution against the prosumer's print comes late, mass pollution created by the prosumer will not flourish by any other solution. On the other hand, there are still a lot of unknown anxieties that need to be considered.

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