"Evaluating Additive Manufacturing Options through TOPSIS Method: A Comprehensive Decision-Making Approach"

Abstract: *In the current competitive landscape, various industries are actively seeking intelligent technologies to maintain competitiveness. These technologies assist research and development teams in clearly expressing ideas and swiftly introducing products to the market while minimizing production timelines and costs. Every additive manufacturing (AM) machine possesses distinct strengths in product fabrication, material utilization, and waste reduction. Key factors such as the costs of machinery and materials hold significant importance and greatly influence the assessment of prototype expenses. The primary considerations in additive manufacturing (AM) are the expenses associated with both machinery and materials. These factors, owing to their distinctive attributes, offer opportunities for cost reduction. Nevertheless, an alternative approach focuses on optimizing the manufacturing process and refining material usage, aiming to effectively lower the overall expenditure related to prototype production.*

Research Significance: *The research article utilized a multi-criteria decision-making method, TOPSIS, to choose the right material for the product, considering both end user preferences and additive manufacturing (AM). The initial step involves selecting the optimal machine from the available options, considering factors such as cost, precision, material range, and waste. Next, the suitable material is chosen based on respondent's needs. Finally, the key criteria impacting overall additive manufacturing (AM) cost are identified and utilized.*

Methodology: *TOPSIS helps decision makers select criteria based on respondent expectations. It employs pairwise comparisons using decision maker rankings to choose the right option. A thorough demonstration is presented, fully aligned with respondent needs. The methodology's output can be adjusted based on respondent requirements and machine availability.*

Alternative parameters: *Vero Black ,Vero White, Tango Black, DurusWhite, TangoPlu, TangoBlackPlus and Vero Clear.*

Evaluation parameters: *Mixing number, Number of digital materials, Cost, Elongation at break, Tensile strength, Shore hardness, Frequent order and Visual and aesthetic modeling.*

Result: *Materials were ranked with Vero White as the top choice and DurusWhite as the lowest. TangoBlackPlus ranked second, followed by Vero Clear in third, TangoPlu in fourth, Vero Black in fifth, and Tango Black in sixth. The final outcome assists in selecting suitable equipment and building materials for the prototype, based on respondent criteria..*

Keywords: *Additive manufacturing, TOPSIS Method, VeroWhite, Number of digital materials and Frequent order.*

1. INTRODUCTION

Rapid prototyping, originating in the 1980s, involves creating 3D objects layer by layer using computer-aided design (CAD). The key benefit of Additive fabrication (AM) is its capability to construct virtually any shape through layer-by-layer fabrication. The STL (STereoLithography or Standard Tessellation Language) file format was introduced by 3D Systems in 1987 and rapidly became a standard in additive manufacturing. It's advantageous as it can be easily generated by all CAD applications.[1] Additive manufacturing (AM) prioritizes sustainability in concept selection, given concerns about pollution and resource scarcity. Sustainability is gaining importance in industrial sectors, allowing the manufacturing industry to achieve economic and social growth without harming the environment. The fourth industrial revolution (Industry 4.0) introduces AM as a smart manufacturing technology. AM is a category of manufacturing technologies that, in contrast to traditional methods, build three-dimensional components by layering materials, contributing to a more sustainable approach. Additive manufacturing is an emerging technique employed by diverse industries, with the potential to reduce environmental impact by minimizing waste and optimizing resource usage [2]. This relatively new manufacturing process enables the creation of intricate shapes rapidly and cost-effectively. Designers, upon realizing this potential, have adopted Design for Additive Manufacturing (DfAM) guidelines. These guidelines facilitate an integrated design approach, empowering product development teams to diminish or eliminate traditional machining constraints. This includes strategies like modular design, standard component utilization, the avoidance of separate fasteners, and minimizing assembly instructions, all aimed at achieving manufacturing parity. [3][4] Various additive manufacturing technologies, including Fused Deposition Modelling (FDM), Selective Laser Sintering (SLS), and Stereolithography (SLA), are available. Additive manufacturing (AM) involves creating parts layer by layer, also known as layered manufacturing. AM is capable of constructing intricate structures more efficiently, with improved material properties. Multi-criterion decision-making (MCDM) problems, alternatively referred to as multi-attribute decision-making problems, pertain to situations where preference decisions are made by evaluating and ranking a limited set of alternatives based on multiple criteria. There are numerous MCDM difficulties in design for conventional manufacturing. This is also true in additive manufacturing (AM) design [7]. AM involves producing less waste during the manufacturing process, as well as the capacity to optimize geometries and manufacture light weight components that reduce material consumption. Furthermore, AM allows for the optimization of process parameters. AM has grown tremendously in popularity in recent years and is now commonly used. It has been motivated by unique properties such as coping with complex geometry, integrated assembly, and providing solutions to challenges encountered in traditional methods. It has certain downsides like as material costs, material availability, high prototype costs, and in some circumstances, real-time functional testing is problematic.[11] Additive Manufacturing (AM) methods have extensive applications in a wide range of industries . Micro fabrication has recently emerged as a viable use. A systematic approach to ranking candidate processes is required in order to identify an appropriate process for Micro fabrication. Many parameters can influence the selection of alternatives during the micro fabrication process. As a result, an approach that takes into consideration all factors is required [12] Nowadays, Additive Manufacturing (AM) is a popular manufacturing technique that introduces a novel approach to making several versions of complicated items with a material range. The key benefits of additive manufacturing include generating complex forms without any additional cost, procedures, or tooling; and decreasing product development cycles, as well as rising demand for customized and personalized items.13] Additive manufacturing, also known as 3D printing, is a new manufacturing technology that involves layering products from digital design files. In contrast to traditional subtractive manufacturing methods, which entail removing material from a solid block, additive manufacturing involves building up material to make the finished thing. In additive manufacturing, a variety of materials such as plastics, metals, ceramics, and even food can be used as "ink" [14]. The process starts with creating a digital 3D model using computer-aided design (CAD) software. This digital model is then divided into thin horizontal layers using slicing software. The physical object is built by the 3D printer, which reads these sliced layers and deposits material one layer at a time. This layer-by-layer approach offers several advantages, including increased design flexibility, reduced waste, and the ability to produce intricate geometries that would be challenging or impossible to achieve through standard manufacturing methods. Aerospace, automotive, healthcare, fashion, architecture, and consumer products have all found applications for additive manufacturing. It's utilized to make prototypes, finished goods, customized things, and even replacement parts. The technology is always evolving, providing new materials, higher precision, and faster production speeds, transforming it into a transformational force in modern manufacturing.[15]

2. MATERIALS AND METHODS

Alternative parameters: VeroBlack ,VeroWhite, TangoBlack, DurusWhite, TangoPlu, TangoBlackPlus and VeroClear.

VeroBlack: This photopolymer resin is a frequent choice for additive manufacturing techniques like stereolithography (SLA) and digital light processing (DLP) 3D printing. Its distinctive feature lies in its intense black hue and its ability to yield refined surface finishes. This characteristic positions it as an apt selection for fabricating models, prototypes, and functional components characterized by intricate details and a polished, professional aesthetic. Key characteristics of Vero Black resin include its high level of detail reproduction, excellent dimensional stability, and good mechanical properties. It is often chosen for applications where aesthetics and visual appeal are important, such as consumer products, jewelry, automotive components, and architectural models.

VeroWhite: This particular photopolymer resin is harnessed within additive manufacturing, specifically finding application in technologies like stereolithography (SLA) and digital light processing (DLP) 3D printing. Renowned for its pristine white hue, it excels in generating refined, polished surfaces. This attribute renders it ideal for crafting intricate models, prototypes, and functional components, all of which demand intricate detailing and a polished, professional appearance. One of the key characteristics of VeroWhite resin is its capacity to accurately reproduce intricate details, ensuring that the printed objects closely resemble the intended design. This is particularly advantageous for applications where aesthetics and visual fidelity are important, such as architectural models, consumer products, and medical prototypes. When working with VeroWhite resin, factors such as layer thickness, post-processing techniques, and the intended application should be taken into account to achieve the desired outcomes. Additionally, as with any material, the properties of Vero White resin can vary based on the specific 3D printer and settings used for printing.

TangoBlack : It refers to a specific type of rubber-like material used in additive manufacturing processes, particularly in technologies like PolyJet 3D printing. This material is characterized by its black color and its ability to replicate the look and feel of rubber, making it suitable for creating flexible and elastomeric parts, prototypes, and products with a range of applications. One of the prominent features of TangoBlack is its flexibility and rubbery texture, which allows for the production of objects with realistic tactile properties. This material is often chosen for applications where parts need to mimic the characteristics of rubber or other flexible materials, such as gaskets, seals, grips, and wearable products.

DurusWhite: It is a type of material commonly used in additive manufacturing processes, particularly in technologies like PolyJet 3D printing. This material is characterized by its durability and strength, making it suitable for creating robust and rigid parts, prototypes, and products across various industries.One of the standout features of DurusWhite is its high durability, which allows for the production of objects that can withstand mechanical stress and impact. This material is often chosen for applications where structural integrity and strength are important, such as functional prototypes, tooling, and components for engineering and manufacturing. When working with DurusWhite material, considerations such as layer thickness, print orientation, and post-processing methods are crucial to achieve the desired mechanical properties in the printed parts. As with any 3D printing material, the specific characteristics of DurusWhite can vary depending on the printer and settings used.

TangoPlu, TangoBlackPlus : TangoGray, TangoBlack, TangoPlus, and TangoBlackPlus are PolyJet rubber-like polymers. They provide varying degrees of elastomer characteristics: Shoreline scale VeroClear possesses the necessary characteristics of hardness, elongation at break, tear resistance, and tensile strength to cater to applications demanding non-slip or soft surfaces. These applications span various domains such as consumer electronics, medical devices, and automotive interiors. It finds ideal use in rubber surrounds over molding, soft-touch coatings, and non-slip surfaces. Moreover, it's well-suited for crafting exhibition and communication models, knobs, grips, handles, gaskets, seals, hoses, and footwear.

Vero Clear: It is a specific kind of photopolymer resin employed in additive manufacturing techniques, notably in technologies such as stereolithography (SLA) and digital light processing (DLP) 3D printing. This resin is known for its transparent and clear appearance, making it suitable for creating parts and prototypes that require optical clarity and visual transparency. Vero Clear resin's capacity to make parts with a smooth and glass-like surface is one of its primary qualities, enabling for the creation of transparent or translucent things with excellent accuracy and detail. This material is often chosen for applications in industries such as optics, design visualization, and consumer products where clear or see-through components are essential.

Evaluation parameters: Mixing number, Number of digital materials, Cost, Elongation at break, Tensile strength, Shore hardness, Frequent order and Visual and aesthetic modeling.

Mixing number: In additive manufacturing denotes the practice of blending multiple materials or substances during the 3D printing procedure. This involves creating customized blends of materials to achieve specific properties, colors, or functionalities in the final printed object. Mixing numbers can determine the ratios of different materials used, affecting the characteristics of the printed product. This technique allows for the creation of multi-material objects with varying textures, colors, and mechanical properties, expanding the possibilities for creating complex and versatile 3D printed items.

Number of digital materials: In additive manufacturing refers to how many different types of materials can be used in a 3D printing process. With advancements in technology, modern 3D printers can work with multiple materials simultaneously. This means that a single 3D print can use different materials to create objects with various colors, textures, and properties. Having a higher number of digital materials available allows for more creativity and customization in creating 3D printed items. It's like having a painter's palette with many colors to choose from, but in this case, it's a 3D printer creating objects with different materials.

Cost: Cost in additive manufacturing refers to how much it costs to create objects using 3D printing technology. This cost includes various factors, such as the materials used, the time taken to print, energy consumption, maintenance of the 3D printer, and any additional post-processing steps. The cost can vary based on the complexity and size of the object, the type of 3D printer, and the specific materials chosen. Additive manufacturing offers the advantage of creating intricate and customized objects, but it's important to consider the cost factors to make informed decisions about using this technology for different projects.

Elongation at break: It is an indicator of a material's ductility and pliability. Usually presented as a percentage, it reflects the extent to which a material can stretch or deform under stress until it ultimately fractures. This measurement provides insight into the material's ability to endure elongation before breaking occurs. Elongation at break is a crucial mechanical property to consider when designing and selecting materials for specific applications, as it indicates how well a material can endure strain and deformation without breaking.

Tensile strength : It refers to the highest level of stress a material can endure under pulling or stretching forces before reaching a point of fracture. This crucial mechanical property aids in gauging a material's resilience when subjected to tensile loads. Typically quantified in units like pounds per square inch (psi) or megapascals (MPa), tensile strength signifies the juncture on a stress-strain graph where a material initiates permanent (plastic) deformation and eventual rupture. In essence, it represents the maximum force a material can withstand per unit area prior to fracturing.

Frequent orders: It refers to a situation where a particular product or service is requested and purchased on a regular or recurring basis. In this context, customers or clients place orders for the same item or service repeatedly, often due to consistent demand or ongoing needs.Managing frequent orders effectively involves optimizing production, inventory management, and delivery processes to meet the recurring demand and ensure customer satisfaction. Subscription models, automatic reorder systems, and personalized customer service often play roles in catering to customers who place frequent orders.

Visual and aesthetic modeling: It refers to the process of creating digital or physical representations of objects, designs, or concepts with a focus on their visual appeal and aesthetics. This type of modeling emphasizes the appearance, form, and overall visual impression of the subject. In various fields, such as art, design, architecture, and product development, visual and aesthetic modeling involves using techniques like 3D modeling software, computer-aided design (CAD), and physical prototyping to bring ideas to life in a visually pleasing way. This can include creating lifelike renderings, sculptures, digital mockups, and prototypes that showcase the design's aesthetics, color schemes, textures, and other visual aspects.

TOPSIS METHOD:

TOPSIS serves as a commonly employed evaluation technique for addressing Multi-Criteria Decision-Making (MCDM) challenges. Its practical utility spans diverse domains, including assessing company performance, evaluating financial ratios within specific industries, and making informed financial investments in advanced manufacturing systems, among various other applications. However, it has some limitations. The TOPSIS technique, however, has several drawbacks. An important consideration that TOPSIS underscores is the potential for rank reversal to occur. This phenomenon arises when the addition or removal of an option within the decision context leads to a shift in the order of preference for the alternatives. The addition or removal of an option in the process can lead to a phenomenon known as total rank reversal. In such cases, the sequence of preferences is completely inverted, causing the formerly considered superior alternative to become the least favorable. In many cases, such an occurrence would be unacceptable. In MCDM, a variety of options must be analysed and evaluated using a number of criteria. The goal of MCDM is to assist the decision-maker in picking among alternatives. In this sense, practical situations are typically defined by a number of conflicting criteria, and no solution may fulfil all requirements at the same time. As a result, the response is a compromise choice depending on the decision-maker's preferences. TOPSIS operates on the principle that the ultimate solution should be maximally distant from the Negative Ideal Solution (NIS) and closest to the Positive Ideal Solution (PIS). The final ranking is established through a proximity measure.

Step 1: The decision matrix X, which displays how various options perform concerning certain criteria, is created.

$$x_{ij} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \tag{1}$$

Step 2: Weights for the criteria are expressed as

$$w_j = [w_1 \cdots w_n], \quad where\,, \sum_{j=1}^{n}(w_1 \; \cdots \; w_n) = 1 \tag{2}$$

Step 3: The matrix x_{ij}'s normalized values are computed as

$$n_{ij} = \frac{x_{ij}}{\sqrt[2]{\sum_{i=1}^{m} x_{ij}^2}} \tag{3}$$

The weighted normalized matrix \(N_{ij}\) is computed using the following formula:

$$N_{ij} = w_j \times n_{ij} \tag{4}$$

Step 4: Let's begin by identifying the optimal best and optimal worst values: Here, we must determine whether the influence is "+" or "-." If a column has a "+" impact, the ideal best value for that column is its highest value; if it has a "-" impact, the ideal worst value is its lowest value.

Step 5: Now we need to calculate the difference between each response from the ideal best,

$$S_i^+ = \sqrt{\sum_{j=1}^{n}(N_{ij} - A_j^+)^2} \quad for\ i \in [1, m]\ and\ \ j \in [1, n] \tag{5}$$

Step 6: Now we need to calculate the difference between each response from the ideal worst,

$$S_i^- = \sqrt{\sum_{j=1}^{n}(N_{ij} - A_j^-)^2}\ for\ i \in [1, m]\ and\ \ j \in [1, n] \tag{6}$$

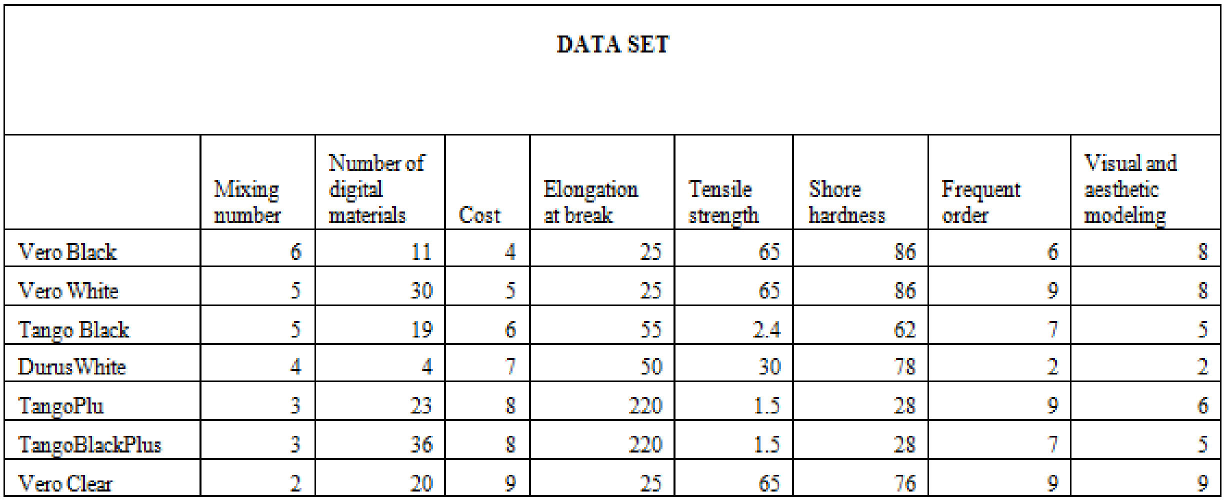
Step 7: Now we need to calculate theCloseness coefficient of i_{th} alternative

$$CC_i = \frac{S_i^-}{S_i^+ + S_i^-} \quad where, 0 \le CC_i \le 1, i \in [1, m] \tag{7}$$

The Closeness Coefficient's value illustrates how superior the alternatives are in comparison. A larger CC_i denotes a substantially better alternative, whereas a smaller CC_idenotes a significantly worse alternative.

3. RESULT AND DISCUSSION

Table 1.Additive manufacturing values



DATA SET								
	Mixing number	Number of digital materials	Cost	Elongation at break	Tensile strength	Shore hardness	Frequent order	Visual and aesthetic modeling
Vero Black	6	11	4	25	65	86	6	8
Vero White	5	30	5	25	65	86	9	8
Tango Black	5	19	6	55	2.4	62	7	5
Durus White	4	4	7	50	30	78	2	2
TangoPlu	3	23	8	220	1.5	28	9	6
TangoBlackPlus	3	36	8	220	1.5	28	7	5
Vero Clear	2	20	9	25	65	76	9	9

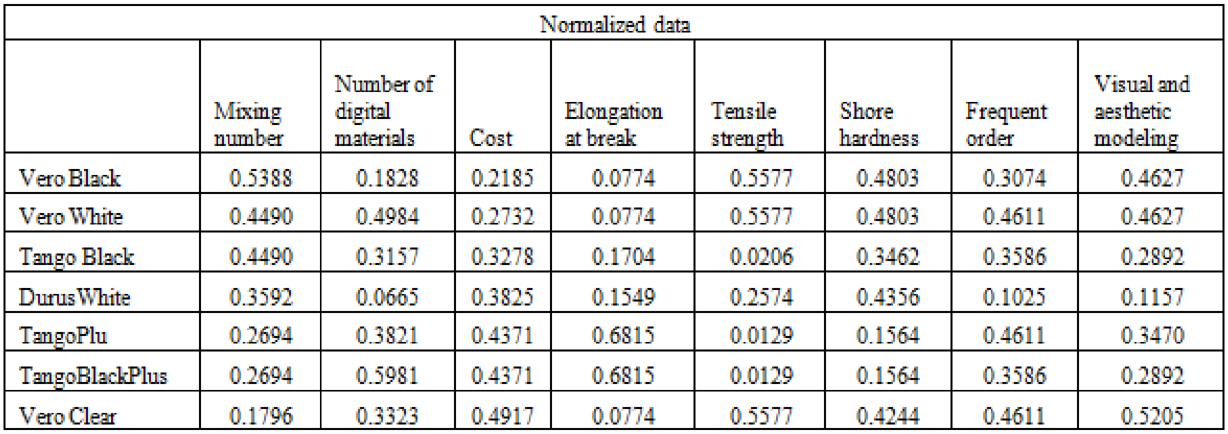
In the table 1 represents the values in the different properties or characteristics of each material, and the scale or units for each property may vary. For example in the Vero black ,the values are Mixing number is 6, There are 11 digital materials available, the cost is rated at 4, elongation at break measures 25, tensile strength stands at 65, Shore hardness reaches 86, there are 6 instances of frequent orders, and the score for visual and aesthetic modeling is 8.

Table2. Square root of Matrix

Square root of Matrix							
36.00	121.00	16.00	625.00	4225.00	7396.00	36.00	64.00
25.00	900.00	25.00	625.00	4225.00	7396.00	81.00	64.00
25.00	361.00	36.00	3025.00	5.76	3844.00	49.00	25.00
16.00	16.00	49.00	2500.00	900.00	6084.00	4.00	4.00
9.00	529.00	64.00	48400.00	2.25	784.00	81.00	36.00
9.00	1296.00	64.00	48400.00	2.25	784.00	49.00	25.00
4.00	400.00	81.00	625.00	4225.00	5776.00	81.00	81.00

In this table 2 shows the square root operation has been applied to the numbers in the matrix provided.

Table 3. Normalized data



Normalized data								
	Mixing number	Number of digital materials	Cost	Elongation at break	Tensile strength	Shore hardness	Frequent order	Visual and aesthetic modeling
Vero Black	0.5388	0.1828	0.2185	0.0774	0.5577	0.4803	0.3074	0.4627
Vero White	0.4490	0.4984	0.2732	0.0774	0.5577	0.4803	0.4611	0.4627
Tango Black	0.4490	0.3157	0.3278	0.1704	0.0206	0.3462	0.3586	0.2892
Durus White	0.3592	0.0665	0.3825	0.1549	0.2574	0.4356	0.1025	0.1157
TangoPlu	0.2694	0.3821	0.4371	0.6815	0.0129	0.1564	0.4611	0.3470
TangoBlackPlus	0.2694	0.5981	0.4371	0.6815	0.0129	0.1564	0.3586	0.2892
Vero Clear	0.1796	0.3323	0.4917	0.0774	0.5577	0.4244	0.4611	0.5205

These table3 shows the values appear to be normalized values based on the original data set, where each value is scaled to fall within a specific range (usually between 0 and 1) to facilitate comparisons and analysis. For example in the Vero White the values are Mixing number is 0.4490, Number of digital materials is 0.4984, Cost is 0.2732, Elongation at break is 0.0774, Tensile strength is 0.5577, Shore hardness is 0.4803, Frequent order is 0.4611 and Visual and aesthetic modeling is 0.4627.

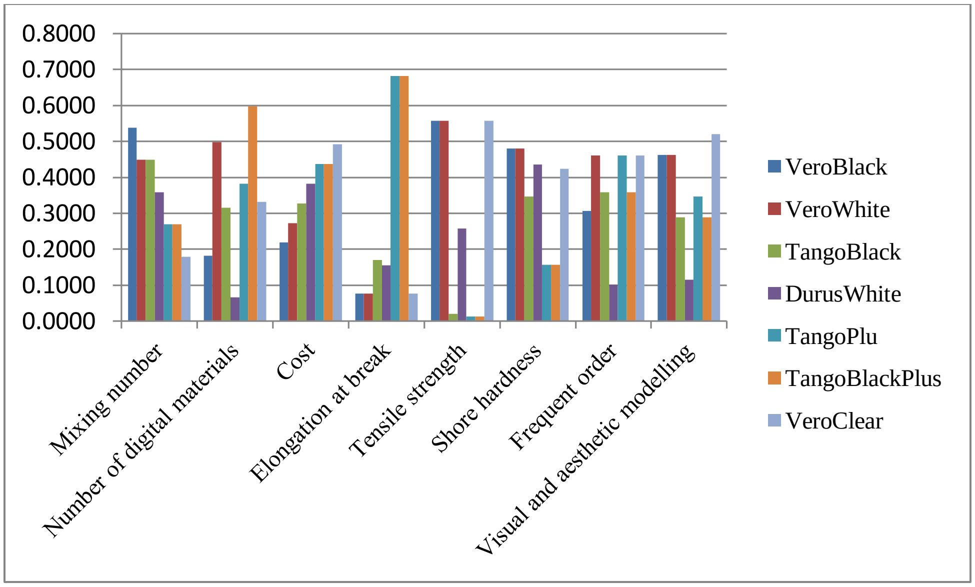
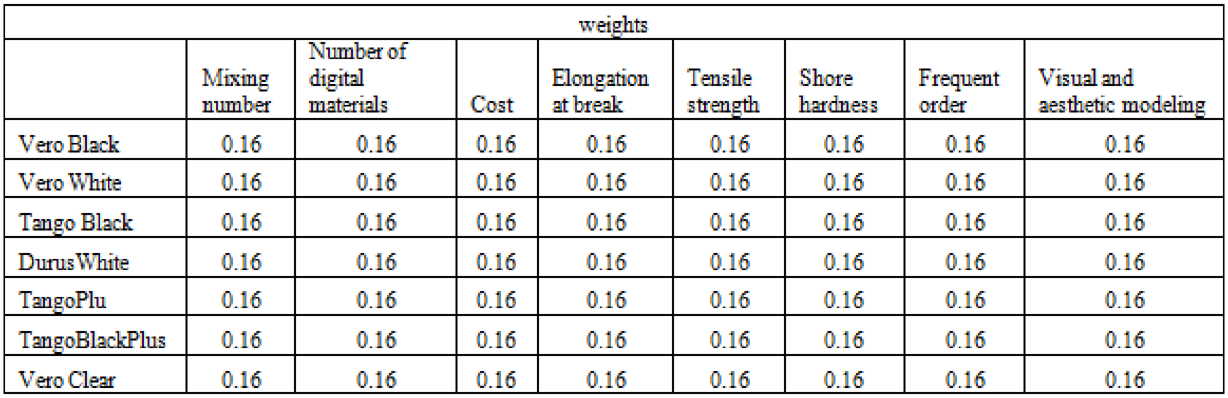


Figure 1 . Normalized data

This figure 1 shows the values appear to be normalized values based on the original data set, where each value is scaled to fall within a specific range (usually between 0 and 1) to facilitate comparisons and analysis. For example in the Vero White the values are Mixing number is 0.4490, Number of digital materials is 0.4984, Cost is 0.2732, Elongation at break is 0.0774, Tensile strength is 0.5577, Shore hardness is 0.4803, Frequent order is 0.4611 and Visual and aesthetic modeling is 0.4627.

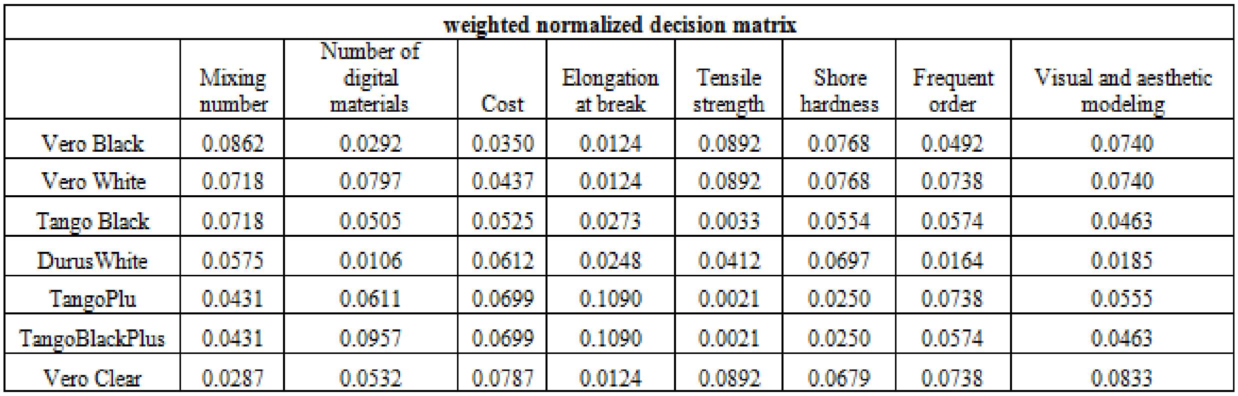
Table 4.weights



	weights							
	Mixing number	Number of digital materials	Cost	Elongation at break	Tensile strength	Shore hardness	Frequent order	Visual and aesthetic modeling
Vero Black	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Vero White	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Tango Black	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Durus White	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
TangoPlu	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
TangoBlackPlus	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16
Vero Clear	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16

These weights are evenly distributed (0.16 each) across all properties for each material. Weighting is often used in analysis to assign different levels of importance to different properties or factors when making evaluations or calculations.

Table 5: Weighted Normalized Decision Matrix



weighted normalized decision matrix								
	Mixing number	Number of digital materials	Cost	Elongation at break	Tensile strength	Shore hardness	Frequent order	Visual and aesthetic modeling
Vero Black	0.0862	0.0292	0.0350	0.0124	0.0892	0.0768	0.0492	0.0740
Vero White	0.0718	0.0797	0.0437	0.0124	0.0892	0.0768	0.0738	0.0740
Tango Black	0.0718	0.0505	0.0525	0.0273	0.0033	0.0554	0.0574	0.0463
Durus White	0.0575	0.0106	0.0612	0.0248	0.0412	0.0697	0.0164	0.0185
TangoPlu	0.0431	0.0611	0.0699	0.1090	0.0021	0.0250	0.0738	0.0555
TangoBlackPlus	0.0431	0.0957	0.0699	0.1090	0.0021	0.0250	0.0574	0.0463
Vero Clear	0.0287	0.0532	0.0787	0.0124	0.0892	0.0679	0.0738	0.0833

In this table 5, the values have been multiplied by the corresponding weights for each property, creating a weighted score for each material across the different properties. This approach allows for a more comprehensive evaluation of the materials, taking into account the assigned importance of each property. For example, in the Tango Black the values are Mixing number is 0.0718, Number of digital materials is 0.0505, Cost is 0.0525, Elongation at break is 0.0273, Tensile strength is 0.0033, Shore hardness is 0.0554, Frequent order is 0.0574 and Visual and aesthetic modeling is 0.0463.

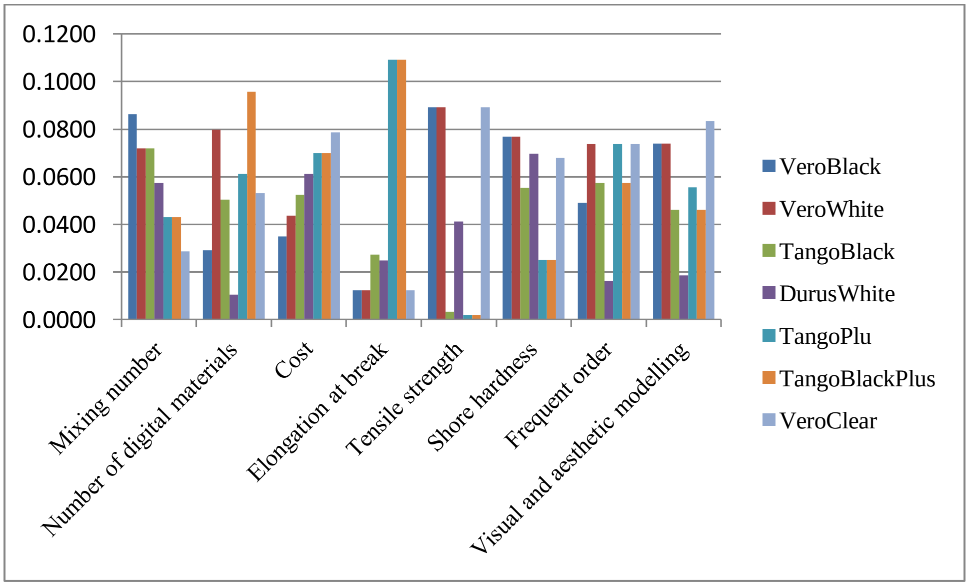


Figure 2.weighted normalized decision matrix

In this figure 2, the values have been multiplied by the corresponding weights for each property, creating a weighted score for each material across the different properties. This approach allows for a more comprehensive evaluation of the materials, taking into account the assigned importance of each property. For example, in the Tango Black the values are Mixing number is 0.0718, Number of digital materials is 0.0505, Cost is 0.0525, Elongation at break is 0.0273, Tensile strength is 0.0033, Shore hardness is 0.0554, Frequent order is 0.0574 and Visual and aesthetic modeling is 0.0463.

Table 6.Positive Matrix

Positive Matrix							
0.0862	0.0957	0.0787	0.1090	0.0892	0.0768	0.0738	0.0833
0.0862	0.0957	0.0787	0.1090	0.0892	0.0768	0.0738	0.0833
0.0862	0.0957	0.0787	0.1090	0.0892	0.0768	0.0738	0.0833
0.0862	0.0957	0.0787	0.1090	0.0892	0.0768	0.0738	0.0833
0.0862	0.0957	0.0787	0.1090	0.0892	0.0768	0.0738	0.0833
0.0862	0.0957	0.0787	0.1090	0.0892	0.0768	0.0738	0.0833
0.0862	0.0957	0.0787	0.1090	0.0892	0.0768	0.0738	0.0833

In this table 6 appears to be a positive matrix with constant values. This matrix consists of the same values repeated throughout, which suggests that each element of the matrix has been assigned a constant value.

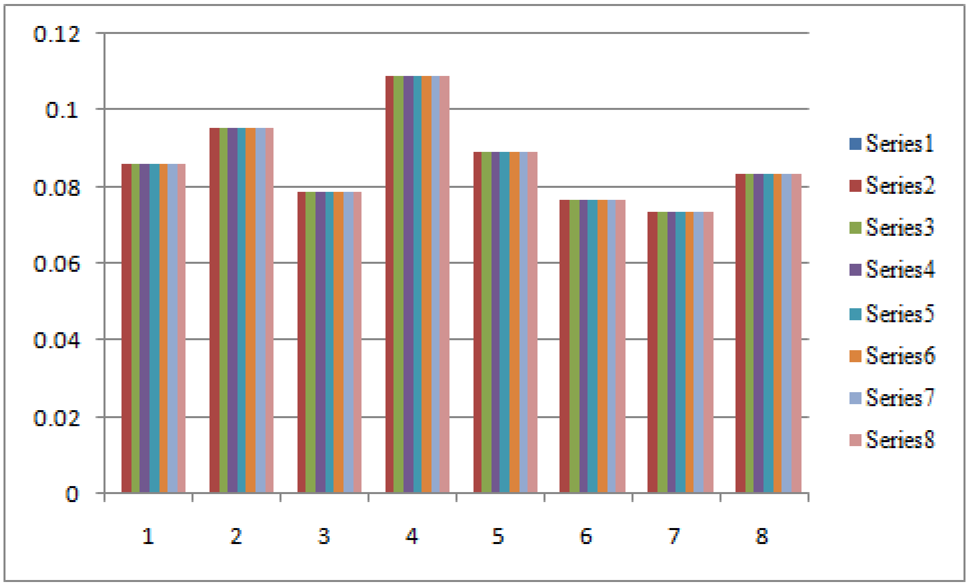


Figure 3.Positive Matrix

In this figure 3 appears to be a positive matrix with constant values. This matrix consists of the same values repeated throughout, which suggests that each element of the matrix has been assigned a constant value.

Table 7. Negative matrix

Negative matrix							
0.0431	0.0106	0.0350	0.0124	0.0021	0.0250	0.0164	0.0185
0.0431	0.0106	0.0350	0.0124	0.0021	0.0250	0.0164	0.0185
0.0431	0.0106	0.0350	0.0124	0.0021	0.0250	0.0164	0.0185
0.0431	0.0106	0.0350	0.0124	0.0021	0.0250	0.0164	0.0185
0.0431	0.0106	0.0350	0.0124	0.0021	0.0250	0.0164	0.0185
0.0431	0.0106	0.0350	0.0124	0.0021	0.0250	0.0164	0.0185
0.0431	0.0106	0.0350	0.0124	0.0021	0.0250	0.0164	0.0185

In this table 7 appears to be a negative matrix with constant values. This matrix consists of the same values repeated throughout, which suggests that each element of the matrix has been assigned a constant negative value.

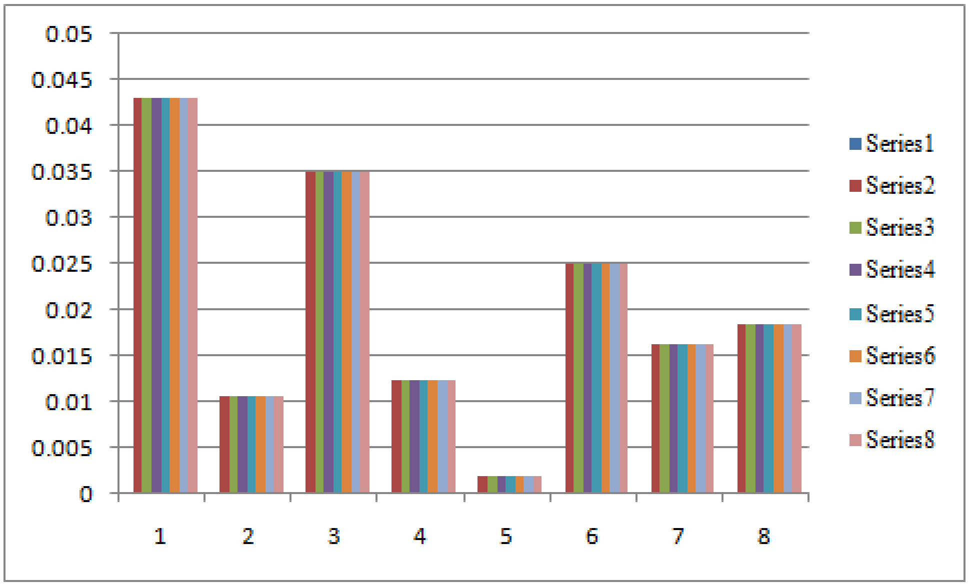


Figure 4. Negative matrix

In this figure 4 appears to be a negative matrix with constant values. This matrix consists of the same values repeated throughout, which suggests that each element of the matrix has been assigned a constant negative value.

Table 8. SI Plus, Si Negative and Ci

	SI Plus	Si Negative	Ci
Vero Black	0.1279	0.1290	0.5022
Vero White	0.1054	0.1495	0.5864
Tango Black	0.1382	0.0795	0.3651

DurusWhite	0.1591	0.0676	0.2983
TangoPlu	0.1191	0.1333	0.5282
TangoBlackPlus	0.1177	0.1423	0.5473
Vero Clear	0.1206	0.1444	0.5450

This table 8 shows to represent different materials with corresponding values for "SI Plus," "Si Negative," and "Ci" properties. For example in the Vero Black the values are SI Plus is 0.1279, Si Negative is 0.1290 and Ci is 0.5022.

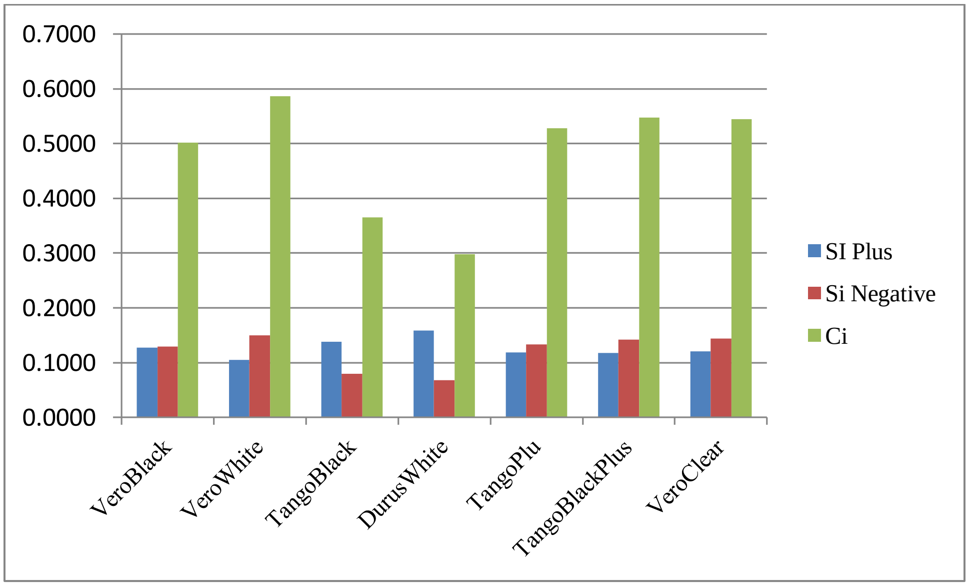


Figure 5.SI Plus, Si Negative and Ci

This figure 5 shows to represent different materials with corresponding values for "SI Plus," "Si Negative," and "Ci" properties. For example in the Vero Black the values are SI Plus is 0.1279, Si Negative is 0.1290 and Ci is 0.5022.

Table 9. Rank

Rank	
Vero Black	5
Vero White	1
Tango Black	6
DurusWhite	7
TangoPlu	4
TangoBlackPlus	2
Vero Clear	3

This table 9 shows the ranking of different materials. Each material is assigned a rank based on its position in the list. Vero White got the first rank and the DurusWhite got the last rank..The second rank has TangoBlackPlus, the third rank has Vero Clear,the fourth rank has TangoPlu, the fifth rank has Vero Black and, the sixth rank has Tango Black.

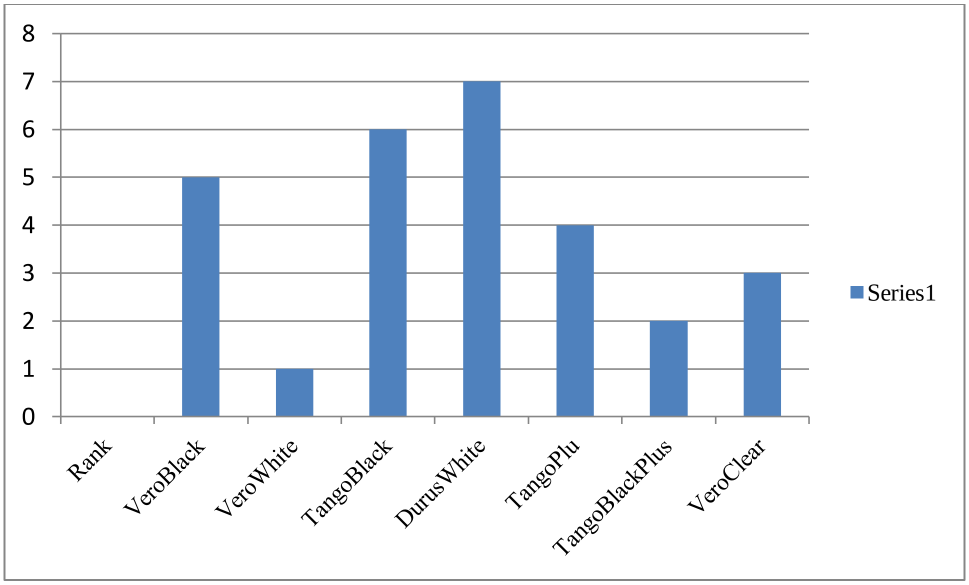


Figure 6. Rank

This figure 6 shows the ranking of different materials. Each material is assigned a rank based on its position in the list. Vero White got the first rank and the DurusWhite got the last rank..The second rank has TangoBlackPlus,the third rank has Vero Clear,the fourth rank has TangoPlu, the fifth rank has Vero Black and, the sixth rank has Tango Black.

4. CONCLUSION

Utilizing additive manufacturing has the capability to swiftly introduce novel designs to the market and contribute to prolonged market viability. The process of selecting the most appropriate Objet260 Connex machine involved a thorough comparison of numerous options among the machines at hand. In this study, the TOPSIS Multi-Criteria Decision-Making (MCDM) methodology is employed. It aids in the choice of an appropriate material from an extensive array of options for the designated Objet260 Connex machine. This research introduces an innovative and optimal approach to both the manufacturing process and decision-making strategies within additive manufacturing, even when faced with intricate design challenges. It offers a superior ranking of construction materials according to the needs of respondents, facilitating tailored services aligned with customer demands. This approach notably minimizes material wastage when transitioning between different materials for varying product types. Furthermore, it empowers customers with a comprehensive understanding of the feasible materials available for their requirements, a perspective that might not have been previously considered. Each material is assigned a rank based on its position in the list. Vero White got the first rank and the DurusWhite got the last rank.The second rank has TangoBlackPlus,the third rank has Vero Clear, the fourth rank has TangoPlu, the fifth rank has Vero Black and, the sixth rank has Tango Black.

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