LE CORBUSIER'S APARTMENT-STUDIO : 3D MODEL DATA OF PRELIMINARY RESEARCH FOR THE RESTORATION

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ABSTRACT:

Fondation Le Corbusier and A-BIME have collaborated to collect, analyse and organize preliminary research data for the restoration of the Le Corbusier's apartment-studio in Paris using a methodology based in a 3D model. This work, developed by A-BIME since 2014, has been financed by Fondation Le Corbusier thanks to a 'Keeping it modern Grant", giving by the Getty Foundation. The aim is to have faster and easier access to various data of the building by using a clear and documented digital graphic document.
For each step, the archives provided by the architect and the companies have been studied to understand and know the nature and quality of materials, technical arrangements and their on-site implementation. A study on technical installations and isolation as be provided as well by investigation in the apartment. By switching between the documents and the images, the know-how increases along with the development of the 3D model; the architectural elements have been drawn and modelled from the archive data and from the survey and diagnostic phase.
The numerical construction, based on precast elements, follows the pioneering efforts of specialized architects with the BIM (Building Information Model) technology. Thanks to the .IFC format the model has been imported in several software in order to proceed structural and hydrothermal simulations. The results have been used has guidelines by the Fondation Le Corbusier to forecast the consequences of restoration choices.

1. INTRODUCTION

1.1 Le Corbusier's apartment-studio

Le Corbusier's studio-apartment occupies the last two floors of the Molitor apartment block, located at 24, rue Nungesser et Coli. Designed and built between 1931 and 1934 by Le Corbusier and Pierre Jeanneret, his cousin and associate, the building called "24 N.C." is situated in the 16th arrondissement at the border between Paris and Boulogne. As a project for a rental building, it offered the architect the opportunity to test the validity of his urban proposals.
Radically renewing the Haussmann typology, the apartment block was built for a private developer. For Le Corbusier this was the beginning of a demonstration that his Radiant City project could provide the city dweller with air, light and greenery. Not overlooked, it benefited from fully glazed facades, constituting a radical novelty and contrasting with the surrounding buildings. Similarly, its reinforced concrete frame structure allowed the "free plan" to be implemented. As a result, the apartments, numbering two or three per floor, were delivered with just the sanitary facilities, each occupier being free to partition his apartment as he pleased. Modern comfort included both personal and service lifts, central heating, a laundry and drying room, cellars and garages in the basement and servants' rooms on the ground floor.

The architect was 44 years old when he received the commission for the Nungesser-et-Coli building. As a leader in the Modern Movement's battle against conventional architecture, the early 1930s were for him a time of great productivity since he had already received numerous commissions and was engaged in a number of urban planning projects.

In order to build his own apartment, Le Corbusier negotiated possession of the 7th and 8th floors, undertaking to build the roof of the property at his own expense. He had just married Yvonne Gallis, whom he met in 1922, and was living with her in an old, cluttered apartment in Saint-Germain-des-Prés. Le Corbusier wanted a family living environment for Yvonne and himself, the housekeeper and the dog Pinceau, as well as space for his painting and writing activities. He used the entire width of the building plot, an area of 240 m2 on two levels, to lay out the four main spaces making up the studio, the apartment, the guest room and the roof garden. All are exceptionally bright thanks to the glazed façades, the windows overlooking the courtyard and the skylights, for which the architect used the full range of Saint-Gobain products, including the famous Nevada glass bricks.
The architect would inhabit this apartment studio from 1934 until his death in 1965.
Access to the apartment is via a passageway reached by a service staircase and equipped with a service lift. The seventh floor contains the entrance, living room, kitchen, and atelier. The eighth and last floor contains a guest room and access to the roof garden.

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The volumes of the studio-apartment were structured by the polychromy of the walls, while spatial continuity was emphasized by the grid-pattern tiles covering the floor.
The main entrance is at the epicentre of the apartment's four areas. The handrail-free helical staircase leads up through a glass cube to the guest room and roof garden.

The large, pivoting wooden doors permit to open and close the various spaces of the apartment.
Marked by a striking contrast between traditional architecture and modern technology, the Studio, this "atelier of patient research", extends under a curving arch 12 meters long.

Figure 1. Le Corbusier in his atelier - © FLC-ADAGP

Situated at the end of the corridor leading to the studio, the servant's room is endowed with real comfort for the time: a picture window looking onto the courtyard, electric lighting, a cupboard and even a water tap.
The living room was arranged around the casing enclosing the lift machinery and the space taken up by the service lift and the chimney. The walls were faced with panels of oak-veneered plywood and the room furnished with the *Canapé* and *Grand Confort* armchair, co-designed by Le Corbusier, Pierre Jeanneret and Charlotte Perriand,. As in the rest of the apartment, works of art (by Le Corbusier himself, but also paintings by Fernand Léger or, sculptures by Jacques Lipchitz) and "poetic reaction" objects (shells, bones, pebbles) were displayed in the niches and on the picture rails. Their arrangement was frequently varied.
The kitchen communicates with the dining room. It is equipped with built-in furniture, a total innovation for the time. Two storage units structure the space and support worktops overlaid with pewter. In the area for preparing meals, the double sink receives light from a small courtyard. The walls are faced with white earthenware tiles. Stove and refrigerator are housed in their own niches. The service door opens on to a passageway leading to the servant's room. This is located on the far side of the apartment, thus preserving the couple's intimacy.
The dining room has a sweeping view of Boulogne from a large picture window, which was remodelled several times, and from a balcony-loggia. The geometrical stained-glass window was made in Reims by the artist Brigitte Simon and added in 1949. A red woollen rug, woven in Tlemcen, Algeria, sets off the marble table designed by Le Corbusier and surrounded by four Thonet armchairs.

Figure 2. After the restoration work, the living room © ANTOINE MERCUSOT/ FLC-ADAGP -

Le Corbusier was fascinated by ocean liners and used their cabins as inspiration for the layout of his marital bedroom. He invented a raised bed resting on two feet and with a headrest fitted to the wall, its height allowing the couple to admire a view of Boulogne over the "dizziness-free" balcony balustrade. Madame had a vanity and her own bathroom with a hip bath; Monsieur had his shower and wash-hand basin - toilet and bidet were shared. Clothes were stored in ingeniously designed furniture, part of a particularly elaborate piece of domestic economy.
The guest room was intended mainly for stays made in Paris by Le Corbusier's mother. It is equipped with a shower and wash-hand basin and divided up by a storage cabinet at mid-height grandly surmounted by a central heating device.
In his projects Le Corbusier conceived a green space on the rooftops of Paris, blending into the surrounding urban environment. Between the two rounded vaults at the top of the building, he laid out a roof garden offering a breathtaking view of Boulogne and Paris.

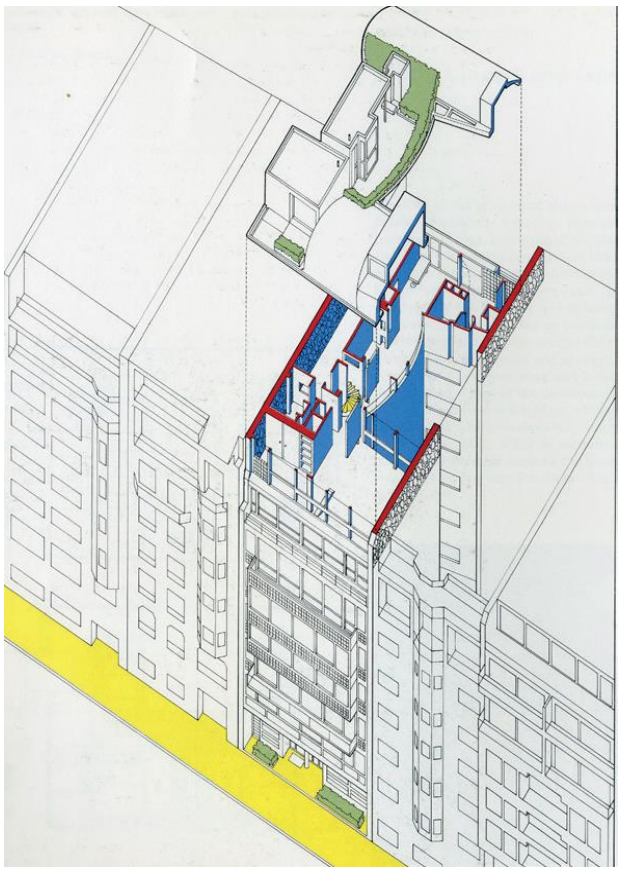


Figure 3. Sherwood, 1978

The property of the Le Corbusier Foundation, the apartment-studio, awarded the Maison des Illustres seal of approval, was listed as a historic monument in 1972, and the entire building in 2017. Since 2016, as the world's first apartment building with entirely glazed façades, it has been part of a UNESCO World Heritage Site comprising a series of 17 works by Le Corbusier.

1.2 The restoration works

The apartment has reopened its doors to the public in 2018, following two years of restoration works led by the Fondation Le Corbusier.
Despite its status as an icon of twentieth-century architecture, together with an aura of memory of the main architect of modernity, Le Corbusier's studio-studio has been little studied. Therefore, the Le Corbusier Foundation decided that this campaign should be an opportunity to increase the historical and material awareness of the apartment, through preliminary studies, but also by paying the greatest attention to the discoveries and observations made during the construction site.
These studies also shed light on the restoration project options that have not yet been defined. The restoration work was based on historical and scientific studies carried out by Graf Franz, Marino Giulia (Graf, Marino, 2014).
Also Hubert Marie-Odile in collaboration with Carolina Hall and Julie Schroeter, Study of polychromes, wood and metal furniture, study 24 by Le Corbusier, 24 rue Nungesser et Coli, Paris 16, provisional version, May 2015.

2. 3D MODEL CONSTRUCTION

2.1 construction method

The 3D model has been built element by element according to the information found in the archives completed and verified with in situ non-destructive investigations.

2.2 Archive

Several archive center have been searched in order to collect has many document has possible. At the end, more than 7500 documents have been collected, documents from different nature : letters, bills, drawing, plans, … A first Excel database has been created to store these informations, reusing some work already done by the Foundation, and adding other documents after (structural works plans, …). A the end the database links each document with the part of the appartement it describes.

2.3 Research in situ (camera-georadar)

The apartment has been analyzed using infrared camera and géoradar. The first device has been used to observe the construction detail of the apartment: the exact position of the poles and the beams, the exact dimension of the bricks, … verifying the archives information and discovering some details never seen before (the specific disposition of the bricks used to build the shower, …).

Figure 4. © A-BIME: Infrared camera picture: structure of the bedroom wall

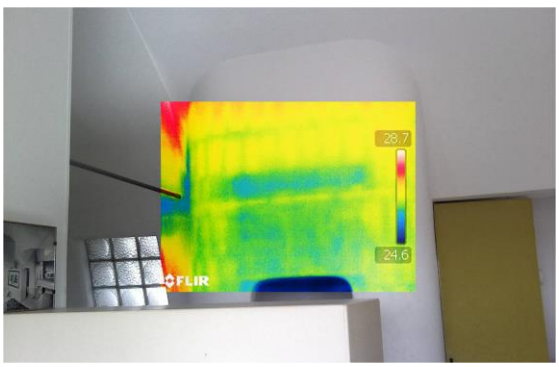


Figure 5. © A-BIME: Infrared camera picture: structure of the shower wall

The radar has then been used to collect information about the thickness of the concert element and about the iron framework.

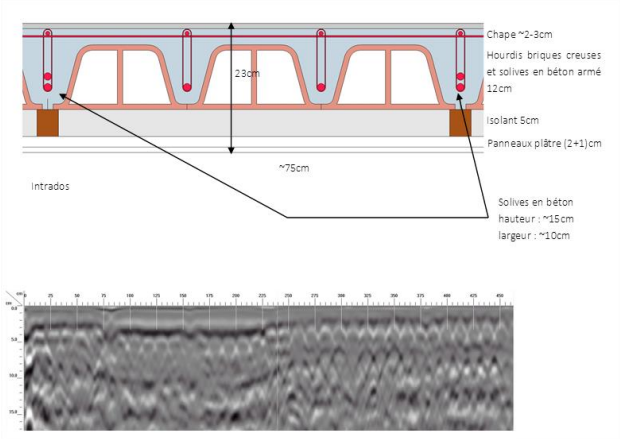


Figure 6. © A-BIME: Radargramme: structure of the vault

2.4 On site measurement

In addition, multiple thermal and hygrothermal sensor have been placed inside and outside of the apartment. The data have been acquired during two years and has been used to compare and calibrate the numerical simulations.

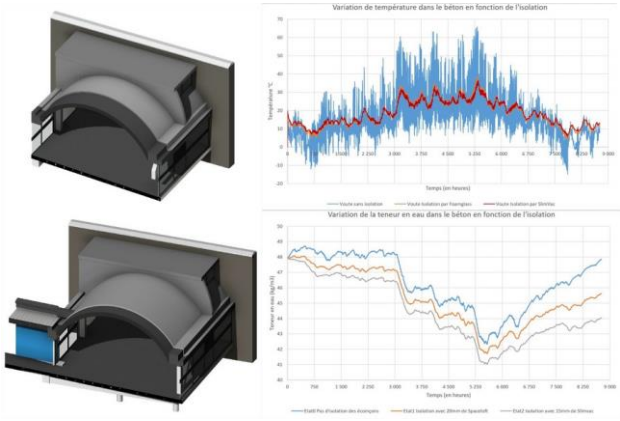


Figure 7. On-site measurement results

2.5 3D model construction

The model has been built with the software Revit with all the information collected before. Each element has been construed thanks to the archive's information and the onsite investigations.
The informed elements have then been placed in the 3D model thanks to a point cloud of the apartment delivering the exact position were each element must be.

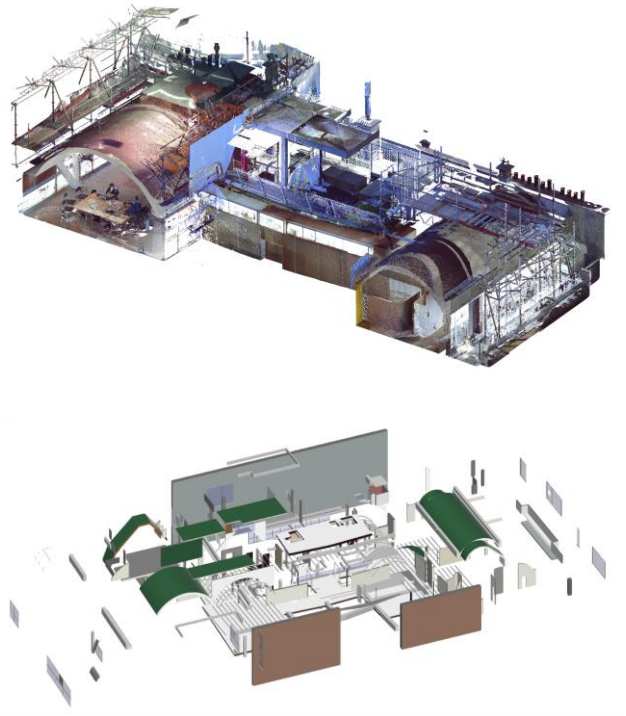
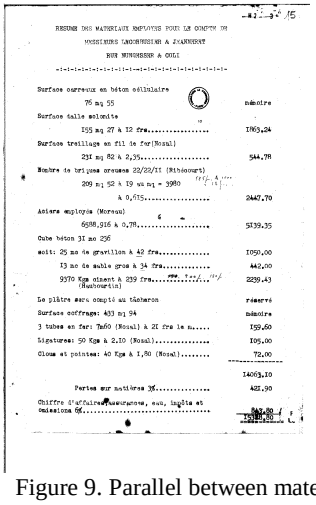


Figure 8. 3D model of the apartment

Requesting the model we verified than the amount of material used to build the numerical model is very close to the amount of materials payed by Le Corbusier for its apartment:



Brique creuse	Volume (m^3)	Surface (m^2)
Toit cuisine	0.8	7.4
Plancher bas 8e Chamrbe amis	2.91	24.49
Toit Sejour	5.84	53.53
Toit atelier	4.64	42.92
Toit Chambre	0.94	8.71
Toit Chambre amis	1.93	17.72
Toit terrasse	3.63	32.99
Toit Edicule	2.34	21.26
Total	23.02	**209.02**

Solomite	Volume (m^3)	Surface (m^2)
Plafond plat Chambre	0.24	3.48
Plancher bas 8e Chamrbe amis	1.85	26.49
Mur Ouest Edicule	0.16	2.24
Toit Chambre amis	1.24	17.72
Mur Sud Chambre amis	0.41	5.83
Toit terrasse	2.31	32.99
Toit Edicule Ascenseur	0.19	2.72
Toit Edicule	1.49	21.26
Toit Atelier plat	1.07	15.34
Toit Chambre amis plat	0.92	13.14
Palfond ascenseur commun	0.18	2.61
Mur Nord Chambre amis	0.81	11.54
Total	10.88	**155.36**

Figure 9. Parallel between materials paid by Le Corbusier and quantities exported from the 3D model

3. UTILISATION MODEL 3D

3.1 IFC format creation

IFC format (Industry Foundation Classes) is an open object-oriented file format used for BIM (Building Information Modeling) based projects. It allows interoperability between different software. So, it is possible to export digital MockUp built thanks to the software Revit (which has a specific format: rvt) in an IFC format. For each object, it contains its geometry and different information such as the materials, the construction date, etc…

However, loss of data is possible during the exportation from .rvt file to .ifc file. That's why, during the building of the digital MockUp in Revit, it is very important to make precise correspondence between the categories used in Revit and the classes IFC in order to limit this lost. The software has the tools needed to define this correspondence.
Some searches are made to erase the loss of data.

Thanks to the ifc format, it is possible to put on the internet the digital MockUp which is a graphical representation of data.

3.2 Archive documents database

IFC format allows an exportation of data to database. This database will store different data from building to all the elements of a room. It will also contain all the historical archives used to the building of the MockUp.

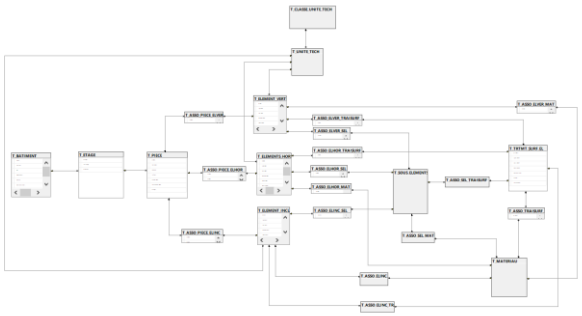


Figure 10 . Actual UML Diagram of the database

In the future, the database will also be filled by a software which will be used by different contributors of a project (from the archaeologist to the structures and materials engineer for instance).

3.3 Numercial simulation

Thanks to the .IFC format the model has been analysed with several software in order to provide different type of simulation to guide the restoration choices.

Structural simulations
Simulations have been made in order to verify the stability of the concrete vaults

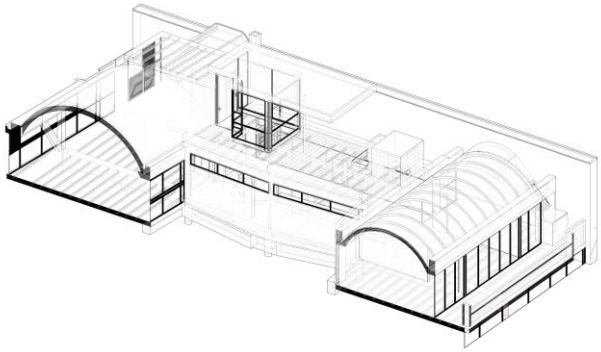


Figure 11. Numerical structure model

Thermal simulation
These simulations have been made in order to verify if an insulating layer on the vaults will be useful to reduce the summer inside temperature.

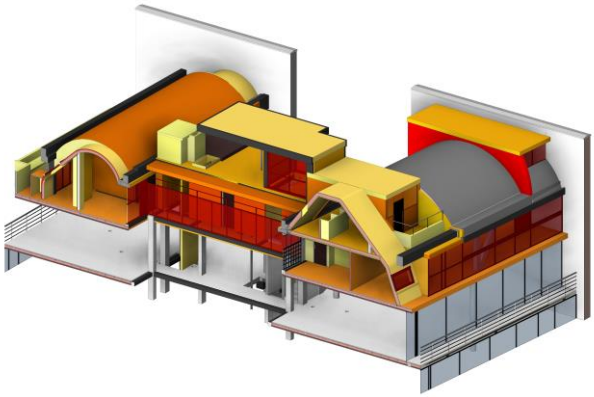


Figure 12 Numerical model with thermal heat loss represent with a scale of red

Hydrothermal simulations
Several hydro thermal simulations have been made in order to understand the impact of an insulation layer on the concrete preservation.

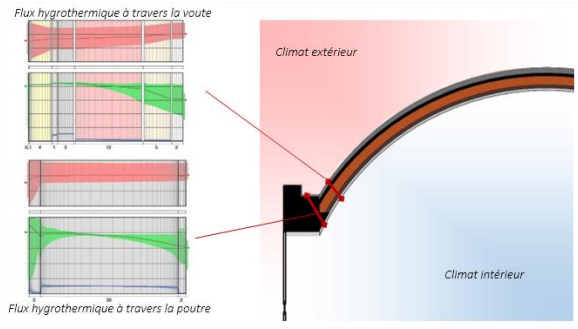


Figure 13. Hydro thermal 2D simulation to study the protection of the concrete layer

Light simulation

The model has also been used to create a light simulation resulting in a map of the apartment with the average natural illumination in a year. This cartography indicates areas where the works of art will not be damaged by sun beams.

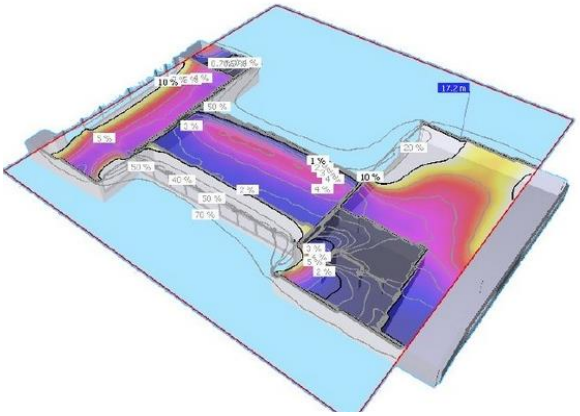


Figure 14. Cartography of natural illumination of the appartement

3.4 Cultural mediation

By linking the MockUp and the database in a web project, it will be possible for people to interact with the MockUp : different data of an element of the building will be accessible online, such as photos, archive about the selected element, etc…

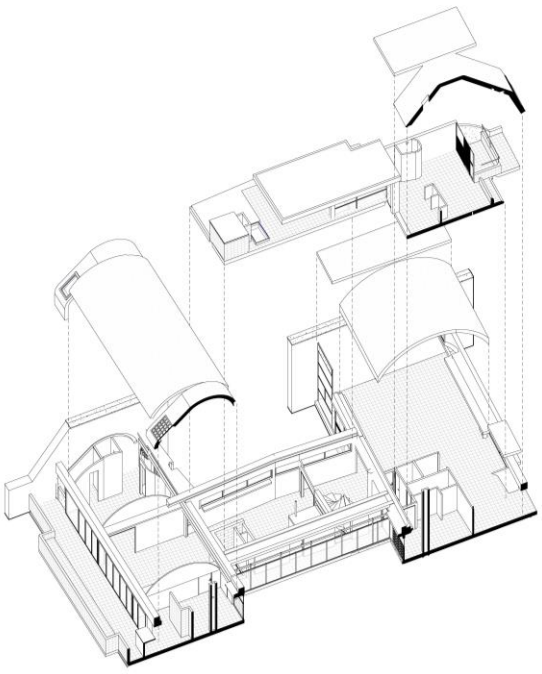


Figure 15. 3D model used to explain the different part of the apartment

The different states of the building through time (for instance Le Corbusier made some change in his apartment during his life)

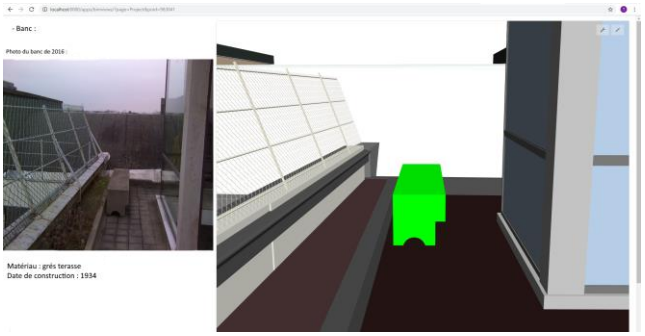


Figure 16. By clicking on the bench, information about it appear.

The second stage of the cultural mediation project is to create a collaborative platform between the MockUp and visitors: For instance, if someone has an information about on element of the building which does not appear on the MockUp, he will be able to add the information. It will allow to have the best knowledge possible of the building.

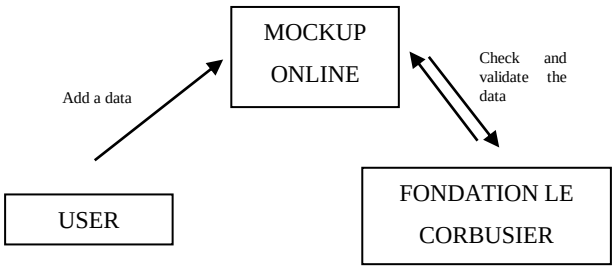


Figure17. Schematic diagram of the collaborative platform

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