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SELECTION OF 3D PRINTING METHOD: A MULTI-CRITERIA DECISION ANALYSIS APPROACH FOR COMPLEX HEALTHCARE CASES

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ABSTRACT

Additive Manufacturing, as an integral part of Industry 4.0, has gained prominence in the medical-hospital sector, particularly in the production of customized anatomical models. Precision and quality in 3D printing depend on accurate parameter configurations, making the proper selection of the printing method essential. Multicriteria Decision Analysis (MCDA) plays a crucial role in enabling a thorough evaluation of alternatives to optimize efficiency, quality, costs, and development time, meeting the rigorous standards required in the medical field. This study applied the PROMETHEE II method to determine 3D printing parameters for a human aorta anatomical model. Criteria such as cost, time, and layer height were assessed across 15 printing models using three types of 3D printers and materials: Polylactic Acid (PLA), Acrylonitrile Butadiene Styrene (ABS), and liquid resin curable by ultraviolet (UV) radiation. Resin parts stood out, achieving the highest rankings, particularly in the X-axis orientation. The results provide technical and strategic support for researchers and healthcare professionals, enabling the use of additive manufacturing technologies in complex applications. The integration of MCDA and 3D printing fosters innovative practices, promoting safety and efficiency while contributing to improved patient outcomes.

Keywords: Additive Manufacturing; Multicriteria Decision; Healthcare.

revista interfaces
Artigos Originais
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INTRODUCTION

Additive Manufacturing (AM) is defined as a manufacturing process that builds components by successively adding material layers, guided by a three-dimensional computational geometric representation (VOLPATO, 2017). With the advent of 3D printers in the 1980s, early AM technologies focused on creating prototypes with minimal material requirements, limited dimensional accuracy, and basic functional performance, primarily for visualization purposes. Over time, the recognition of AM's potential has significantly expanded its applications, promoting advances in the quality of components, in the utilization of new materials, and in the diversity of functionalities (VOLPATO, 2017). As one of the cornerstones of Industry 4.0, 3D printing has become an essential trend in the production sector, finding increasing use across industries such as manufacturing, electronics, and healthcare (VOLPATO, 2017).

In the healthcare field, personalized models generated from medical exams have significantly broadened their applications, being employed in research, education, and the planning of complex surgeries to prevent iatrogenic outcomes (UTIYAMA *et al.*, 2014). These models allow the fabrication of various types of tissues, including bones, joints, vascular, and neural tissues, enhancing the delivery of more specialized healthcare services, as well as the development of organs, prosthetics, and customized devices (TAMIR *et al.*, 2023; DONG; PETROVIC; DAVIES, 2024; MATOZINHOS *et al.*, 2017). Moreover, they support the customization of medications, providing more efficient and precise solutions for addressing the needs of modern medicine (DONG; PETROVIC; DAVIES, 2024).

Risks and failures in 3D printing parameterization, especially in medical settings where precision is paramount, can jeopardize the efficacy of procedures and patient safety. The determination of these parameters is vital to achieving satisfactory printing results (BOL; ŠAVIJA, 2023). According to Wang *et al*. (2020), factors such as printing speed, angle and direction, infill density, temperature, and filament type significantly affect quality, accuracy, and functionality in medical applications. Accurate part configuration is essential to defining the final product characteristics and impacts production time and cost.

In the medical-hospital context, Khan *et al*. (2024) present, in their research, advancements in 3D printing technology applied to cardiovascular medicine, highlighting the feasibility of customizing medical implants tailored to the specific vascular anatomy of each patient. This approach enhances therapeutic efficacy and reduces the occurrence of adverse effects. Furthermore, within the scope of human health, Jewell and Stones (2024) discuss, in their study, not only the applicability of 3D printing in the pharmaceutical industry but also the technical barriers surrounding its production across different usage contexts. The authors emphasize operational costs ranging from material acquisition to post-processing, as well as regulatory challenges associated with patent legislation for this technology.

Additionally, 3D printing demonstrated its effectiveness in healthcare emergencies during the COVID-19 pandemic by enabling the rapid production of components for diagnosis, treatment, and the protection of healthcare professionals. This technology facilitated the rapid design creation and decentralized manufacturing through the sharing of digital models, establishing an international production network (WANG *et al.*, 2020). In another instance, the analysis of three complex surgical oncology cases (KRAEL *et al.*, 2016) resulted in the development of full-scale 3D models, allowing the surgical team to perform practical simulations, thereby enhancing preparation and increasing practitioners' confidence prior to interventions. 3D printing can also revolutionize academic learning by replacing cadaveric dissection with detailed anatomical models, eliminating undesirable biological effects and facilitating the handling, transport, and reproduction of anatomical structures (SILVA *et al*., 2023).

The definition and selection of various factors to achieve the optimal quality of a part represent a multicriteria decision problem. In this context, MCDA, a branch of Operations Research (OR), arises as a valuable method for evaluating conflicting criteria and assisting in decision-making (MONDAL *et al.*, 2023; ISHIZAKA; NEMERY, 2013; LESSA *et al*., 2024), as it provides a systematic approach to consider various criteria and assess printing alternatives based on their relative performances. MCDA is a set of methods aimed at supporting complex decisions, particularly well-suited for cases where different perspectives on a specific decision result in conflicting outcomes. The methodology allows the integration of data and information through a Decision Matrix, enabling the selection, classification, and ranking of alternatives, thus making decision-making more grounded (CAMPELLO; GHIDINI, 2022; CAMPOLINA *et al*., 2017; LEITE, 2019).

MCDA, like additive manufacturing, has been extensively utilized to address complex problems in the healthcare sector. For instance, the Analytic Hierarchy Process (AHP) was referenced to identify key prioritization criteria in the treatment of osteoporosis in postmenopausal women at high risk of fractures, within the context of the Brazilian Unified Health System (SUS) (MENSOR *et al.*, 2022). Additionally, the Preference Ranking Organization METHod for Enrichment Evaluation (PROMETHEE) II was applied in the screening of Chagas disease, caused by *Trypanosoma cruzi*, to identify regions with the highest prevalence and, therefore, direct healthcare resources more efficiently in Brazil (LIMA *et al.*, 2021). Other examples of the growing interest in using the MCDA methodology were explored for the procurement of medical-hospital supplies, highlighting the inclusion of criteria beyond cost to ensure quality and prevent shortages of medications and medical devices in countries across Africa and Asia (ELEZBAWY *et al.*, 2022; HOLTORF *et al.*, 2021; KRISTIN *et al.*, 2023).

Based on Tomerelli *et al.* (2025), the MCDA methods AHP, Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), and Multiattribute Value Theory (MAVT) are presented, highlighting their characteristics and applications in 3D printing within the industrial context. The author points out that AHP is intuitive and allows subjective judgments but heavily depends on expert opinion and may present inconsistencies and rank reversal. TOPSIS ranks alternatives based on proximity to the ideal solution, yet assumes linear relationships and is sensitive to the composi-tion of alternatives. MAVT offers greater flexibility to model nonlinear preferences and uncertain-ties, although it requires higher cognitive effort. According to the authors, the choice of method should consider the decision context, data availability, and the complexity needed for preference modeling (TOMERELLI *et al*., 2025).

The improper utilization of 3D printing parameters to produce anatomical parts can lead to inaccurate diagnoses, delays in emergency surgeries, and incorrect procedures (CARUSO; SILVA; MARCONDES, 2023). Therefore, there is a need to explore how MCDA methods can optimize resources in printing, taking into account the specific demands of the medical-hospital sector for complex surgeries. In this way, this study aims to develop a multicriteria decision strategy for selecting the most efficient 3D printing method for a complex clinical case.

MATERIALS AND METHODS

Phases of the study

This study was carried out in three main phases. In the first phase, the central issue was identified by analyzing the context, knowledge gaps, and research objectives, followed by a literature review to understand the state of the art and determine the MCDA method to be applied. In the second phase, interviews were conducted with an expert in AM applied to healthcare, allowing for an understanding of priorities and the construction of a decision matrix with criteria and alternatives based on both the literature and the decision-maker's preferences. After collecting data and defining the weights and preferences of the criteria, the third phase involved applying the PROMETHEE II method to the matrix, identifying the most suitable alternative for 3D printing based on the complex clinical case.

Additionally, preference functions were established, considering the specific context of each criterion, along with the preference (p) and indifference (q) parameters. The criteria were selected based on a literature review, with particular reference to the work of Mondal *et al*. (2023). Furthermore, the parameters p and q were determined with the support of the Visual PROMETHEE software thorough interactions with the decision-maker, and were optimized ac-cording to each preference function. The configuration of these functions is illustrated in Fig. 4, and each preference function requires different (p) and (q) parameters. This information was incorporated into the Decision Matrix, solidifying the analysis process. In the case where the decision-maker is a healthcare professional, such as a radiologist, it is

revista interfaces
Artigos Originais
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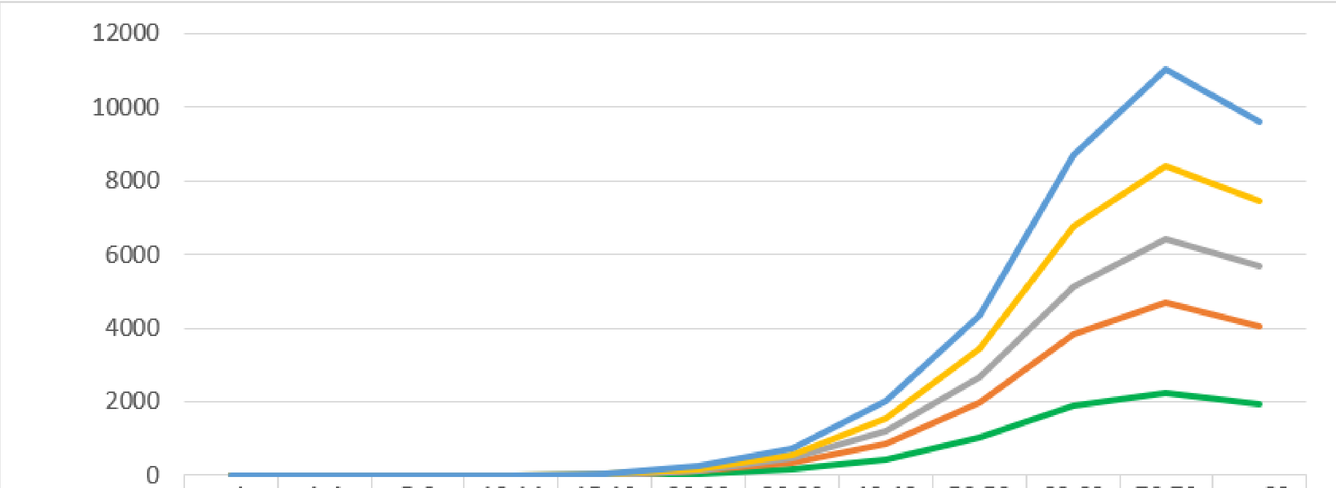
recommended that this same evaluation be conducted through the interaction between the analyst, the decision-maker, and the software, so that all parameters are chosen considering the professional's expertise. This way, clinical sensitivity or other subjective aspects can be incorporated into the decision-making process. Finally, a sensitivity analysis was conducted, the chosen model was printed, and recommendations for future research were made.

Object of study

The organ analyzed in this study, for which data collection is intended to apply the PROMETHEE method, is the human aorta, the largest artery in the body. Starting from the heart and ending at the fourth lumbar vertebra, it branches into arteries that extend throughout the body, primarily functioning to transport oxygenated blood to nourish organs and cells (TORTORA; NIELSEN, 2019). Throughout life, the aorta may exhibit variations in diameter, length, thickness, and microstructural composition, with age being a critical risk factor for the onset of degenerative changes and aortic diseases. Understanding these morphological variations is vital for advancing effective clinical therapies for treating aortic diseases (KOMUTRATTANANONT; MAHAKKANKRAH; DAS, 2019).

Aortic pathologies are a significant cause of cardiovascular mortality and morbidity, posing critical challenges for cardiologists and surgeons (ALBUQUERQUE *et al.*, 2009). According to data from SUS, 36,716 deaths related to aortic aneurysms and dissections were recorded in Brazil between 2018 and 2022. Of these, 79.79% occurred in individuals aged over 60 years, and 59.72% were male. Fig. 1 visually depicts the trend in mortality rates from these conditions in Brazil during the given period. This analysis underscores the rising incidence of such pathologies over the years, offering valuable insights into their associated epidemiological trends (DATASUS, 2024).

Figure 1. Mortality Trends Due to Aneurysm and Aortic Dissection in Brazil (2018–2022).



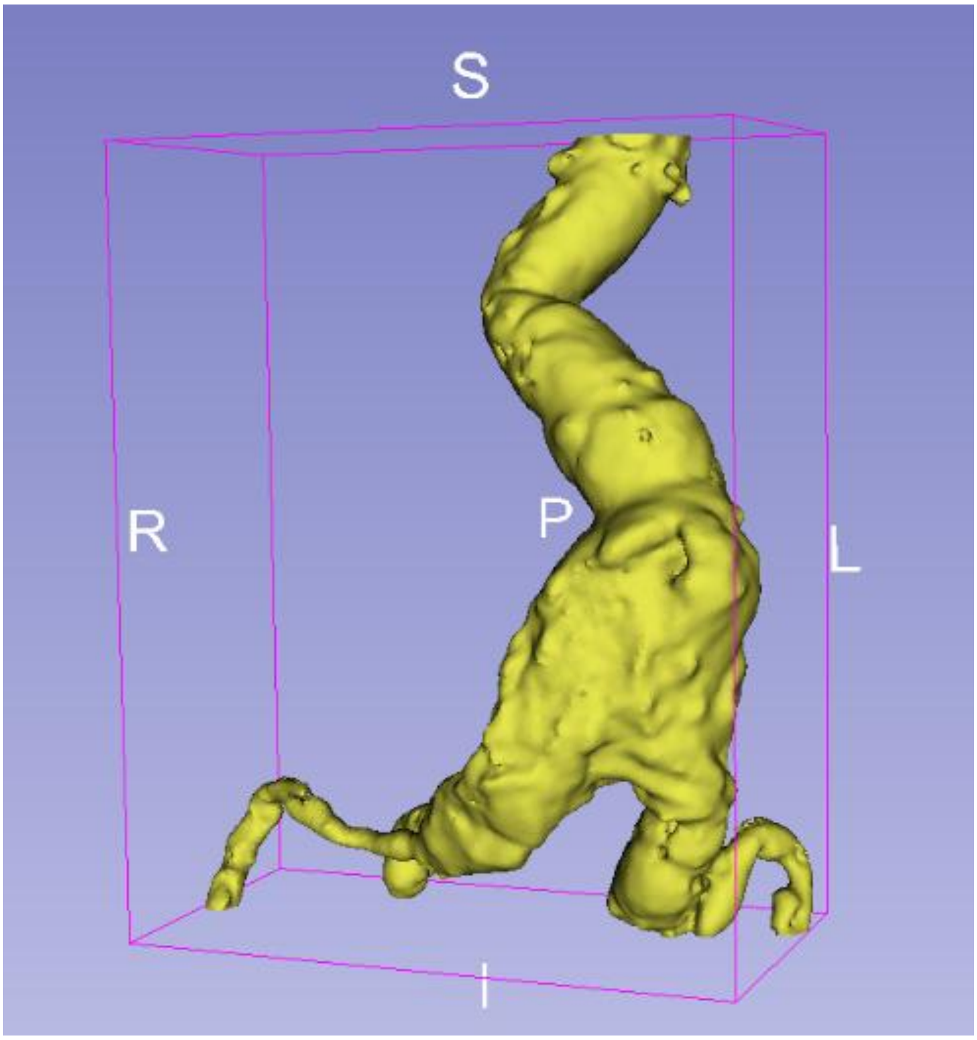
	< 1 year	1-4 years	5-9 years	10-14 years	15-19 years	20-29 years	30-39 years	40-49 years	50-59 years	60-69 years	70-79 years	>= 80 years
2022	1	1	1	5	8	67	174	468	906	1931	2602	2142
2021	1	1	1	3	3	38	107	361	768	1606	1997	1745
2020	0	1	2	4	5	35	119	319	689	1317	1735	1658
2019	0	0	0	0	4	53	189	428	977	1950	2451	2098
2018	0	0	0	0	5	52	159	441	1009	1877	2236	1949

revista interfaces
Artigos Originais
V. 13, N. 4 (2025) | ISSN 2317-434X

For this case study, computed tomography angiography (CTA), an advanced imaging technique utilizing tomographic technology for the precise detection of vascular anomalies, was employed. The aortic scan was obtained from a medical imaging database (LHS, 2019). This scan, provided in the Digital Imaging and Communications in Medicine (DICOM) format, offers a non-invasive means for detailed visualization of anatomical structures. The findings revealed a large abdominal aneurysm alongside structural alterations in other arteries, significantly increasing the risk of clinical complications.

The file processing followed structured steps: segmentation of the DICOM image, digital mesh creation, removal of extraneous structures, surface refinement, and the generation of a Standard Triangle Language (STL) file compatible with 3D printing software (LINDQUIST, 2021). Slicer software was used for a detailed analysis of the anatomical layers and refinement of the model, ensuring that the region of interest, from the infrarenal aorta to the iliac arteries, was preserved. Fig. 2 depicts the 3D model ready for printing, which was applied to the decision matrix.

Figure 2. 3D Image of the Aorta in Slicer Software.



revista interfaces
Artigos Originais
V. 13, N. 4 (2025) | ISSN 2317-434X

Construction of the decision matrix

Given the anatomical complexity of the aorta and the need to ensure high-quality models with superior performance in medical analysis and preparation, addressing the "stair-step effect" is crucial (CHEIRAM, 2020; MENDONÇA, 2018; QUINTELA *et al.*, 2019). This phenomenon, stemming from the layering process during 3D printing, depends on the layer thickness and model orientation. Properly selecting the printing angle mitigates the "stair-step effect" and optimizes support usage, enhancing precision and overall quality. Moreover, production cost, linked to the material mass used, and manufacturing time, which depends on the employed technology, are pivotal factors in the evaluation. Shortening manufacturing time not only streamlines the process but also avoids delays in medical procedures, boosting operational efficiency (CHEIRAM, 2020; MENDONÇA, 2018).

Thus, guided by a specialist decision-maker, a Ph.D. in mechanical engineering specializing in AM with extensive experience in developing anatomical models and in-depth knowledge of AM materials and Technologies, the selected printing criteria were: Layer Height, Material Cost (determined by the mass of material used and its market value), and Printing Time in minutes. These criteria were applied to the Ender 3 v2 Neo and Bambu X1 Carbon Fused Deposition Modeling (FDM) printers, which employ a layer-by-layer thermoplastic material deposition process to create three-dimensional objects. Additionally, the Creality Halot Sky stereolithography (SLA) printer was utilized, producing plastic parts by curing a liquid photopolymer resin using an ultraviolet laser. The analysis supported the use of "Tree" supports. While not integrated into the final product, these supports are vital for sustaining overhanging areas without direct contact with the printing bed. Particularly suitable for complex geometries, this support model reduces waste, facilitates removal, and minimizes defects in the final piece (CHEIRAM, 2020; MENDONÇA, 2018; 3DLAB, 2024; 3DLAB, 2020).

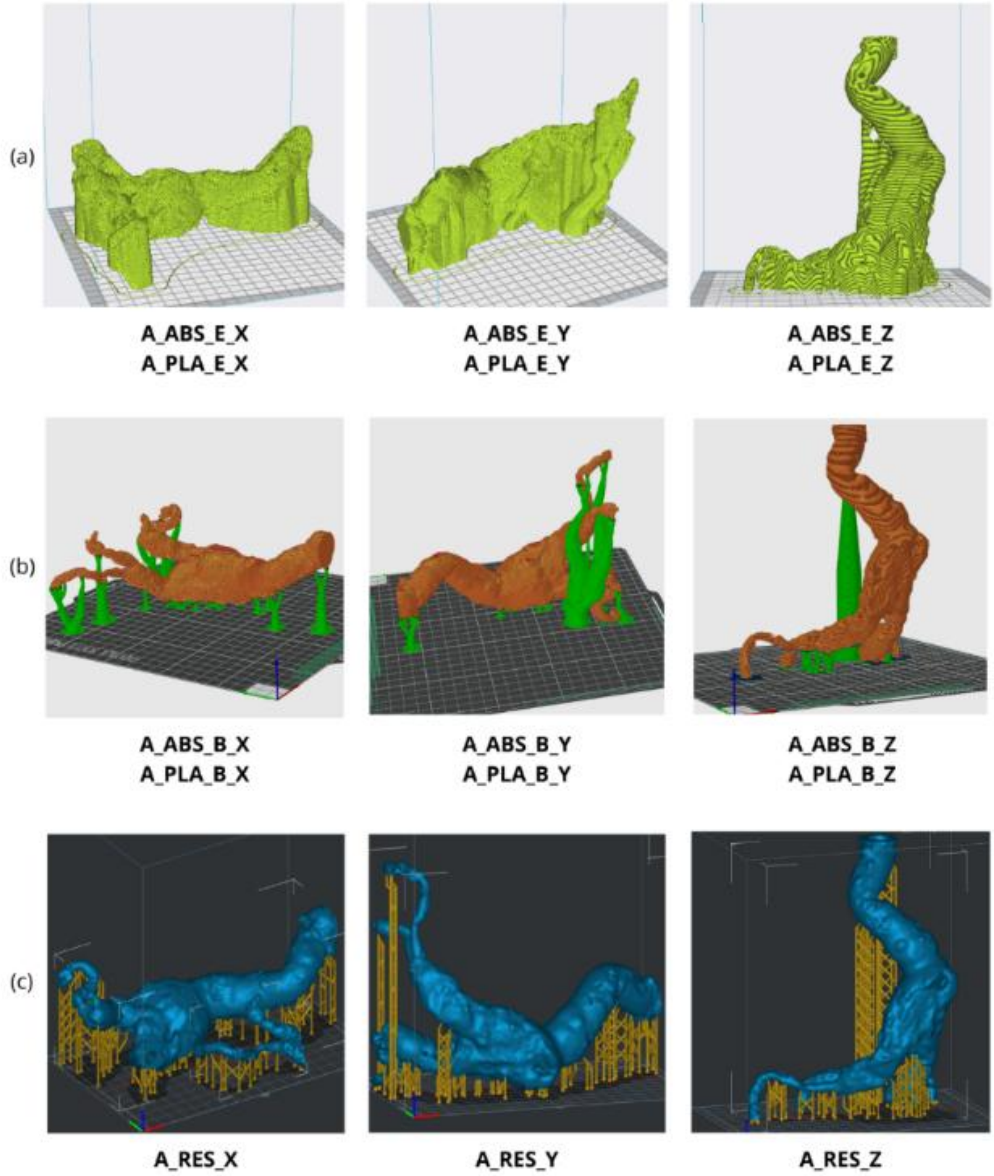
Given the availability of equipment and materials, data collection was performed via slicing using Creality Slicer, Bambu Studio, and Halot Box software, selected based on each printer's compatibility. The Ender 3 v2 Neo and Bambu X1 Carbon printers were configured for PLA and ABS polymers, whereas the Creality Halot Sky printer, due to its exclusive compatibility with liquid resin, was restricted to this material. A denser support structure was required to sustain the part during its suspended printing process. To ensure a thorough analysis, prints were conducted along the X, Y, and Z axes, offering distinct perspectives on fabrication and support utilization. Figures of the parts, including their supports, are presented in Fig. 3. Configuration variations reflect the necessary adjustments to accommodate the specific characteristics of each printer. Additionally, for the A_RES_X part, the model was cut using Meshmixer software, as the original piece in the highlighted position exceeded the SLA printer's dimensional limits.

RESULTS AND DISCUSSIONS

With the definition of alternatives and criteria for the study, additional adjustments were necessary for constructing the Decision Matrix. The decision-maker assigned weights to the criteria, highlighting the importance of the "Layer Height" criterion due to its significant influence on the construction of complex structures and achieving greater detail in anatomical models. The criteria were set with minimization polarity (i.e., smaller values indicate better performance for that criterion) and are displayed in Table 1.

revista interfaces Artigos Originais
V. 13, N. 4 (2025) | ISSN 2317-434X

Figure 3. 3D Images of the Aorta in Printer Slicing Software **a** Slicing in Creality Slicer for the Ender 3 V2 Neo using ABS and PLA **b** Slicing in Bambu Studio for the Bambu X1 Carbon using ABS and PLA **c** Slicing in Halot Box for the Creality Halot Sky using resin.



In this context, the codes "ABS" and "PLA" denote the materials used in FDM-type printers. whereas "RES" refers to the resin employed in SLA-type printer. The printers were labeled with the codes "E" for the Ender 3 V2 Neo and "B" for the Bambu X1 Carbon. The orientation angles of the piece during the manufacturing process are represented by the X. Y. and Z coordinates.

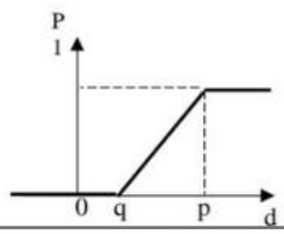
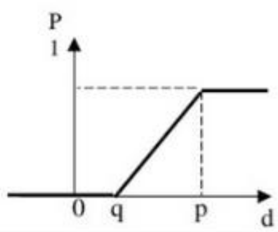
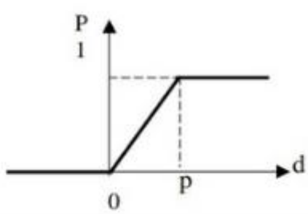
Based on the data structured in the decision matrix and the configuration of the preference functions. calculations for the Positive, Negative and Net Flows were carried out using the Visual PROMETHEE software.

revista interfaces
Artigos Originais
V. 13, N. 4 (2025) | ISSN 2317-434X

Table 1. Decision Matrix.

	Cost (R$)	Time (min)	Layer Height (mm)
Characteristics of the criteria	Min	Min	Min
A_ABS_E_X	3.37	653	0.20
A_ABS_E_Y	2.92	584	0.20
A_ABS_E_Z	2.60	463	0.20
A_ABS_B_X	2.24	165	0.20
A_ABS_B_Y	2.32	152	0.20
A_ABS_B_Z	2.14	125	0.20
A_PLA_E_X	5.03	589	0.20
A_PLA_E_Y	4.46	538	0.20
A_PLA_E_Z	4.08	434	0.20
A_PLA_B_X	4.09	166	0.20
A_PLA_B_Y	4.25	156	0.20
A_PLA_B_Z	3.90	132	0.20
A_RES_X	17.38	338	0.05
A_RES_Y	16.69	587	0.05
A_RES_Z	18.04	727	0.05
Wheights	0.25	0.25	0.5
Preference Function	Linear	Linear	V-Shape
Fixed Parameters (p.q)	p = 10.83 q = 5.66	p = 434 q = 179	p = 0.12

Figure 4. Configuration of the Linear and V-Shape Preference Functions (OUBAHMAN; DULEBA, 2021).

Preference function	Definition	Parameters
	Type: Linear $P(d) = \begin{cases} 0 & \text{if } d \le q \\ \frac{d-q}{p-q} & \text{if } q < d \le p \\ 1 & \text{if } d > p \end{cases}$	Cost p = 10.83 q = 5.66
	Type: Linear $P(d) = \begin{cases} 0 & \text{if } d \le q \\ \frac{d-q}{p-q} & \text{if } q < d \le p \\ 1 & \text{if } d > p \end{cases}$	Time p = 434 q = 179
	Type: V-Shape $P(d) = \begin{cases} 0 & \text{if } d \le 0 \\ d/p & \text{if } 0 < d \le p \\ 1 & \text{if } d > p \end{cases}$	Layer Height p = 0.12

revista interfaces
Artigos Originais
V. 13, N. 4 (2025) | ISSN 2317-434X

This automated process facilitated the assessment of each alternative's overall performance. identifying the most suitable option for 3D printing the aorta model according to the defined criteria. The results. presented in Table 2. offer a structured and comparative evaluation of the alternatives. showcasing the method's effectiveness in determining the most efficient printing solution.

Table 2. Net Flow and Ranking of Alternatives.

	Flow Positive (Φ^+)	Flow Negative (Φ^-)	Flow Net (Φ)	Ranking
A_RES_X	0.4689	0.2193	0.2496	1º
A_RES_Y	0.4286	0.3244	0.1042	2º
A_RES_Z	0.4286	0.3508	0.0778	3º
A_ABS_B_Z	0.1819	0.1071	0.0747	4º
A_PLA_B_Z	0.1799	0.1071	0.0728	5º
A_ABS_B_Y	0.1742	0.1071	0.0670	6º
A_PLA_B_Y	0.1725	0.1071	0.0653	7º
A_ABS_B_X	0.1685	0.1071	0.0613	8º
A_PLA_B_X	0.1681	0.1071	0.0609	9º
A_PLA_E_Z	0.0644	0.1515	-0.0872	10º
A_ABS_E_Z	0.0603	0.1637	-0.1034	11º
A_PLA_E_Y	0.0543	0.1967	-0.1424	12º
A_ABS_E_Y	0.0536	0.2162	-0.1627	13º
A_PLA_E_X	0.0536	0.2178	-0.1642	14º
A_ABS_E_X	0.0536	0.2274	-0.1738	15º

As presented, the chosen criteria highlighted the superior performance of the Creality Halot Sky printer. Although its material cost is higher compared to the others, its ability to produce thinner and more detailed layers, identified as the most relevant criterion in this context, was decisive for its selection. Based on the ranking analysis, there was alternation between the results of PLA and ABS materials, attributed to the minimal variation in printing times within the same printer. This analysis also indicated that the Bambu X1 Carbon outperformed the Ender 3 V2 Neo due to its time-efficiency in production. Nonetheless, resin-based prints consistently ranked among the top three alternatives, underscoring the significance of layer height in producing complex anatomical models. To illustrate the manufacturing process, Fig. 5 shows the A_RES_X piece in four distinct stages. Additionally, the piece was adhered using the same resin employed in its fabrication, preserving its original characteristics. The final result of the printed piece, following post-processing (washing and curing), is shown in Fig. 6.

revista interfaces Artigos Originais
V. 13, N. 4 (2025) | ISSN 2317-434X

Figure 5. Complete production workflow (**a**) Beginning of the printing process (**b)** Final stage (**c**) Piece still on the printing bed with supports (**d)** UV resin curing.

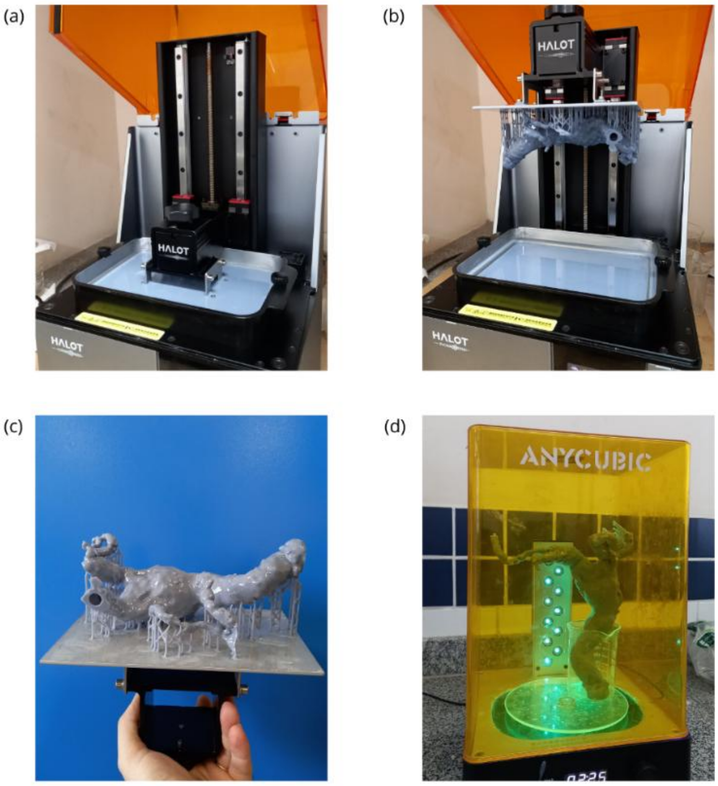


Figure 6. Final result of the 3D-printed aorta.

revista interfaces
Artigos Originais
V. 13, N. 4 (2025) | ISSN 2317-434X

The application of the PROMETHEE II method provided critical insights for defining the ideal parameters for 3D printing an anatomical model of the human aorta. The superior quality of the final product, pivotal in addressing complex clinical cases, emphasizes the strategic advantages of employing this methodology. The findings also highlighted the need for more granular analyses to determine priority criteria, enabling refinements in production processes and the implementation of strategic measures to improve both efficiency and effectiveness. Additionally, the multicriteria decision-making model developed in this study unveiled insights that the decision-maker was previously unable to discern solely through their expertise, thereby transforming the decision-making process into a well-founded practice based on predefined criteria and preference functions. Based on the results obtained from the Visual PROMETHEE software, a Sensitivity Analysis was conducted to assess how small variations in the criteria could influence the final ranking of the alternatives. This analysis identifies the stability or instability of the solutions when dynamically adjusting these values (ISHIZAKA; NEMERY, 2013). As shown in Table 3, the results revealed stability in the evaluated criteria. The Cost and Time criteria, even at their lowest values, maintained proportional contributions to the decision. In contrast, the Layer Height criterion demonstrated significant stability, even with substantial parameter changes, preserving its importance within the model. The absence of abrupt changes confirms the robustness and reliability of the solutions generated by the method.

Table 3. Sensitivity analysis of the criteria.

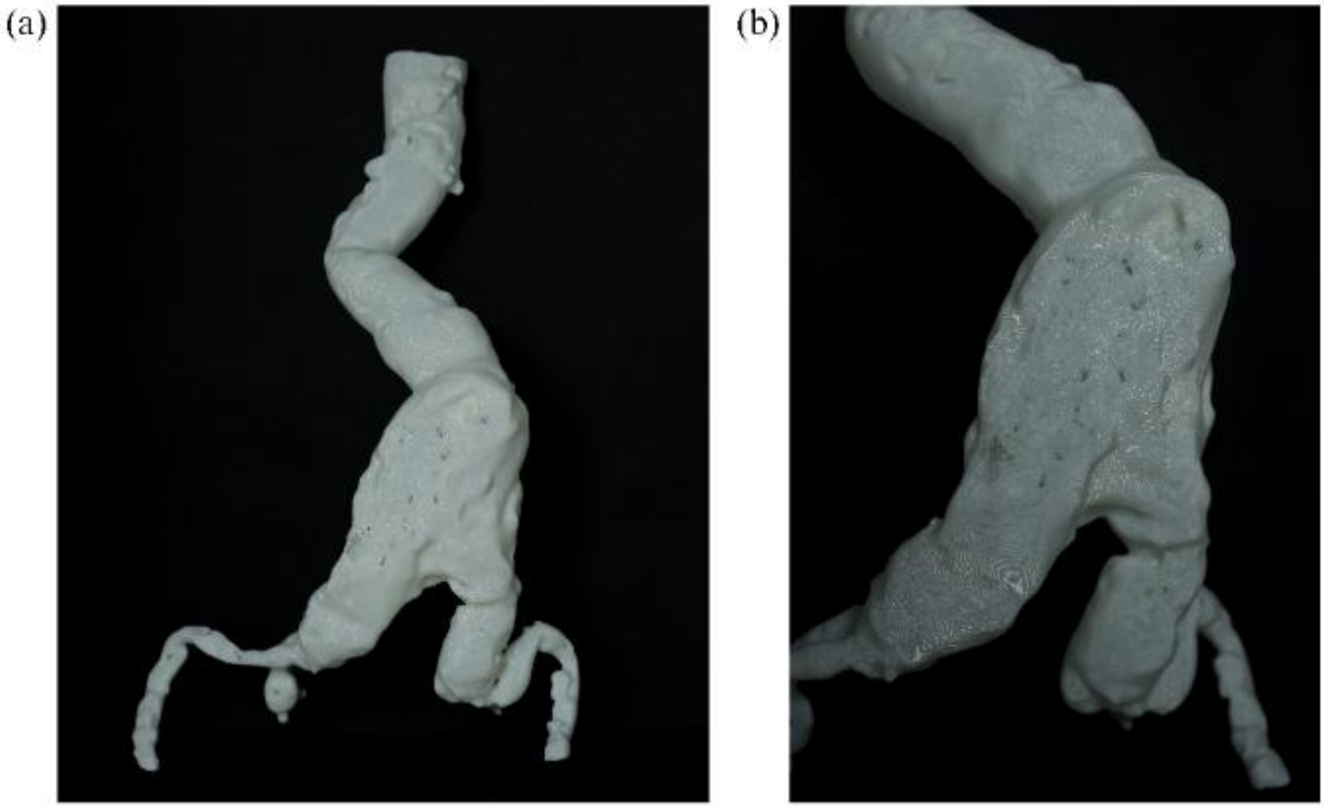
Criteria	Stability intervals of the weights
Cost	[0.00 %; 25.22%]
Time	[0.00 %; 25.22%]
Layer Height	[49.86%; 100.00%]

A comparison was conducted between this study, which employs the PROMETHEE method, and the one presented by Mondal *et al*. (2023), which utilized the AHP and TOPSIS methods. While the work by Mondal *et al*. (2023) was limited to the use of PLA and ABS as materials, this study expanded the analysis to three distinct types of printers and materials, providing a broader perspective.

Regarding the evaluated criteria, the study by Mondal *et al*. (2023) considered Time, Cost, Weight, and Length, whereas our work integrated Weight and Length into the Cost criteri-on, given the direct relationship of these factors with material consumption. Furthermore, the study by Dimitrellou *et al*. (2025) employed a wide variety of materials and scenarios where the inclusion of criteria such as tensile strength and flexural strength was necessary, presented for applications in industry and extreme conditions. In contrast, our study used a more limited set, due to our infrastructure restrictions.

To highlight the relevance of the Layer Height criterion for complex and detailed pieces, a test was conducted with the A_ABS_B_X piece, which revealed that printing was feasible, but imperfections in refinement were observed, as shown in Fig. 7. Although the study by Mondal *et al*. (2023) presents limitations in terms of the scope of criteria and materials, its approach was essential to support and guide the methodology of this work, enabling the development of a more robust analysis tailored to the specific needs of 3D printing for healthcare.

Figure 7. Test print of model A_ABS_B_X (**a**) Complete aorta (**b**) Region with refinement defect.



The application of the PROMETHEE II method for selecting 3D printing parameters of an aorta demonstrates significant potential to be expanded to other anatomical models. Through the method developed in this study, it is possible to incorporate specific technical, clinical, and economic criteria, and apply it to several cases such as heart valves, bones, liver, or even tumor models for surgical planning. Each complex case can consider its own parameters—such as material type, printing time, level of detail, or mechanical strength—allowing the decision-making process to be precisely adapted to the demands of each medical application. In this way, the methodology maintains its robustness and ability to weigh different perspectives, ensuring that the final model simultaneously meets technical requirements and clinical needs.

In addition, the method can also be adapted to hospital contexts with different levels of infrastructure. Large hospitals with their own 3D printing laboratories may include criteria that prioritize model complexity or printing quality, while institutions with more limited resources may adopt criteria that emphasize cost, production time, and ease of operation. PROMETHEE II allows for the adjustment of weights and preference functions according to these conditions, making it a flexible tool to guide strategic and operational decisions. Thus, the approach initially developed for printing an aorta can become a comprehensive protocol to support the adoption and optimization of 3D printing across different realities and needs in the healthcare sector.

CONCLUSION

The application of this method enabled the ranking of alternatives most aligned with established medical standards, highlighting layer height as the most relevant criterion for complex and detailed parts. Additionally, the selected best alternative demonstrated a production time below the average of the other options, while high costs proved relatively insignificant in the context of the obtained results. The active involvement of a decision-making specialist throughout the model development process was crucial, and the PROMETHEE method, with its ability to integrate weights, scales, and preference functions, supported a comprehensive analysis. The Visual PROMETHEE software played an essential role in organizing and efficiently processing the data, ensuring the methodology's robustness.

The present study was limited to the use of desktop printers and widely available materials, which may restrict its applicability to more advanced technologies, as observed by Jewell and Stones (2024) in their analysis of contemporary barriers. Research exploring the potential of 3D printing in conjunction with MCDA, as well as its applications in the healthcare sector, such as the studies conducted by Dimetrellou *et al.* (2025) and Khan *et al.* (2024), is currently under discussion. In this context, future investigations may consider additional multicriteria methods, simultaneously integrating multiple criteria with emerging 3D printing technologies and assessing more complex geometries. Furthermore, the consideration of total costs, including energy consumption, post-processing, and production lead time, is deemed an essential factor for subsequent studies.

A relevant aspect for future research is the practical application of the models, particularly regarding their use in hospital settings or as support in surgical procedures. In the case presented in this study, liquid resin was used, which can be sterilized with isopropyl alcohol but is sensitive to exposure to high temperatures that may cause deformation. In this context, it is essential to investigate appropriate sterilization methods for the printed parts, evaluating both different techniques and the material’s resistance to these processes. We recommend that, for cases requiring sterilization, the analyst and the decision-maker include a “sterilization” criterion with an appropriate preference function, such as the usual function, in which it is possible to indicate whether the material is suitable or not for cleaning or autoclave use.

This study developed a multicriteria decision-making approach for selecting the most suitable 3D printing method for a complex clinical case, which may serve as a reference for future studies requiring optimized selection of printer models and printing axes. The results highlight the effectiveness of the PROMETHEE II method in optimizing parameters for 3D printing, contributing to safer, more efficient, and personalized medical practices. Thus, the application of this approach not only enhances decision-making quality regarding the selection of printing models but also enables the development of action plans focused on optimizing production processes and fostering continuous improvement of additive manufacturing in medical contexts.

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