



# Challenges and Benefits of Using TPU Material For 3D Printing Fashion Clothes- An Empirical Study

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Received: 📅 February 27, 2023

Published: 📅 April 05, 2023

## Abstract

The present research has been focused on identifying and understanding the challenges and benefits of using TPU material for 3D printing fashion clothes. It has been observed in the past that a difference in perception exists between gender in different spheres of life. Thus, the present study has researched to understand if there is any difference in the perception of males and females on the challenges and benefits of using TPU material for 3D printing fashion clothes. No study was found to be addressing this issue in the existing literature. Thus, the present research will bridge this gap in the existing literature. Quantitative analysis has been conducted based on the data collected using a close-ended questionnaire. Both descriptive and inferential analysis has been conducted. The identified challenges and benefits of using TPU material for 3D printing fashion clothes can be used by the manufacturers and designers of the industry. This will then facilitate the expansion of this futuristic technology in the fashion industry.

**Keywords:** TPU Fabric; 3D printing; additive manufacturing

## Introduction

### 3D Printing in Fashion Industry

The textile and fashion industry are known to generate a huge amount of waste and consume a lot of resources like energy and water. Some of the harmful effects of textiles on the environment are-

- Textiles emit harmful greenhouse gas called methane during their decomposition.
- Textiles take more than 200 years to decompose in landfills [1].
- It takes around 2,700 liters of water for manufacturing a single cotton T-shirt [2].
- Around 15-30% of the fabric material is wasted in tailoring or the garment.

Thus, it is imperative to move to a sustainable alternative. 3D printing on sustainable material like TPU can be one such alternative of cotton-based textiles. 3D printing (3DP), also called additive manufacturing, is a computerized additive manufacturing (AM) procedure that physiquis a creation by putting material into continual uninterrupted sheets or layers till the time it is not completed [3]. The usage of 3D printing is growing in many industries, the fashion industry is one of them. There are several advantages that 3D printing offers over traditional manufacturing processes like faster design procedure, reduced production time, and lesser costs associated with storage and warehousing, portfolio, inventory, packing, and conveyance.

In the fashion industry, 3D printing is used to create patterns, works of haute couture, and custom-designed garments and textiles that offer customers an interactive communicating choice-

driven experience. Many companies like Nike, New Balance, Adidas, and Reebok already use 3D printing. Thus, the use of TPU material for 3D printing is emerging as an obvious choice for textiles and garments. But before moving on to the proper full-time utilization of TPU material for 3D printing, it is important to identify and understand the challenges and benefits of using TPU material for 3D printing fashion clothes. The present research has been dedicated to identifying this issue. No study was found to be addressing this issue in the existing literature. Thus, the present research will bridge this gap in the existing literature. Further, it has been observed in the past that a difference in perception exists between gender in different spheres of life [4-6]. Thus, the present study has researched to understand if there is any difference in the perception of males and females on the challenges and benefits of using TPU material for 3d printing fashion clothes.

## Material and Methods

The present research has been focused on petrochemical-based TPU material. Quantitative analysis has been conducted based on the data collected using a close-ended questionnaire. The questionnaire was administered to the managerial level employees of different textile companies associated with 3D printing on TPU material in Southeast Asia (ASEAN Countries), working in departments namely Fabric Testing Lab, Production Planning and Control, Quality Control department, and Printing department. A

quantitative questionnaire was e-mailed to the employees in form of Google forms. The e-mail ids of the employees were collected from the HR department of their associated companies. A total of 109 questionnaires were e-mailed out of which 87 filled questionnaires were received. Thus, the response rate of the study is 79.8%.

Analysis of the collected data will be done through the quantitative analysis software SPSS. Descriptive analysis has been conducted using cross-tabulation while data has been presented in charts and graphs. Further, inferential analysis has been conducted using an Independent sample t-test.

## Analysis and Results

### Demographic Profile

The demographic profile of the respondents has been presented in Table 1 below. It can be inferred from Table 1 above that number of male respondents in the research are much more than the female respondents. Maximum respondents of the research were found to lie in the age group of 40-45 years followed by 45-50 Years. Only one respondent was found to lie in the age group of 25-30 Years. The maximum respondents on the research were found to be associated with Fabric Testing Lab department. Finally, maximum respondents in the research were found to have spent tenure of 5-7 Years in industry followed by 7-10 Years of tenure. Only two respondents were found to have tenure of 6months-2 Years in the industry.

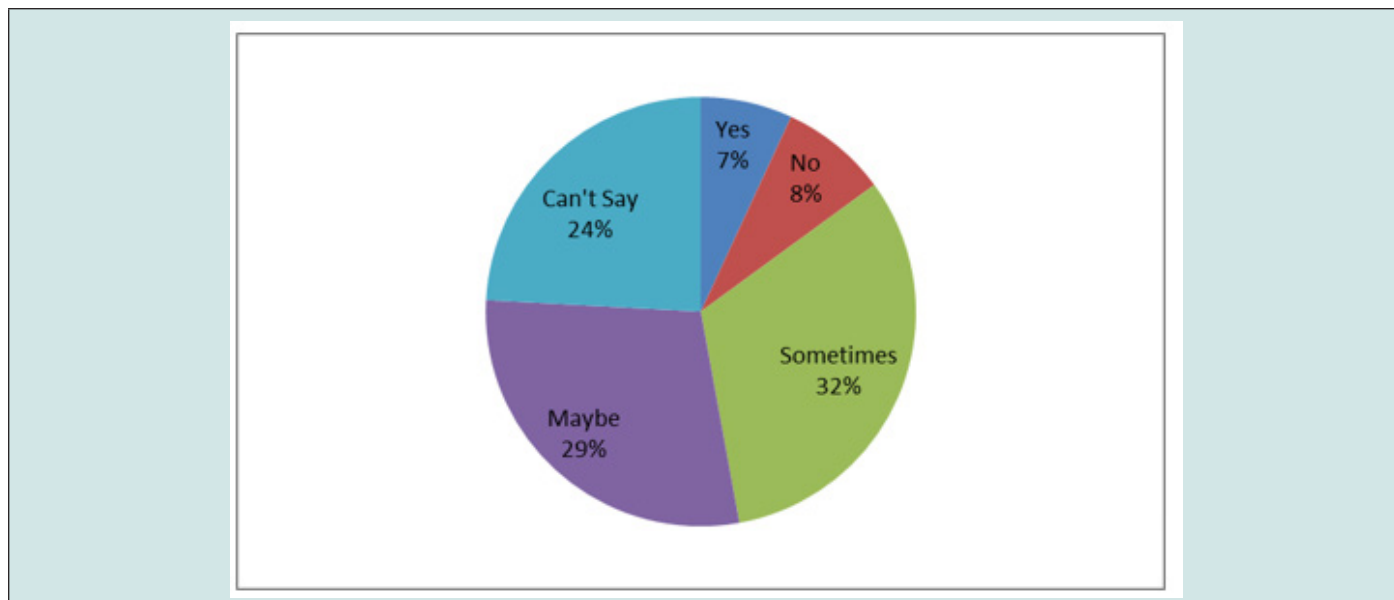
**Table 1:** Demographic profile of respondents.

Gender	Male	50	57.5
	Female	37	42.5
Age	25-30	1	1.1
	30-35	3	3.4
	35-40	7	8
	40-45	26	29.9
	45-50	21	24.1
	50-55	15	17.2
	55-60	9	10.3
	60 and Above	5	5.7
Department of Association	Fabric Testing Lab	26	29.9
	Production Planning and Control	18	20.7
	Quality Control department	21	24.1
	Printing department	22	25.3
Tenure	6months-2 Years	2	2.3
	2-5 Years	10	11.5
	5-7 Years	25	28.7
	7-10 Years	23	26.4
	10-13 Years	18	20.7
	13-15 Years	6	6.9
	15 or more Years	3	3.4

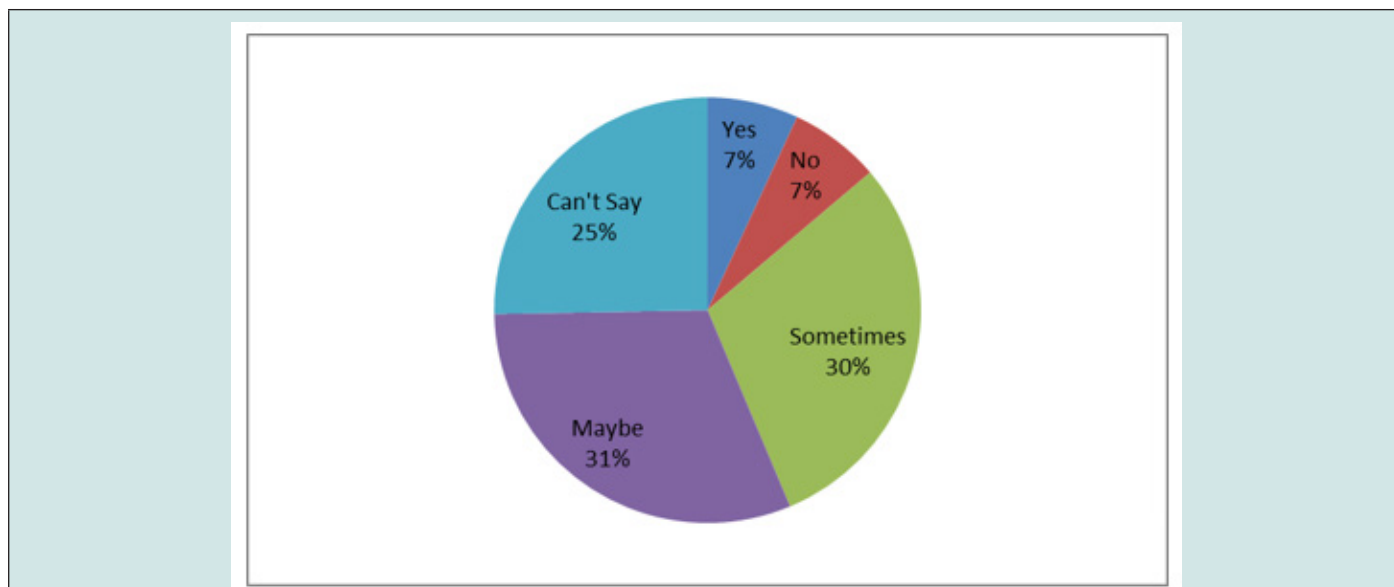
**General Background**

It can be inferred from Figure 1 above that maximum respondents (32%) only sometimes consider TPU material to be a good option for 3d printing for fashion clothes while only 7%

actually considered it to be a good option. It can be inferred from Figure 2 above that maximum respondents (30%) only sometimes consider TPU material to be a successful for 3d printing for fashion clothes while only 7% actually considered it to be a successful option run keeping into consideration the future of fashion industry.



**Figure 1:** Perception of Respondents on TPU Material Being A Good Option For 3D Printing For Fashion Clothes.



**Figure 2:** Perception of Respondents on if TPU material will be successful for 3D printed clothing keeping into consideration the future of Fashion Industry.

**Benefits of using TPU material for 3d printing fashion clothes**

To assess the benefits of using TPU material for 3d printing fashion clothes, cross-tabulation between the department of respondents and benefits has been conducted. The analysis found a maximum of respondents take 3D printed parts with TPU to be

durable and consider it to be the biggest benefit irrespective of their department of an association. Herein, the maximum respondents (42.3%) of Production Planning and Control are in favor of this benefit. Further, the maximum number of respondents take “Such material can withstand ambient temperatures of up to 80 degrees Celsius” not to be a benefit as a maximum of respondents disagreed

with it irrespective of their department of an association. Also, a maximum of respondents take "Available in a range of colors" to be a benefit as the maximum of respondents agree to it irrespective of their department of an association. Herein, the maximum number of respondents (42.9%) of the Quality Control department is in favor of this benefit. It was further found that a maximum of respondents take "Good vibration damping and shock absorption" not to be a benefit as maximum respondents disagreed with it irrespective of their department of an association.

The study inferred a maximum of respondents take "Chemical-resistant" to be a benefit as the maximum of respondents agree to it irrespective of their department of an association. Herein, the maximum number of respondents (47.6%) of the Quality Control department is in favor of this benefit. It was observed that a maximum of respondents take "Low warpage and shrinkage" to be

a benefit as the maximum of respondents agrees to it irrespective of their department of an association. Herein, the maximum number of respondents (45.5%) of the printing department is in favor of this benefit. It can be inferred from Table 2 (Supplementary Information) that a maximum of respondents take "Can be very stretchy depending on the elongation at break" not to be a benefit as maximum respondents disagreed with it irrespective of their department of an association. Further, maximum respondents take "Elastic and soft material" to be a benefit as maximum respondents agree to it irrespective of their department of an association. Herein, the maximum number of respondents (52.4%) of the Quality Control department is in favor of this benefit. It can be inferred from Table 4 (Supplementary Information) that a maximum of respondents take "Simulates rubber-like characteristics" not to be a benefit as maximum respondents disagreed with it irrespective of their department of an association.

**Table 2:** Group Statistics of Benefits for t-test.

Group Statistics					
Benefits	Gender	N	Mean	Std. Deviation	Std. Error Mean
	Male	50	2.78	0.284	0.04
	Female	37	2.85	0.367	0.06

Also, the study found that a maximum of respondents take "Good chemical and thermal stability" not to be a benefit as maximum respondents disagreed with it irrespective of their department of an association. It can be inferred from Table 4 (Supplementary Information) that a maximum of respondents takes "Excellent printability" to be a benefit as maximum respondents agree to it irrespective of their department of an association. Herein, the maximum number of respondents (42.3%) of the Fabric Testing Lab

department is in favor of this benefit. It can be inferred from Table 4 (Supplementary Information) that a maximum of respondents take "Semi-transparent" not to be a benefit as the maximum of respondents disagreed with it irrespective of their department of an association. Also, a maximum of respondents were found to take "Better chemical resistance to oils and greases" not to be a benefit as the maximum of respondents disagreed with it irrespective of their department of an association.

**Table 3:** Independent Sample t-test for Benefits.

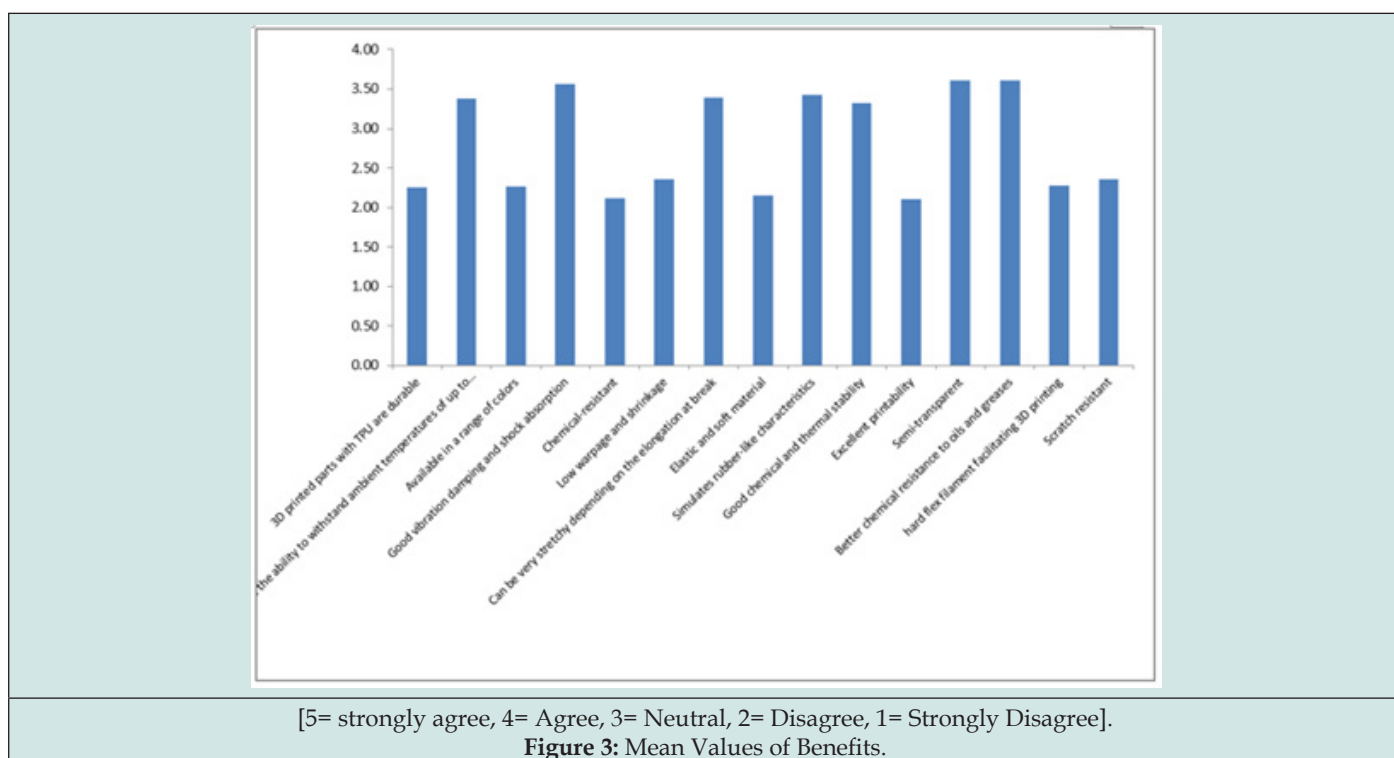
Independent Samples Test										
F		Levene's Test for Equality of Variances		t-test for Equality of Means						
		Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		
								Lower	Upper	
Benefits	Equal variances assumed	3.013	0.086	-0.971	85	0.334	-0.068	0.07	-0.207	0.071
	Equal variances not assumed			-0.935	65.536	0.353	-0.068	0.072	-0.213	0.077

**Table 4:** Group Statistics of Challenges for t-test.

Group Statistics					
Challenges	Department	N	Mean	Std. Deviation	Std. Error Mean
	Male	50	2.77	0.416	0.059
	Female	37	2.63	0.421	0.069

The study inferred that a maximum of respondents take “hard flex filament facilitating 3D printing” to be a benefit as maximum respondents agree to it irrespective of their department of an association. Herein, the maximum number of respondents (42.3%) of the Fabric Testing Lab department is in favor of this benefit. Finally, it was found that a maximum of respondents take “Scratch resistant” to be a benefit as a maximum of respondents agree to it irrespective of their department of an association. Herein, the maximum number of respondents (50%) of the Production Planning and Control department is in favor of this benefit. The graphical representation of the mean values of the benefits is depicted in Figure 3. “Better chemical resistance to oils and greases” was found

to be the biggest benefit (Mean=3.61). The major benefits identified are that 3D printed parts with TPU are ability to withstand ambient temperatures, good vibration damping and shock absorption, stretchy, rubber like characteristics, thermal and chemical stability, semi-transparent and resistance to oil and greases [7]. In research conducted by Vanderploeg, Lee, and Mamp, (2017), it was stated that TPU material has characteristics of being flexible, rubber like and soft which makes it idle to be a fabric for 3D printing which then facilitates giving a texture and look and feel of a dress [8]. Thus, the findings of this study are in sync with the findings of the present research thereby supporting the present research.



### Challenges of using TPU material for 3d printing fashion clothes

To assess the challenges of using TPU material for 3D printing fashion clothes, cross-tabulation between departments of respondents and challenges. It was inferred that a maximum of respondents take “While it is possible to print TPU using a desktop printer, the flexible filament is difficult to work with as it can easily disrupt layer thickness and jam or clog the print head” to be a challenge as the maximum respondents agree to it irrespective of their department of an association. Herein, the maximum number of respondents (45.4%) of the printing department is in favor of this challenge. The maximum number of respondents take “TPU 3D printed parts also take much longer than traditional non-flexible materials because the print speed must be reduced” to be a challenge as the maximum respondents agree to it irrespective of their department of an association. Herein, the maximum number

of respondents (45.5%) of the printing department is in favor of this challenge. Further, the maximum number of respondents take “Depending on the make and model of the extrusion printer, the shore hardness of the TPU filament can be limited” not to be a challenge as the maximum respondents disagreed with it irrespective of their department of an association. Also, it was found that a maximum of respondents take “If the temperature is too high, stringing can occur” not to be a challenge as the maximum respondents disagreed with it irrespective of their department of an association.

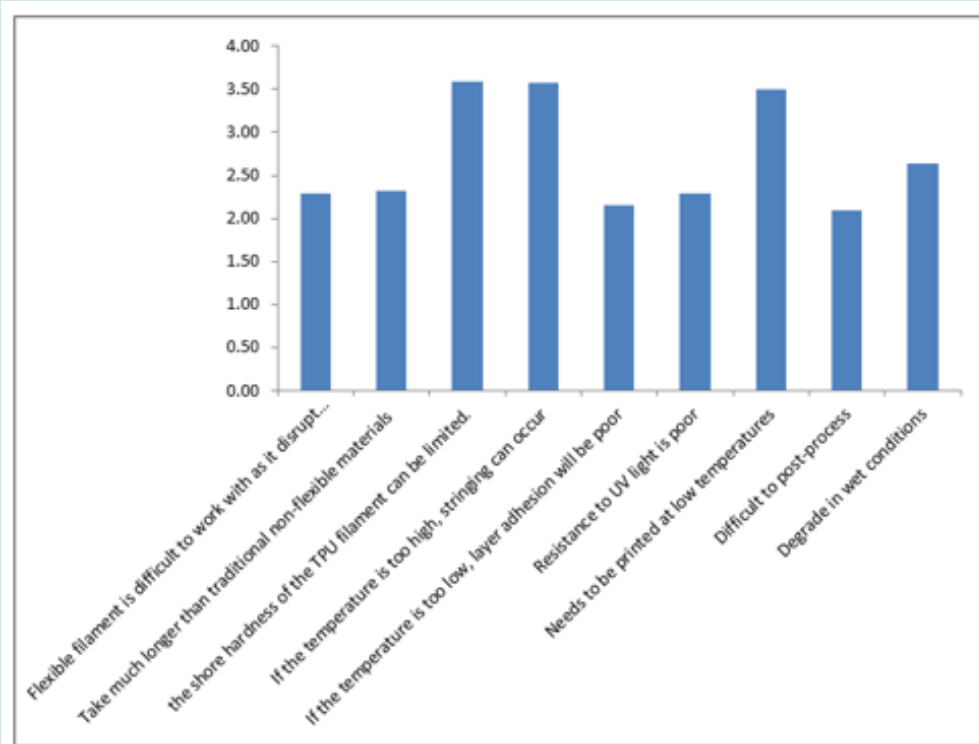
It was found that the maximum number of respondents take “If the temperature is too low, layer adhesion will be poor” to be a challenge as maximum respondents agree to it irrespective of their department of an association. Herein, the maximum number of respondents (42.9%) of the Quality Control department is in favor of this challenge. A maximum of respondents reported

“Resistance to UV light is poor” to be a challenge irrespective of their department of an association. Herein, the maximum number of respondents (44.4%) of the Production Planning and Control department is in favor of this challenge. Also, the maximum number of respondents take “Needs to be printed at low temperatures” not to be a challenge as the maximum number of respondents disagreed with it irrespective of their department of an association.

Further, maximum respondents take “Difficult to post-process” to be a challenge as maximum respondents agree to it irrespective of their department of an association. Herein, the maximum number of respondents (50%) of both the Production Planning and Control and Printing department are in favor of this challenge.

Finally, the maximum number of respondents take “Difficult to post-process” to be a challenge irrespective of their department of an association. Herein, the maximum number of respondents

(38.9%) belonging to the Fabric Testing Lab is in favor of this challenge. The graphical representation of the mean values of the challenges is depicted in Figure 4. “Shore hardness of the TPU filament can be limited.” was found to be the biggest challenge (Mean=3.59). The other major identified challenges are flexible filament is difficult to work with as it can easily disrupt layer thickness and jam or clog the print head, TPU 3D printed material takes longer than traditional non-flexible materials, poor layer adhesion in low temperatures, poor resistance to UV light, difficult to post-process, degrade in wet conditions. Research conducted by Zhu et al. [9] stated poor layer adhesion in low temperatures and poor resistance to UV light are challenges associated with TPU in using it in 3D printing for fashion fabrics [10]. Thus, the findings of this study are in sync with the findings of the present research thereby supporting the present research.



[5= strongly agree, 4= Agree, 3= Neutral, 2= Disagree, 1= Strongly Disagree].

Figure 4: Mean Values of Challenges.

### The difference in the Perception of Males and Females on Challenges And Benefits Of Using TPU Material For 3d Printing Fashion Clothes

#### The difference in perception of Benefits

An Independent sample t-test has been conducted here to assess if the difference in the perception of males and females on the benefits of using TPU material for 3d printing fashion clothes exists or not.

a. H01: There is no significant difference in the perception of males and females on the benefits of using TPU material for 3d

printing fashion clothes.

b. HA1: There is a significant difference in the perception of males and females on the benefits of using TPU material for 3d printing fashion clothes.

It can be inferred from Table 2 above that the mean values for the Male group (2.78) are more than that of the Female group (2.85). Thus, not much difference can be observed between the two groups. There has been tested using an independent t-test in the Table 3 below. Levene's Test for Equality of Variances has been conducted in Table 3 above for which the significance value is not

significant ( $0.086 > 0.05$ ). Thus, there is no significant difference in the variances (Standard Deviation). It can be inferred from the table that the significance value for the independent sample t-test is  $0.334 (> 0.05)$ . Thus null hypothesis can be accepted and it can

be stated that there is no significant difference in the means of the two groups (males and females). Hence, the present study found no significant difference in the perception of males and females on the benefits of using TPU material for 3d printing fashion clothes.

**Table 5:** Independent Sample t-test for Challenges.

Independent Samples Test										
F		Levene's Test for Equality of Variances		t-test for Equality of Means						
		Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		
								Lower	Upper	
Challenges	Equal variances assumed	0.133	0.716	1.539	85	0.127	0.14	0.091	-0.041	0.32
	Equal variances not assumed			1.537	77.2	0.128	0.14	0.091	-0.041	0.321

### The difference in perception of Challenges

An Independent sample t-test has been conducted here to assess if the difference in the perception of males and females on the Challenges of using TPU material for 3d printing fashion clothes exists or not.

- H01: There is no significant difference in the perception of males and females on challenges of using TPU material for 3d printing fashion clothes.
- HA1: There is a significant difference in the perception of males and females on challenges of using TPU material for 3d printing fashion clothes.

It can be inferred from Table 4 above that the mean values for the Male group (2.77) are more than that of the Female group (2.63). Thus, not much difference can be observed between the two groups. There has been tested using an independent t-test in Table 5 below. Levene's Test for Equality of Variances has been conducted in the table above for which the significance value is not significant ( $0.716 > 0.05$ ). Thus, there is no significant difference in the variances (Standard Deviation). It can be inferred from the table that the significance value for the independent sample t-test is  $0.127 (> 0.05)$ . Thus null hypothesis can be accepted and it can be stated that there is no significant difference in the means of the two groups (males and females). Hence, the present study found no significant difference in the perception of males and females on challenges of using TPU material for 3d printing fashion clothes

### Conclusion

The present research has been focused on identifying and understanding the challenges and benefits of using TPU material

for 3D printing fashion clothes along with assessing if there is any difference in the perception of males and females on the challenges and benefits of using TPU material for 3D printing fashion clothes. The major benefits identified are that 3D printed parts with TPU are durable, available in a range of colors, are chemical-resistant, have low warpage and shrinkage, are elastic and soft material, have excellent printability, are hard flex filament facilitating 3D printing, and are scratch resistant. The major identified challenges are flexible filament is difficult to work with as it can easily disrupt layer thickness and jam or clog the print head, TPU 3D printed material takes longer than traditional non-flexible materials, poor layer adhesion in low temperatures, poor resistance to UV light, difficult to post-process, degrade in wet conditions. Further, the study found no significant difference in the perception of males and females on the benefits and challenges of using TPU material for 3d printing fashion clothes. The present research has one limitation. This study has been focused on only ASEAN countries thereby presenting the perception of ASEAN countries and not at the global level. Future research can be conducted to understand and highlight the perception of customers on TPU-based 3D printed textiles and clothes.

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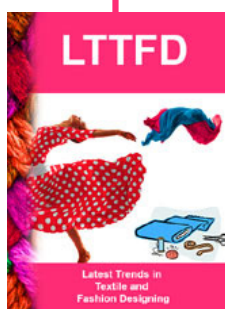
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DOI: [10.32474/LTTFD.2023.05.000218](https://doi.org/10.32474/LTTFD.2023.05.000218)



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