



# BIM and Rapid Prototyping for Architectural Archive Heritage

Giulia Bertola<sup>(✉)</sup>

Department of Architecture and Design, Politecnico di Torino, Viale Mattioli 39, Turin, Italy  
giulia.bertola@polito.com

**Abstract.** The present work intends to show a rapid prototyping experience carried out starting from a three-dimensional model realized with the Revit 2021® software of the never realized project of the “Due ville a Capri” by the Turin architect Aldo Morbelli. The scale model was realized through the application of two digital manufacturing techniques: additive, the Fused Deposition Modeling (FDM), used for the buildings and for the external built elements made of plastic and subtractive, the Laser Beam Machining (LBM), for the slope on which the two buildings stand, realized through the superimposition of cardboard layers.

The research after a first phase of redesign of the archival documents of the project in Revit 2021® focused on the preparation of the file for the realization of the real model, defining the printing scale, the materials, the exporting the file in STL format and the necessary operations to repair the file using Autodesk’s software for additive manufacturing, Netfabb®.

**Keywords:** Rapid prototyping · Manufacturing · BIM

## 1 Introduction

The present work intends to continue a study previously carried out on the archival material relating to the project of “Due ville a Capri” by Aldo Morbelli (1942) through the use of traditional techniques and tools [1] and subsequently developed through digital modeling using the BIM Revit 2021® software (see Fig. 1).

This proposal is aimed at the valorization, cataloguing, digitalization and prototyping of the Archival Heritage present in the Archives of the Central Library of Architecture “Roberto Gabetti”, Politecnico di Torino, in particular the BCA Archives. Aldo Morbelli fond. Three-dimensional models and the digitization of archival records represent today a key element for a deep understanding of the architectural projects of contemporary architects. The real models built must be able to be used at different scales, for different users and for different uses and also play an important role in communication and dissemination processes [2]. Here, the author, following a brief exposition of the case study, intends to focus on the elaboration of the BIM digital model aimed at rapid prototyping, exported in STL format and corrected by Autodesk’s software for additive manufacturing, Netfabb®. In the following paragraphs, an in-depth study is developed on the printing techniques most suitable for the realization of the real scale model: Fused Deposition Modeling (FDM) and Laser Beam Machining (LBM).



**Fig. 1.** Interpretative drawings for the project of the “Due case a Capri” (Drawings by Giulia Bertola)

## 2 Architectural Language of Aldo Morbelli and the Project for the “Due Case a Capri”

Aldo Morbelli (1903–1963) is an Italian architect, born in Orsara Bormida in Piemonte. In the Thirties, after graduating from the Faculty of Architecture in Rome, he founded his own professional studio in Turin. During his professional activity Aldo Morbelli deals mainly with the design of single-family houses, social housing for the INA-CASA floor, buildings for entertainment, corporate headquarters and post-war reconstruction works, also dealing with interior design and furniture design.

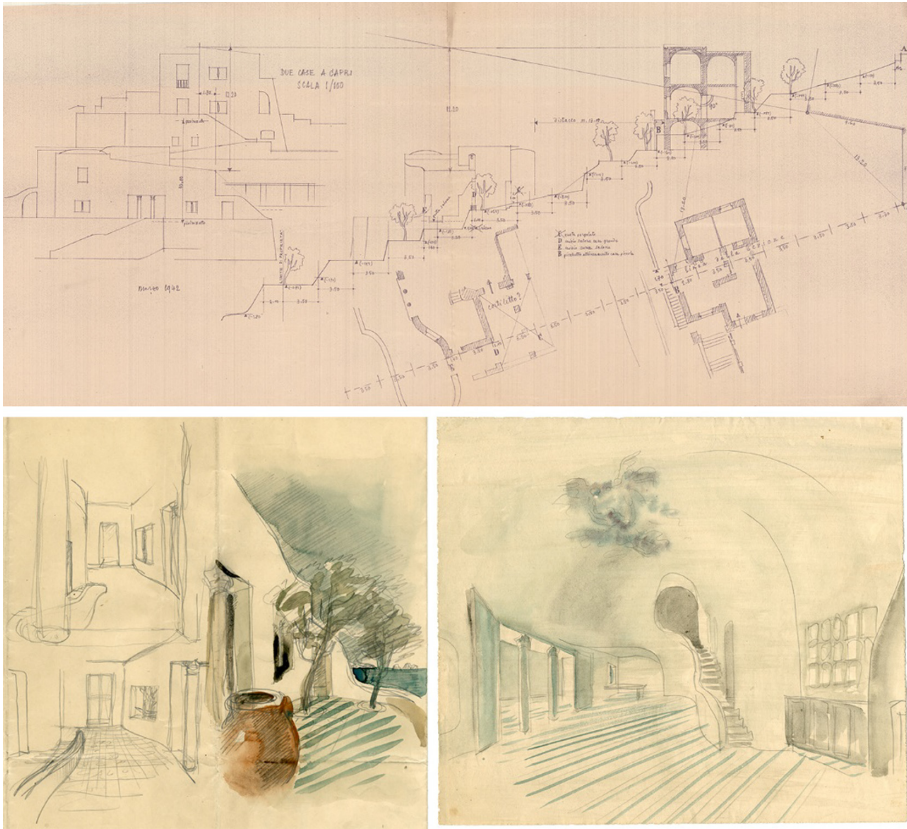
Aldo Morbelli’s archive, preserved in the Library of Architecture “Roberto Gabetti” of the Polytechnic of Turin, contains numerous documents relating to his projects, both completed and unfinished. The figure of Morbelli, despite the fact that in the past many of his projects were recognized in internationally renowned magazines and that critics dedicated a monographic issue on *L’architettura Italiana* to his single-family houses, is still little studied today [3].

In the present case study, he affirms himself through a poetics that tends to a process of formal simplification, to a careful search for balance between the project and its insertion in the context, bringing out a strong reference to Mediterranean architecture. In particular, he obtains interesting poetic results through the composition of white plastered walls combined with wood and other traditional materials used for the realization of pergolas, terraces and walls.

The buildings (see Fig. 2), never realized and defined by Morbelli Casa Grande (the lower) and Casa Piccola (the higher), are located on a plot of land among the olive groves at the foot of Mount Tuoro, in the region “La Cercola”. The two buildings are oriented towards the west because of the slope of the land.

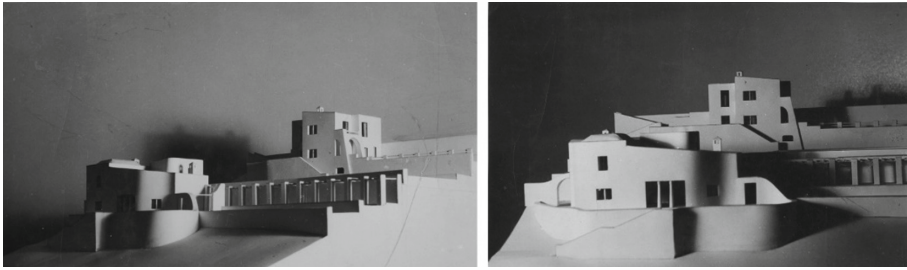
The compactness of the volumes is interrupted thanks to the reference to local architecture, solved through the insertion of lowered arches and the choice of white color for the floor and wall covering, without seeming vernacular. The wall masses were modelled through sinuous volutes interrupted by simple cubic volumes in which the architect went to cut out the openings.

Both buildings are enriched by large pergolas arranged along the level lines that represent an extension of the houses themselves. Even in the interior spaces there is a



**Fig. 2.** A. Morbelli, technical drawings of “Due case a Capri” and study sketches for the two houses in Capri (Archivi BCA. Fondo Aldo Morbelli).

clear intention to give the rooms a plastic sense: the walls and distributive elements, such as the “S” staircase of the Casa Grande adapt to the plan. The small house is on three levels, basement floor for servants and storage, ground floor with living room and kitchen, through which is accessed through a sloping wall with arched entrance, and first floor with two bedrooms. The Casa Grande is on two levels only, the lower one is intended for the living area, with the living and dining area at double height that occupies the entire front with sea view and that of the services develops towards the mountain, while the highest one is intended for the sleeping area, with four bedrooms. The architect wanted to experiment with the insertion of different types of roofing: horizontal flat, sloping flat for the small house; barrel vaulted for the big house. Until now the three-dimensional characteristics of the project were perceptible only through photographs of a real model that had been lost (see Fig. 3).



**Fig. 3.** A. Morbelli, the real model of “Due case a Capri” (Archivi BCA. Fondo Aldo Morbelli).

### 3 The BIM Model for Digital Manufacturing

For this case study, we started with the creation of a BIM digital model generated from the import of archival documents into Revit 2021®. The BIM model provides a complete representation of both geometric and semantic data [4].

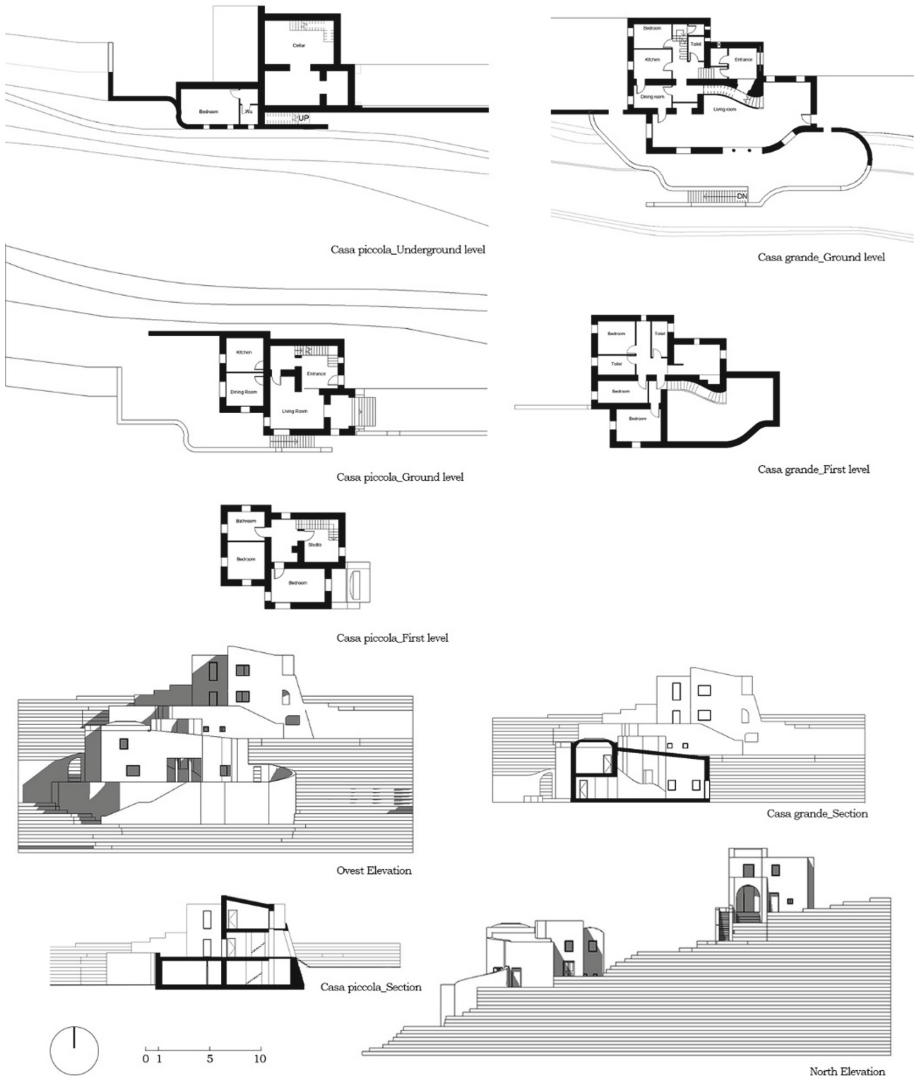
By connecting these data, it is possible to reach a more complete knowledge of the project, inserting inside a single file and 3D model information about the quantities, the geometric and volumetric characteristics and the construction characteristics of the architectural artefact. Being a 3D model aimed at the realization of a full-scale object, it was necessary, before the modelling operations, to define: the printing scale, the levels of detail, the most suitable materials and rapid prototyping techniques.

#### 3.1 Dimensional Choices and File Preparation for the Printing Phases

Depending on the scale of reproduction, real or reduced it is necessary to enrich or simplify the model depending on how it is to be made. Usually the more complex is the shape, the more complex will be the production process [2].

This case study, being referred to a project not realized, having only drawings in scale 1:100 and not being possible to have additional information about the internal structures and stratigraphies, for the BIM model and the subsequent production of the physical model, it was initially decided to keep the same scale 1:100. Later, however, it was decided to work at scale 1:200, both for the export of plans, elevations and sections and for the processing of the real model.

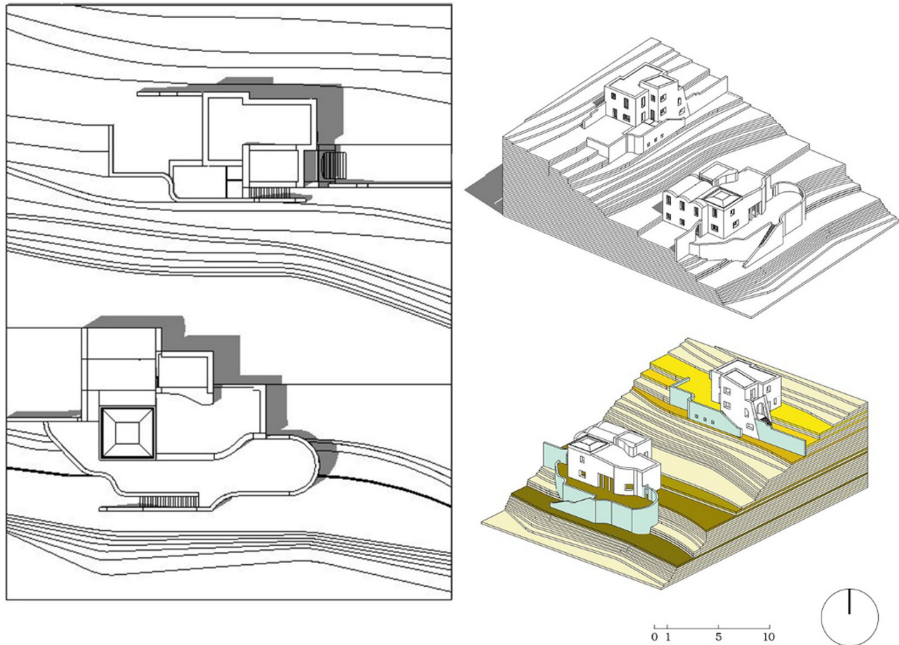
The choice was mainly dictated by the dimensional requirements of the printing machines. To achieve the leap in scale, the model had to be simplified using Revit 2021®'s Visibility/Graphic Overrides tools, making the elements not to be printed invisible. The model was brought to the print scale 1:200, the system families related to windows and doors and all the internal elements (partitions and stairs) except the main floors were made invisible, so that only the external envelope (roof and perimeter walls) remained (see Fig. 4).



**Fig. 4.** “Due case a Capri”, plans, sections and elevation from Revit 2021® (drawings by Giulia Bertola)

On Revit 2021®, the planes were subsequently brought to the same level so that a 2D CAD file could be exported.

As far as the terrain is concerned, the BIM model was used to make the topography of the terrain invisible and to design the terrain properly for the construction of the model. For the realization of the terracing it has been used the family category “floor” considering a thickness of the plans equal to 40 cm, in order to obtain a thickness of the real model in scale 1:200 equal to 2 mm (see Fig. 5).



**Fig. 5.** “Due case a Capri”, planimetric view, axonometric views from Revit 2021® (drawings by Giulia Bertola)

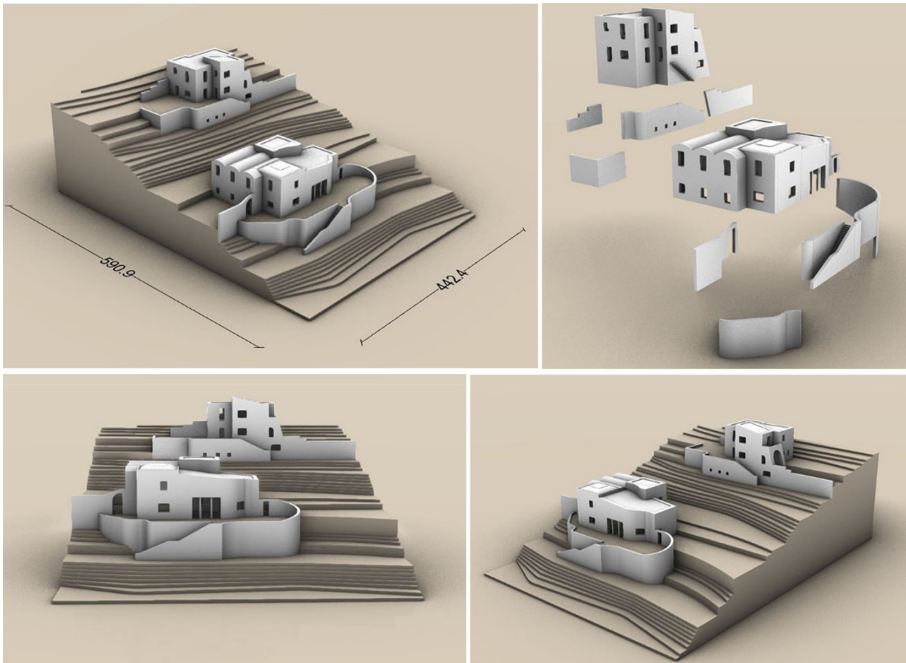
### 3.2 Exporting and Editing the File in STL Format

To proceed with the 3D printing, since an STL Exporter for Revit 2021® is not yet available, the file was exported in 1:100 scale in FBX format, imported into Rhinoceros® and then exported into STL. During the import phase in Rhinoceros®, the 3D model was scaled to scale 1:200 and the unit of measurement was changed to millimeters.

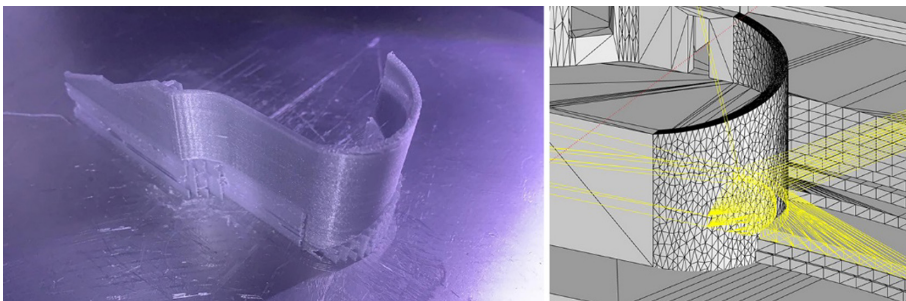
For dimensional issues related to the printing size of the machine, the models has been divided into parts: building blocks and exterior walls (see Fig. 6).

Standard Triangle Language (STL) is a format that uses small, interlinked triangles to recreate the surface of the solid model (see Fig. 7).

The level of complexity of the model determines the amount of triangles needed and their size. In turn, the amount of triangles determines the size of the file. As happened in this case, it may happen that during the conversion of the Revit file to STL, critical issues emerge and the exported file may contain some errors. These errors can be of various types: holes or blanks, inverted or intersected triangles.



**Fig. 6.** “Due case a Capri”, axonometric rendering view and axonometric cutaway from Rhinoceros® (drawings by Giulia Bertola)



**Fig. 7.** “Due case a Capri”, 3D printing of an external wall and axonometric view of STL file from Rhinoceros® (drawings and 3D printing by Giulia Bertola)

#### 4 Digital Manufacturing Techniques: FDM E LBM

Digital Fabrication is a process by which solid objects can be created from digital drawings. A process capable of exploiting different manufacturing techniques, both additive, such as 3D printing and subtractive printing, laser cutting and milling.

As described above, two rapid prototyping methods were chosen for this case study: Fused Deposition Modeling (FDM) for buildings and built parts and Laser Beam Machining (LBM) for the ground [5].

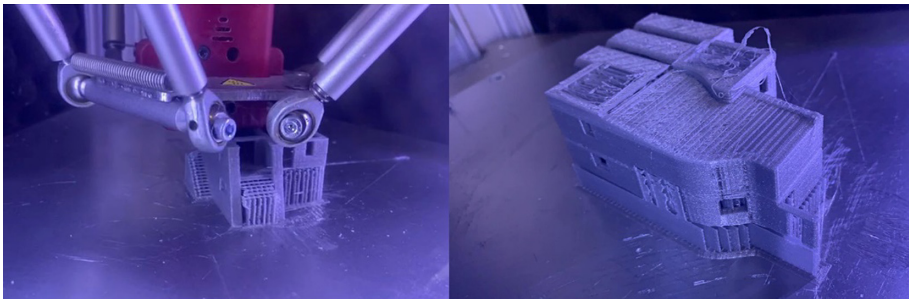
#### 4.1 Fused Deposition Modeling (FDM)

Nowadays there are several additive manufacturing processes that differ from each other depending on the different materials that can be used and how they are deposited to create the various objects. Some methods melt or soften materials to produce the layers, e.g. selective laser melting (SLM), selective laser sintering (SLS) and fused deposition modelling (FDM), while others cure liquid materials, e.g. stereolithography (SLA). The choice of a technique is usually made following some considerations made on the speed of processing, the cost, the material and the final aesthetic performance [6].

The buildings were made of plastic filament and printed using the Delta Wasp 2040 Industrial line 4.0® printer. This technique is referred to as additive manufacturing. Through a nozzle, it extrudes thermoplastic polymeric material, depositing it layer after layer on a construction surface [7].

Once the STL format was obtained, a test was made to verify the file through the software Cura, an open source slicing application for 3D printers through which an analysis of the model was carried out: thickness, stability, positioning and orientation of the model on the surface. The STL file was also automatically divided by the software into sections (slices). The software also automatically generates the support structures.

The plastic filament is conducted in a reel, pushed and melted through the extrusion nozzle. When the loose filament comes into contact with the construction plane it hardens and the rest of the material is gradually released (see Fig. 8).



**Fig. 8.** “Due case a Capri”, 3D printing process.

#### 4.2 Laser Beam Machining (LBM)

The soil was made of 2 mm thick cardboard using the Totrec Speedy 400® printer. Laser cutting is a process of thermal separation. The laser beam hits the surface of the material and heats it up to the point of melting or vaporizing it completely. Once the laser beam has completely penetrated the material at a certain point, the actual cutting process begins. The laser system follows the selected geometry and during this process the material is separated. From the 2D file generated by revit 2021® you can proceed with the print layout operations, defining the cutting power values using the Job Control® software.



## 5 Conclusion

The present work has shown the methodology of how it is possible to obtain a real model from a BIM project, having within a single file all the information necessary for an in-depth knowledge of an architectural project.

At the same time, however, numerous critical issues related to file management during the printing process have emerged.

Looking at the images related to the final model, which is still in the complete phase, it is possible to notice the difference between the correct models and not through the Netfabb® software. In the first case, the Casa Piccola has no surface defects or missing parts, in the second case, the Casa Piccola, there are many surface imperfections such as the trace of the internal floors on the perimeter walls and whole missing parts that will have to be printed separately and added (see Fig. 9).



**Fig. 9.** “Due case a Capri”, real model (by Giulia Bertola)

For a more effective, fast and dynamic printing process, it would be necessary to add to the BIM project a 3D model made with CAD software, however, this would not allow a complete management, within a single file, of the reconstruction process of the archival project, which is the subject of this study. The future intention is to take forward the theme of prototyping from a BIM project, trying to optimize and improve the entire process as much as possible.

During the different phases of application of the BIM methodology the different heterogeneous data are collected within a single digital model. The data are then discretized to arrive at the definition of a geometric model enriched by the information of a semantic nature.

In the case of unbuilt architecture, the construction of digital models can be an opportunity to learn and clarify the aspects of architecture [8].

This cognitive process can lead to the construction of new digital representations that not only represent the virtual image of the building but become its only existential reality. We are therefore witnessing a reinterpretation of the documents and data collected during which it is necessary to take care not to generate ambiguous and confusing representations [9].

In the scenario of the digitization of archives, the 3D modeling phase allows extending the consultation of archival material, placing drawings and photographs alongside three-dimensional models that can be explored through virtual reality and augmented reality experiences, with the application of different digital interfaces, machine learning techniques, and computer supports.

The prototyping phase could, in addition to becoming an ideal context to experiment with the flexibility of the different printing techniques, give users the possibility, during the visit to the archive, to consult not only the original drawings but also plastic models that allow a better understanding of the three-dimensionality of the artifact. This could be particularly useful and significant in the case of unrealized architectures, such as those treated in this case study, and thus become the first and only physical representation of the artifact.

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