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3D printing for the reinterpretation of architectural heritage: Proposal of a model

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Abstract

3D printing for the reinterpretation of architectural heritage stands out as one of the most efficient ways of using contemporary printing technologies in terms of architecture. The aim of the study is to present a comprehensive methodology on how to use 3D printing techniques for reinterpretation of architectural heritage. In this context, the scope of the study consists of pioneering information obtained from literature studies focusing on the details of the use of three-dimensional printing techniques in the promotion, preservation and remodeling of cultural heritage and architectural heritage components. The method of the study was determined as identifying leading themes through literature research and presenting a method proposal by grouping conceptually related themes. The unique value of the study is important in that the model to be created offers a potential to affect mass production tools, offices and local governments by incorporating contemporary architectural heritage products into a modeling process that can produce more innovative and faster solutions. The findings of the study show that the different techniques used can respond to different detail scales and different contextual challenges. Each modeling method and strategy creates different feedback mechanisms, mediating the recognition of the architectural heritage element by larger user groups or the more effective protection of the architectural heritage element. In the model presented as a result of the study, which mediates the gathering of the techniques used in different sample projects on a common working ground with a series of successive strategies, a comprehensive basis for which 3D printing solution will be used for which problem is presented and solution suggestions are offered for a case-oriented 3D printing strategy.

1. Introduction

By past and present heritage conservation studies' evaluation, it is understood that some basic steps need to be taken to develop strategies for differences and similarities. In this context, the purpose of the study is to present a comprehensive methodology on how to use 3D printing techniques for reinterpretation of architectural heritage. The scope of the study consists of pioneering information obtained from literature studies focusing on the details of the use of three-dimensional printing techniques in the promotion, preservation and remodeling of cultural heritage and architectural heritage components. While cultural and architectural heritage is evaluated as a part of the past, the differences and similarities between abstract and concrete concepts should be examined in detail. The fact that standardization consisting of definitive criteria has not yet been achieved for determining the value of architectural and cultural heritage works creates certain uncertainties in the sector. However, although there is no official working method based on a scorecard in this context, two basic situations can be mentioned in which the specific prominent values of each work are determined by evaluating it in the context of its relationship with the past and are included in the development processes [1]. Related to this issue, it is understood that 3D printing techniques offer indispensable potential for architecture and cities. A possible standardization would facilitate the integration of cities into modeling strategies. Expansion of cities can sometimes lead to the deterioration of some structures directly due to new urban planning. Instead of demolishing these structures due to updating the urban design, carrying out an evolutionary research process to determine the current situation and define the extension of the design is important both in terms of urban identity and in terms of preserving the current identity of the building and making it known to a wider audience. In the context of more sustainable cities and the integration of sustainability strategies that help make the structure more usable, not only cultural diversity but also tourism and education should support strategies to highlight national treasures. Lack of authority and organizational

problems in this regard basically lead to some impulsive interventions lacking expert knowledge and an increase in the margin of error due to the direct use of traditional professional groups such as carpenters in restoring the building. In order to understand this, it is necessary to investigate architectural evolution in detail and make academic and strategic planning accordingly [2]. With the help of digital technological developments, where special equipment and expertise are needed less and less, the ability to copy many cultural heritage outputs, especially monuments and basic works, has become commonplace, despite various difficulties, in virtual screenings and motivational studies for the dissemination of restoration practices. In addition, an atmosphere in which concerns about the preservation of objects are less prominent with the help of technological modeling facilities dominates cultural heritage conservation strategies [3]. A detailed laser scanning is required to vectorize the structures. In addition, the fact that the teams are multidisciplinary means that the team is not limited to just architects and modelers, but also includes historians and archaeologists. Examining the textures of historical buildings and, in this context, discussing a complex with a rich character in terms of restoration and improvement requires a comprehensive research process. Taking three-dimensional prints of building parts of cultural heritage can be only a part of the holistic steps. Contemporary modeling to be carried out with the aim of restoring an existing monumental structure and reintroducing the value of this structure to the masses should be supported with updates at different detail scales and should be made more comprehensive with more inferences on how a photogrammetric examination can be improved in terms of material typology [4]. In the study, potential work areas and holistic solution suggestions regarding how 3D printing techniques can be used for architectural heritage will be presented, respectively. The extracts that mediate the creation of a contemporary context on this subject can be listed as follows (Figure 1).

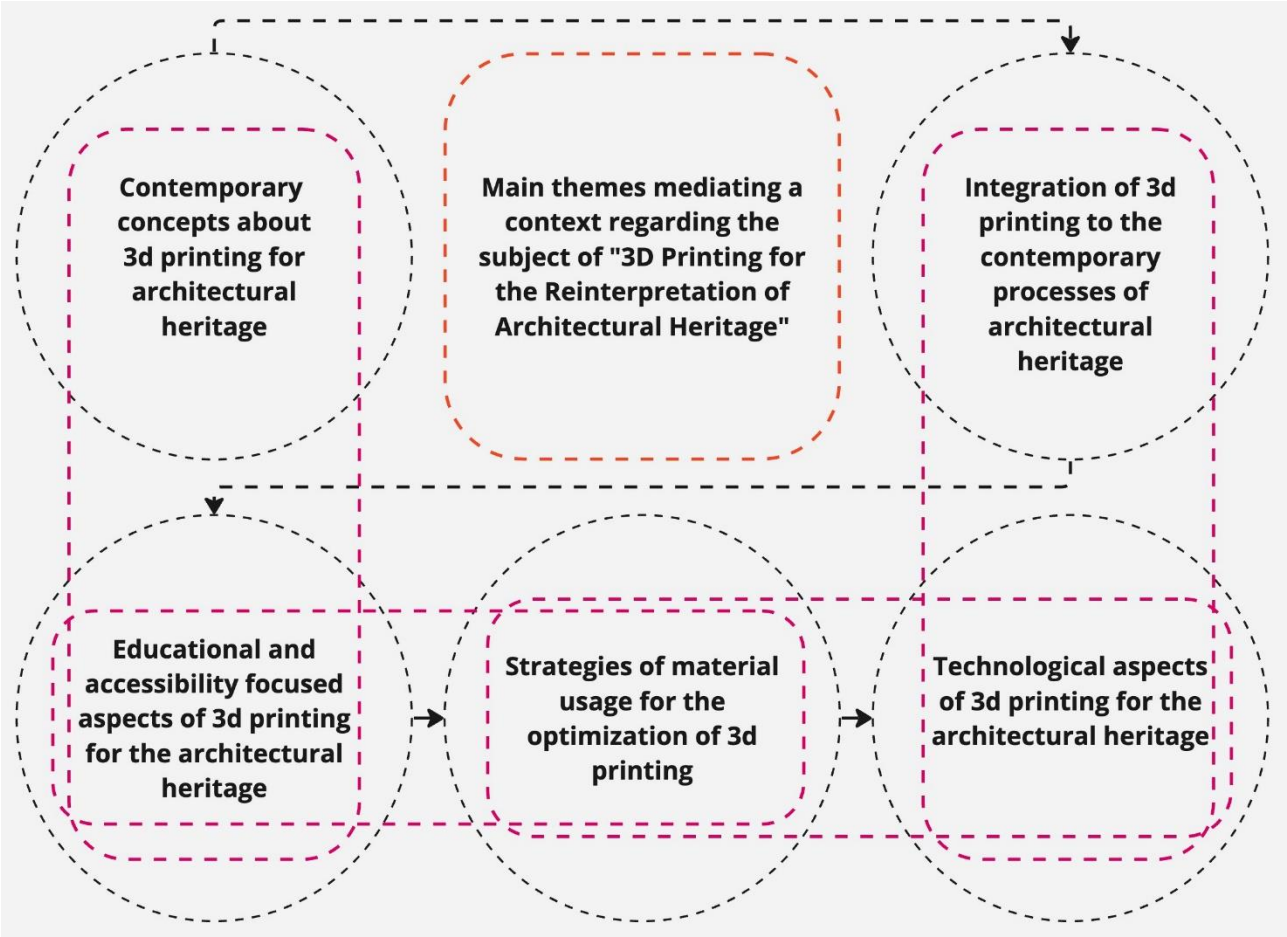

Figure 1. Main themes mediating a context regarding the subject of "3D Printing for the reinterpretation of architectural heritage". Related themes are evaluated together.

2. Method

In the study, basic approaches about the integration of 3D printing to the contemporary processes of architectural heritage were determined, and in line with these approaches, important details about the application examples of three-dimensional modeling and printing processes in the context of leading cases, technology, education, accessibility and materials. has been associated. In this context, the scope of the study consists of pioneering information obtained from literature studies focusing on the details of the use of three-dimensional printing techniques in the promotion, preservation and remodeling of cultural heritage and architectural heritage components. The method of the study was determined as identifying leading themes through literature research and presenting a method proposal by grouping conceptually related themes.

3. Integration of 3D printing to the contemporary processes of architectural heritage

3D modeling stands out as a mandatory support rather than an option, not only in terms of paying attention to performance criteria, but also in solution-oriented approaches directly related to the function. The conveniences provided through digital archiving will trigger different, more technological archiving methods that will be developed with the help of three-dimensional scanning methods in the following stages. The start of preserving cultural heritage items through three-dimensional digitalization will take its place among current studies as a very comprehensive and detailed archiving method, and it will also mediate the reduction of basic risks such as damage to the monument when working with historical buildings. Preliminary studies on the structure can be carried out primarily through models, instead of studies based on close contact that will cause possible damage to the structure, and in the next step, processes based on direct contact with the structure can thus be reduced [5]. Relatedly, as an applied example, professors John Lin and Lidia Ratoi from the University of Hong Kong, blended tradition and 3D printing for adaptive architecture (Figure 2).

Figure 2. Blended tradition and 3D printing for adaptive architecture, Lin, J., Ratoi, L., University of Hong Kong [6].

As an example to the concrete advantages of 3D modeling, in addition to the now well-known utilities of BIM, in terms of operational practice of building conservation, this sample generates agile solutions for complex combinations. It is important to archive 3D models so that they can be used both in analysis and visualization studies and in original studies containing geometric and historical features. As all the steps towards developing a new approach to rationalize the reconstruction process of unbuilt architectures have been tested over the years in architectural drawing courses, it is seen that higher efficiency can be achieved in this regard. It should be taken into consideration that the main motivation for digital reconstructions designed to be used in different scenarios is that they are products that can be adapted to many different solutions and developed as a result of trials and calibration processes. Archiving 3D models so that they can be used both in analysis and visualization studies and in original studies containing geometric and historical features is one of the most concrete achievements in this regard [7]. However, it should not be forgotten that discussing the limitations of three-dimensional modeling is at least as important as discussing its benefits and what it can do. It is known that virtual graphics offer more efficient solutions in both animation creation and infographic solutions, if the basic inputs regarding the limitations of three-dimensional printing are taken into account in the processes of representing textures and color features [8]. In this context, Barry Wark uses sand to create an intricate 3D-printed wall which include sequences represents dramatic phases (Figure 3).

When all these are evaluated together, it becomes clear that all situations in which architectural heritage becomes more accessible to the public can directly affect the rate of use of three-dimensional modeling in future scenarios. It is understood that new additive techniques in printing technologies and the integration of special software into modern topographic solutions can accelerate this process [9]. The frequent repetition of some architectural themes and the failure to directly address the new problems arising from the current era through original solution scenarios constitute a major obstacle to supporting design-construction processes. While the design theory of three-dimensional printing and its role in determining the living spaces of tomorrow are analyzed through case studies, it is important to evaluate the subject of home for everyone and additive home production in terms of the integration of a series of mass production methods through different paradigms

[10]. The potentials of the basic integration scheme regarding this subject are shown in the image below (Figure 4).

It seems that contemporary studies on this subject have achieved success after many trials and prototyping steps. As one of the most successful examples of producing strategies that will provide solutions to specific scenarios, another prominent example related to this subject is the 3D print work produced for the Notre-Dame de Paris Cathedral in situ in the CRIACIV wind tunnel (Figure 5).

Figure 3. 3D-printed Wall, Wark, B., Photo Credits: Wark, B., [11].

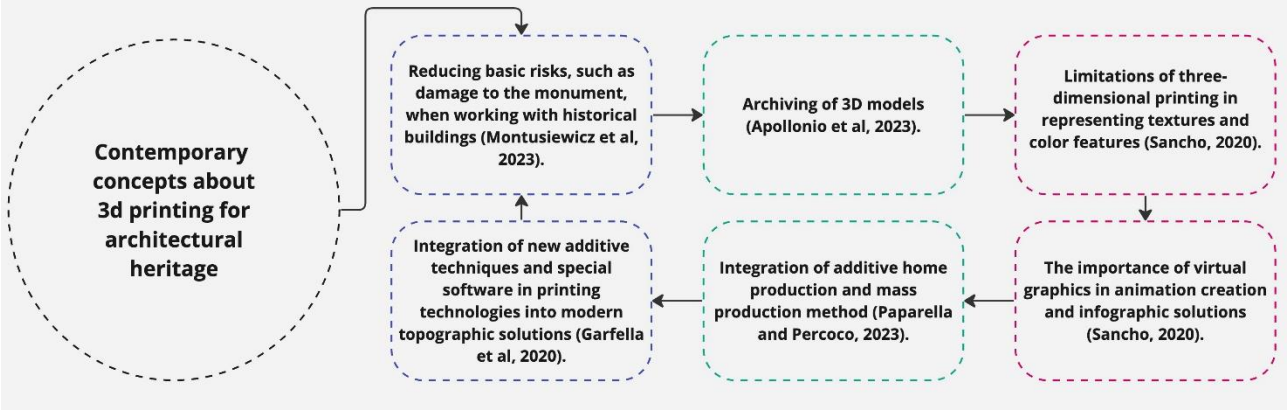

Figure 4. Contemporary concepts about 3D printing for architectural heritage.

Figure 5. Notre-Dame de Paris Cathedral in situ in the CRIACIV wind tunnel, Lynxter, Photo Credits: Lynxter., [12].

3.1. Developing strategies via cases in terms of potentials and necessities

Pereira et al. [13] emphasizes that the glaze via different cases are evaluated together, leading conclusions are reached. In this context, it becomes important to revitalize the basic complex planning in design in a contemporary style while also developing it in parallel with the interests of the manufacturers. In order to include basic planning for future residences in a strategy aimed at increasing functional performance, the importance of using digital preservation and production technologies becomes evident in cases where the restoration and reproduction of architectural structures is required. Market share studies related to 3D modeling concerning the Gulf countries indicate that this technology can be used at much more affordable prices in the near future [14]. In the case of THK in Singapore, a series of applications that include the definition of new coordination steps based on eye movement and hand movement of breakthroughs in perceptual interaction technology can be included in the working processes for modeling architectural cultural heritage. Utilizing three-dimensional modeling and output techniques for the protection of architectural and cultural heritage has also become a digital trend, so it finds its place in the industry, and support is received from virtual reality and augmented reality technologies by incorporating the interaction mode into the process to disseminate this approach to protecting cultural heritage [15]. Similarly, the results of research by a team that developed a workflow to create a virtual replica of the Acropolis for 3D printing are striking. It is seen that three-dimensional modeling provides a great efficiency in experiencing huge ancient structures such as the Acropolis, which has its own details and positioning style, as visitors have a more holistic experience and the three-dimensional copy can be experienced more easily than the believer. Including students in the listening process with an active program and updating both students' programs and travel routes accordingly provides significant added value. Such studies also provide original contributions in terms of documenting the architectural complex with digital research techniques [16].

In addition, in the example of post-fire reconstruction, the striking gains of three-dimensional modeling can be seen more clearly. The flexible opportunities offered by wooden structures to present and re-evaluate documents belonging to historical heritage in a way that contributes to the experimental method also produce unique solutions in terms of three-dimensional modeling offering flexibility solutions specific to each building material [17]. Similarly, if a residential building has modern features, developing a strategy on how to improve the algorithm that creates it by analyzing the basic elements and the dominant system can provide important clues about how the housing units that make up the urban environment may change in the future. Details that can be reflected in the external form require going beyond the conceptual foundations of architectural design, not only in terms of urban planning and building architecture, but also in terms of ecology and building design [18].

Findings regarding the importance of artificial intelligence in the three-dimensional printing process require a systematic analysis including the application processes of artificial intelligence techniques. In this context, the use of artificial intelligence in the optimization of the process in the context of the difficulties that arise for the standardization of the details of building manufacturing, not only the basic stages such as print quality control, but also more complex steps for changing the printing parameters, improving the printing and output process, and therefore errors in the modeling process. It provides clues that correction may be possible [19]. It is clear that technologies such as Building Information Modeling, 3D printing and 3D scanners, through the development of complex answers, offer some unique fundamental variables not only in the context of producing effective solutions for the protection and preservation of traditional buildings, but also in terms of re-investigating and improving conservation processes in terms of deficiencies and errors. can be seen. Gathering and storing architectural heritage and cultural heritage in a digital archive through three-dimensional modeling is no longer considered an extraordinary action as it used to be, and is considered one of the cornerstones of contemporary museology. It is known that photogrammetry offers very practical solutions to create models of old buildings in technologically lagging countries such as Pakistan. Photogrammetry is also meaningful because it resolves old structures without damaging them [20]. In addition, unlike other studies, in order to achieve a healthy result in modeling, a high-resolution reticulated structure was first created, and with the help of this reticulated structure, a geometric compatibility was achieved in which high-depth internal and external details that make important details and basic folds visible in non-typical solutions can be accurately represented. It is possible. The Porta del Drac example in Pavelló Güell is one of the important examples in the sense that it contains a lot of detail that three-dimensional modeling steps that offer a comprehensive combining approach can be considered technically more successful than other competitors [21]. When a comprehensive and relational inference is made regarding this issue, the following conclusions are reached (Figure 6).

3.2. Technological aspects of 3d printing for the architectural heritage

Developing strategies via technological aspects of 3d printing for the architectural heritage works as a balancing tool for reorganizing existing buildings' preservation processes. In this context, it becomes clear that virtual promoters should be included in traditional heritage-oriented conservation practices. The importance of collecting 3D geometric documentation of historical buildings in addition to 2D geographical data is supported by the creation of a 3D environment based on webGL, in addition to the use of a webGIS viewer, when large data files can be examined as three-dimensional contents through any web browser without downloading. and it becomes possible to experience it. In this context, it can be seen that cultural and architectural

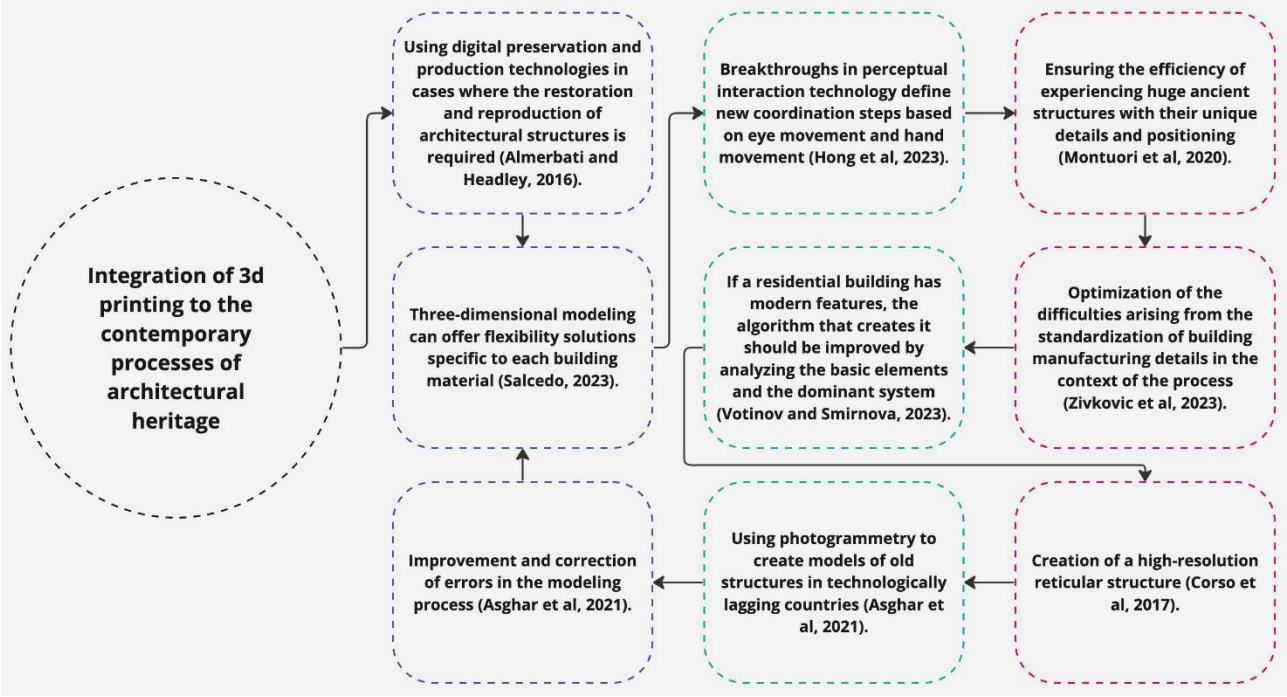

Figure 6. Integration of 3d printing to the contemporary processes of architectural heritage.

heritage inventories can be included in a seamless flow in terms of cartographic archiving, presentation and representation [22]. One of the most important details in creating a digital model using photogrammetry technology is related to the opportunities offered by photogrammetry, helping to clearly document even the finest details of the existing architectural and cultural heritage. The importance of a detailed representation not only in wooden walls and ceilings, but also in contemporary modeling techniques for masonry, carved images and inscriptions on stone, points to the importance of taking advantage of the opportunities offered by photogrammetry. Modeling of cultural heritage objects of federal importance with contemporary approaches without causing any information or representation errors is achieved by using polygonal 3D modeling and FFF 3D printing technologies, in addition to photogrammetry [23]. Many cases that aim to develop a solution that will benefit the socio-economic structure of the country while investigating the reasonableness of the means will be considered successful to the extent that they can suggest guidelines for the development of strategies for the virtual retrieval of cultural heritage. In this regard, any approach that details how architecture plays an important role in designing the metadatabase with optimal user experience and the relationship of sustainable development plans with the architectural scope in the metadatabase will be of great importance. Additionally, an approach that combines holographic elements with physical architectural elements, as well as using Midjourney to present detailed representations of virtual reality (VR) and augmented reality (AR) systems, is considered efficient in many respects. This issue can be mentioned in all cases where rediscovering a heritage or examining the discovered heritage in detail chronologically has special meaning, as in the case of Egypt [24]. Related to this issue, it is seen that the inclusion of three-dimensional scanning data in the process by evaluating it together with the data obtained from BIM, in addition to presenting research reports, also has a critical role in the more meaningful evaluation of data sets that have a direct meaning in the creation of digital cities. In this context, the wooden architectural heritage of cities such as Korea can be re-evaluated and developed [25]. Similarly, the infrared thermography (IRT) technique may open new horizons in terms of thermal imaging through the potential of developing thermal cameras. Diagnostics of architectural heritage can present a complex approach in terms of additional data integration and in the context of temporal analysis of historic buildings. The development of the possibilities of renewal and modeling of historical information will, in this context, point to new horizons in terms of adaptability to future challenges. In line with these gains, the overlap value of the results of infrared thermography in energy efficiency is different from each other [26]. In addition to the criteria mentioned above, it is known that a textured modeling is one of the most fundamental deficiencies in basic three-dimensional modeling techniques. In the decision-making processes, the development of key criteria such as deep excavations and imaging technologies using a combination of multiple imaging strategies, the efficiency of UAV photogrammetry and the definition of the SfM workflow, not only the traditional plan and section-based modeling solutions, but also the multi-layered models developed to complement the facades and interiors of the work. It participates in the workflow by bringing opinion-based solutions to the fore. It is clearly understood that some deep excavations do not have legal basis and three-dimensional modeling is essential for data collection, and the potential of UAV and CV should be used mostly in study, documentation, diagnosis, intervention planning, monitoring and decision-making processes [27]. In another example where a three-dimensional model was

developed using a stereogram miniature of a collapsed cathedral, image parallax was used to provide a comprehensive configuration. In this context, it should not be forgotten that a matching and optimization process is carried out with the help of human hands and minds in the use of old photographs and sketches. On the other hand, it is understood that creating and printing three-dimensional models that can be used to graphically redesign and edit old architectural pieces can only be completed by incorporating digital technologies into the system [28]. As a related issue, one of the main initiatives that will completely change the perspective of the sector by occupying one of the most important points in the finding of three-dimensional modeling in the construction sector is to take an approach that focuses on extrusion printing in concrete to eliminate the need for formwork. Innovations in concrete production methods based on 3D printed molds not only offer some basic strategies to reduce the corrosive effect on polymer shells, but also help produce an alternative to the inefficiency of traditional flat panel molds. Optimizing polymer shells for the development of polymer shells also offers a solution to reduce carbon emissions from concrete [29].

The fact that 3DP and 3D scanning can be combined with photogrammetry and laser scanning techniques makes it important to determine the role of some important opportunities in the process flow in many basic areas such as the rehabilitation of building elements. Important real-life solutions that require the evaluation of the information summarized in the rehabilitation of cultural heritage and the development of new mixtures such as lime trees compatible with the existing surface are also important indicators that digital modeling technologies play a direct role [30]. However, of course, three-dimensional modeling can be positioned at a disadvantage compared to manual markets due to some uncertainties in digital processes and the incompleteness of manual solution processes. One of the main advantages that compensate for these disadvantages is the elimination of basic errors based on human movements and basic variables such as the flawless operation of CNC machines in matters requiring technical details such as scaling. On the other hand, it can be observed that while rapid prototyping technology provides an easier printing and analysis process among students in basic tools such as parametric modeling, there are cases where it is inadequate in more multi-layered solutions [31]. The fact that basic information obtained through building information modeling technology and which has the potential to be used for restoration can be used to contribute to the evaluation process of architectural heritage in the context of historical buildings shows that both two-dimensional and three-dimensional drawings can initiate an integration process that can directly contribute to buildings in the repair steps. It is observed that in order to make urbanization more sustainable, multidimensional information should be optimized in layers, as in the Chinese example, and included in urban renewal strategies in the sustainable urbanization process, and included in work areas as a whole of complex systems where three-dimensional modeling is used together with building information modeling technologies [32]. In a holistic conclusion regarding this issue, the details of a technological staging scheme that can contribute to the holistic model in the next step can be seen (Figure 7).

Figure 7. Technological aspects of 3d printing for the architectural heritage.

3.3. Educational and accessibility focused aspects of 3D printing for the architectural heritage

Prioritizing the use of museums and architecture schools is of critical importance in terms of three-dimensional modeling of cultural heritage. The complexity of the 3D printing process related to many variables such as budget, time, size, labor, material, purpose and the direct relationship of modeling for 3D printing with the teaching analysis and design, file formats, software, integration and development of 3D printing equipment, cultural development by modeling with 3D printing. These emerge as fundamental problems and leading variables in the representation of heritage. In this context, it should also be mentioned that representing the differences and similarities between the three-dimensional model, which is one of the least mentioned topics in the representation of cultural heritage, and the original version of the design, has an important place in the process [33].

While some strategies are being developed for the development of architectural project courses in architecture schools, it is understood that the use of three-dimensional modeling and its output in studio courses has some basic advantages. These advantages have many different features and basically provide flexibility between the steps regarding the difference in the way of thinking in the design process, parametric modeling's concept thinking. It offers some important gains, such as reorganizing the steps of associating with models more frequently and developing competencies among students regarding the use of technology in the design process more gradually [34]. Some basic steps that support and improve students' conceptual learning during architectural education are directly related to the issues of how correspondence theory can be used in education together with three-dimensional printing methodologies. The shortcomings and changeable aspects of three-dimensional printing research regarding technology and construction applications provide a detailed study area, especially through the use of concrete material, in order to explain architectural design to students in three-dimensional printing methodologies in architecture schools [35].

Although accessibility represents a wide field of study, it is known that today, the most fundamental field in which architectural products, as cultural heritage objects through three-dimensional outputs, mediate connections with users who have accessibility problems, is provided through strategies developed for the visually impaired. All changes that can be made in contemporary museums to provide visually impaired people with more advanced opportunities can be made more effective with the help of three-dimensional scanning and digitalization technologies. The conveniences this situation provides in creating virtual museums can be explained through a powerful example, with the experiment of making prototypes of museum objects to be updated for the use of blind people in the Silk Road region available to large audiences through the use of scanning, modeling and 3D printing. It is clearly understood that new technologies to be developed in this regard must be compatible with the Braille alphabet. An advanced technology in terms of interchangeability and smoothness will mediate the faster and more effective use of the Braille alphabet in contemporary museum techniques [36]. Another detail that can be related to this issue is that the way visually impaired people perceive and experience the world is completely different. Here, kinesthetic recognition of the architectural element and its ability to be included in the work will be considered an important added value. Since the act of seeing is a title that should be evaluated directly within the cognitive context, three-dimensional modeling stands out as an added value for the constraints of the cognitive field in terms of museum studies and history teaching. In an exemplary study that presents a modified procedure for creating scalable copies of architectural objects using additive technology to obtain digital 3D models with the use of Autodesk Inventor 2021 version, findings are presented that diversified scaling of elements facilitates kinesthetic recognition of the relevant architectural object for participants and their near future potential. its importance is understood [37]. Education and accessibility are diversified as cornerstones of a similar motivation, and the related overarching and gradual scheme forms an important pillar of the subsequent holistic scheme (Figure 8).

3.4. Strategies of material usage for the optimization of 3D printing

Developing autonomous techniques regarding the use of materials contains important information that each architectural structure and the context of this structure differ. In this context, in addition to normal filament use, innovative concrete casting techniques and composite material use also point to areas that can be improved in the sector. The use of recycled clay in three-dimensional printing technologies, as an effective answer and alternative to the constraints of three-dimensional modeling with the use of traditional filament and the adaptation to new natural materials of the near future, is suitable for many technological situations where environmental impact is directly related to material waste. It can produce natural answers. Using recyclable clay for a circular economy means that recycled clay obtained from energy-intensive production processes, construction and demolition waste or other sources can contribute to sustainable architecture in different aspects. In this approach, clay waste is first collected, then processed and finally converted into printable material [38].

The production method that stands out as additive manufacturing, which mediates the creation of intricate objects by using many materials such as plastic, metal, concrete and sand, offers strong clues about how the technology can develop. It is understood that three-dimensional solutions developed by using different materials together, instead of the restrictions in the use of conventional filaments, will provide much more efficient results. It is seen that the solutions to be provided in this context can be found not only in construction technology, but also in many areas such as human body parts and new technological clothing [39]. In contemporary studies on the subject, light-sensitive resin, nylon and stainless steel as three-dimensional

printing materials are evaluated in terms of their advantages and disadvantages, and material science tests are carried out according to the material performance index, triggering some basic solutions to meet the need for cultural and creative products in historical buildings. By integrating and evaluating the advantages of the materials to be used in three-dimensional modeling, the most suitable product in terms of three-dimensional modeling can be used. The integration of material performance index composition, cultural heritage, product design, quality system and material science literature will be decisive at this point [40].

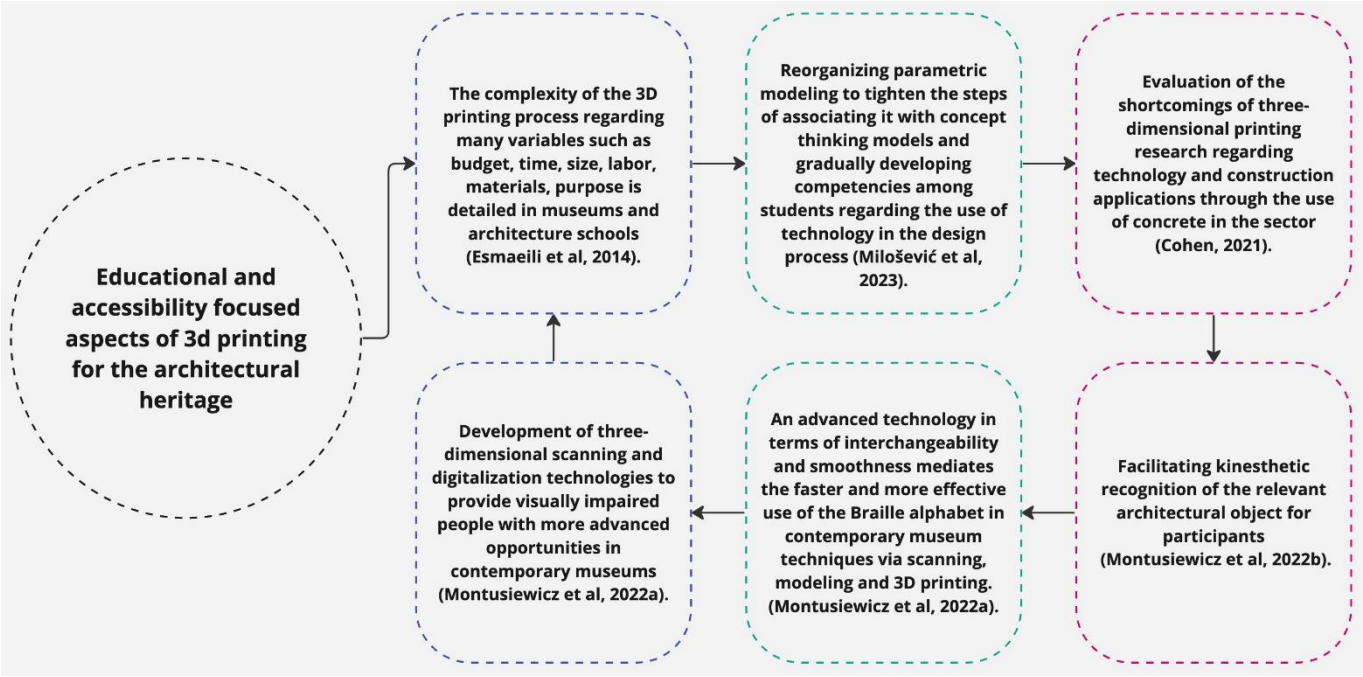

Figure 8. Educational and accessibility focused aspects of 3d printing for the architectural heritage.

One of the most common problems experienced in three-dimensional modeling in areas of use related to architecture is that the bridging steps that occur during printing are too few and weak, preventing the creation of a strong enough model. For example, in order to successfully model an architectural brick prototype, these bridging mechanisms must be handled with a solution-oriented approach, where the properties of the filament materials are evaluated through a multi-stage development process. It is understood that the methods that can be used for filament-reinforced three-dimensional printing of the material also require a comprehensive testing phase for the composite material as an extrusion step. In this context, it is seen that basic criteria such as lightness, reticulated structure, tensile strength or pressure resistance can be improved with filament-reinforced prints and modeling techniques with increased bridging ability [41]. In this context, it is extremely important that the strategies developed for material use match the right software selection. An example of modeling a Roman sarcophagus and tomb stele in the Aksaray Museum using two different software can provide a comparison matrix to ensure maximum efficiency in the 3D context of the historical environment by choosing the right software [42]. All related strategies that enable the assessment of the damage status of the building, in order to support the use of digital technologies that facilitate the storage, sharing and management of existing data, are decisive in this context [43]. Holistic and sequential approaches to material use represent a field of study directly related to innovative solutions in modeling architectural heritage through three-dimensional printing processes in the context of technology, education and accessibility (Figure 9).

4. Discussion and Conclusion

In this context, bringing together the data obtained through the prominent cases and interpreting them in the context of technological possibilities stands out as the first step. The data obtained here is developed for use in the field of education to help children, young people and those with accessibility problems easily access cultural and architectural heritage elements. Finally, a process similar to the development studies carried out in the field of education functions as a laboratory of processing the results of the cases with the help of technology. Respectively, the data obtained from the cases, technology and training steps are combined with the innovations that will be made and are being made in the field of materials in order to model the cultural heritage and architectural heritage elements more easily and more realistically and in accordance with the experience, and a final product is aimed to be achieved. The most common references to addressing today's problems in this order are the basic concerns about reducing basic risks such as damage to monuments when working with historical buildings, strategies for archiving 3D models, identifying the limitations of three-dimensional printing in the representation of textures and color features, creating animations and infographic solutions, It is seen that the understanding of the importance of virtual graphics, the integration of new additive techniques in

printing technologies into modern topographic solutions, and the integration of additive house production and mass production method. In this regard, the holistic model is presented below, and then the basic determinations that will mediate the development of this model for 3D printing for the reinterpretation of architectural heritage are listed (Figure 10).

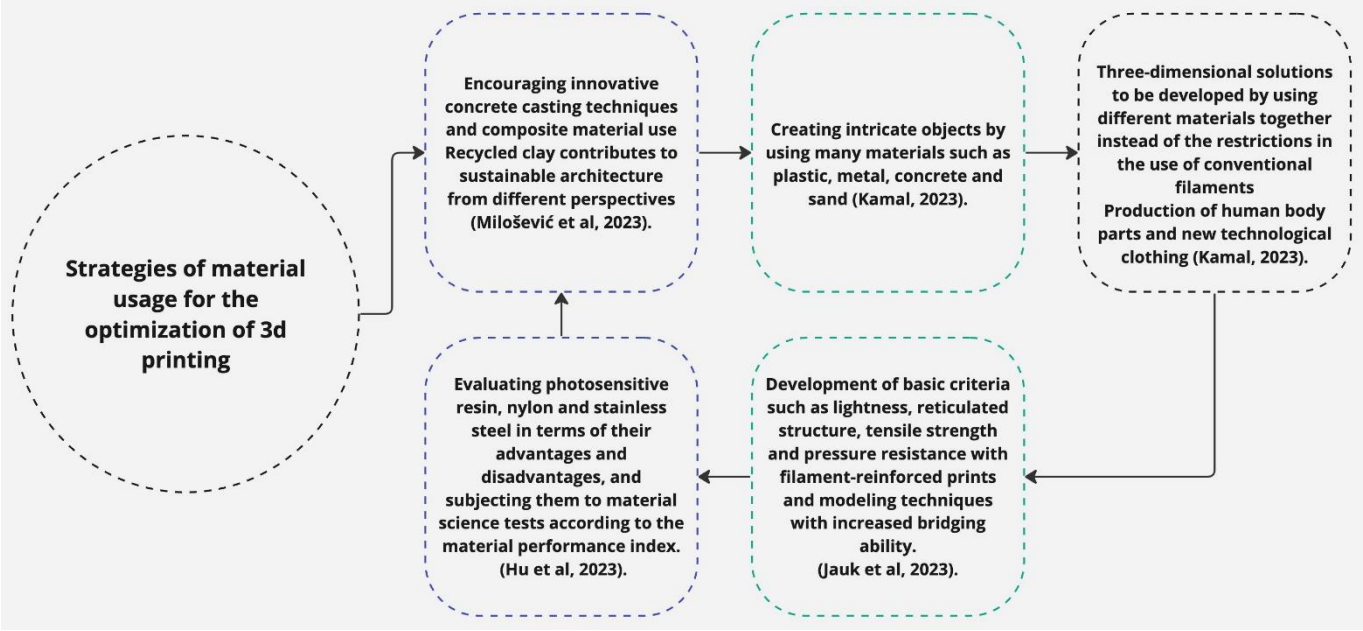

Figure 9. Strategies of material usage for the optimization of 3d printing.

The basic determinations that will mediate the development of this model for 3D printing for the reinterpretation of architectural heritage are as follows:

• In cases where restoration and reproduction of architectural structures are required, the use of digital preservation and production technologies stands out as a necessity, not an option.

• In order to ensure the efficiency of experiencing huge ancient architectural structures with their unique details and positioning style, new coordination steps based on eye movement and hand movement of breakthroughs in perceptual interaction technology should be defined.

• Optimization of the difficulties that arise in the standardization of building manufacturing details in the context of the architectural heritage focused process can be possible by determining a strategy to improve and correct errors in the modeling process.

• If the collection of 3D geometric documentation in addition to 2D geographical data is achieved by creating a 3D environment based on WebGL, offices can include and benefit from holistic databases for modeling of architectural heritage into their systems.

• In addition to photogrammetry, the use of polygonal 3D modeling and FFF 3D printing technologies mediates the modeling of architectural heritage in accordance with contemporary scenarios. The use of photogrammetry and different workflow diagrams in documentation, diagnosis, intervention planning, monitoring and decision-making processes is the clearest example of this.

• Using Midjourney to present detailed representations of virtual reality (VR) and augmented reality (AR) systems and contributing to the creation of research reports by evaluating three-dimensional scanning data together with data obtained from BIM, not as two separate topics, but a common working area. They should be evaluated and operated as serving components.

• Evaluating the infrared thermography (IRT) technique in terms of thermal imaging imaging and utilizing image parallax to provide a comprehensive configuration will enable the technology to be used in a wider area in the future as alternative solutions in remodeling the architectural heritage.

• In extrusion printing on concrete, reducing the corrosive effect on polymer shells and sector-based development and rapid prototyping in CNC machines should be connected to a common line of work. Incorporating BIM-based information into urban renewal and architectural heritage strategies in the process of sustainable urbanization should also support this process.

• The complexity of the 3D printing process regarding many variables such as budget, time, size, labor, material, purpose should be detailed in museums and architecture schools, and parametric modeling should be reorganized to increase the frequency of association steps with concept thinking models, and the proficiency in the use of technology in the design process should be gradually increased among students. Its development will play a direct impetus for the development of contemporary museology techniques in the field of education.

• Evaluation of the shortcomings of three-dimensional printing research in architectural heritage regarding technology and construction applications through the use of concrete in the sector and the ability to deliver prototypes of museum objects to large masses through the use of scanning, modeling and 3D printing can also be integrated into mass production processes as an accessibility problem.

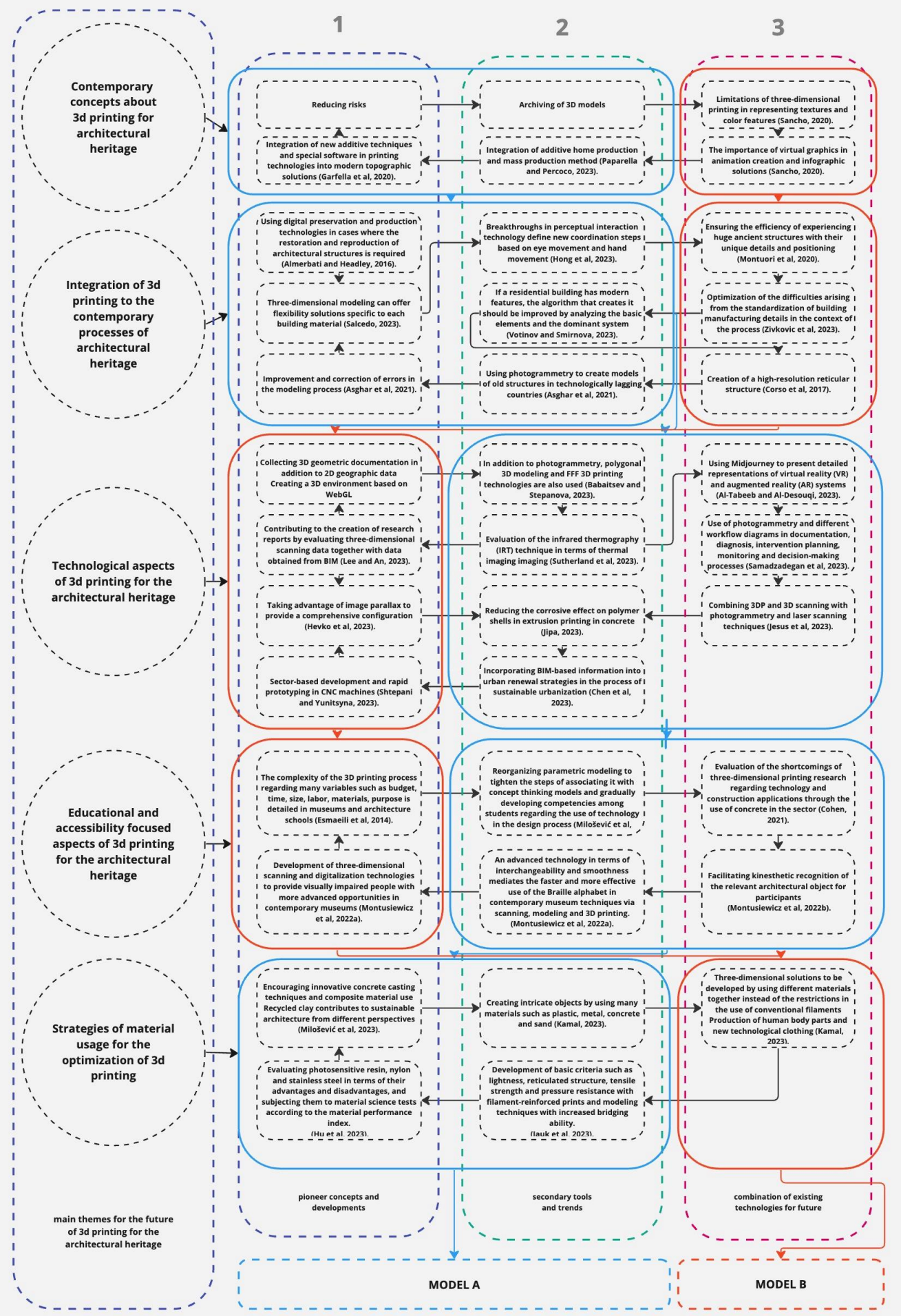

Figure 10. Model A and Model B, including main themes for the future of 3d printing for the architectural heritage, pioneer concepts and developments, secondary tools and trends and combination of existing technologies for future.

• In addition to the development of three-dimensional scanning and digitization technologies to provide visually impaired people with more advanced opportunities in contemporary museums, the advantages to be gained through the faster and more effective use of the Braille alphabet in contemporary museology techniques in terms of changeability and smoothness will enable the three-dimensional output system to be widely used. transfers it to the fields. In this way, facilitating the kinesthetic recognition of the relevant architectural object for the innovators is also achieved as a lateral gain.

• The easiest way to introduce and implement the promotion of innovative concrete casting techniques and the use of composite materials is seen in the contribution of recycled clay to sustainable architecture from different perspectives.

• The impact of architecture will be felt more in work areas that create intersections through the production of human body parts and new technological clothing, with three-dimensional solutions to be developed by using different materials together instead of the restrictions in the use of conventional filament.

Conflicts of interest

The authors declare no conflicts of interest.

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