Ambient topologies in the museum route (light, sound, and thermal): the method of analysis and visualization.

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Abstract:

Defining architectural space comes with multiple and diverse aspects. Our theorical reflection, however, aims at establishing new bases for a newer definition, in the sense that theorical topology, like geometry, is a good aspect to define the from of architectural spatiality based on the notion of ambiences.

Topology definitions already developed by some renown architects will give us meaning to build more understanding of route and sequence, thus, help the formation of our analysis model.

This research is focused on the museum, which is a public-facing architectural construction. According to the approach, a thirty-European-museum corpus was submitted for examination. The data collected for this corpus was statistically analysed.

Based, on the ambience discontinuities, the sequential analysis allowed us to create ambient topologies transforming into ambient events that are linked to the displacement of the space user in connection with ambiance change.

We endeavour to develop a micro study reflected on the interaction between different environmental sources as a means to comprehend therein the influence on the future spatial-energetic behaviour. This would serve our approach in getting improved analysis of our subject matter.

This study lays the groundwork for a novel approach of defining architectural space based on differences in users' sensitive perceptions and the environment of a given space.

Keywords: topology, sequences, route, light, sound, thermal, ambiences.

1. Introduction:

One of the most difficult concepts to define is architectural space (Parsaee et al, 2015). It will provide a wide range of definitions. It could be defined as a space arranged by construction, which frequently relates to a location where the architectural object is produced. (Wilhoit, 2016). Some studies describe it as an empty place with a purpose and a meaningful inner/outer relationship. (Von Meiss, 1993)

This concept considers man´s indoor space to be the scene where life commonly unfolds; it frequently happens to be the surrounding space together with the three-dimensional space incorporating man. (Zevi, 1984)

Jean Cousin's definition of architectural space is one of the most commonly utilized in studies on the subject, which is based on the ability of human beings to identify and protect themselves with the volumes and space that surround them. He observes that the human body is contained in a bubble that serves as its personal space, a space that is not confined to the skin's surface but expands spatially thanks to the visual field (based on what a person observes in his environment). (Cousin, 1980)

Architectural space is also defined as an empty entity or negative volume, an immaterial entity that sculpts space when it intersects a solid entity. (Kurmann et al, 1997; Goulette, 1999)

The act of designing in an architectural environment refers to the fact that we add meaning to the space rather than the construction. Therefore, we can note two data i) Extrinsic: quantitative linked to geometric characteristics, location, ... ii) Intrinsic: qualitative linked to the experience to topological characteristics. In this component we can talk about the feeling of the human being (the ambience Light, sound, thermal, degrees of openness, ...). The topology of space is significant because it concentrates on the sensory perception of space. (Siala et al, 2016)

Owing to such delicate proportions of architectural space, academic definitions are frequently taking anthropological connotation (Sfintes, 2019). When we remove architectural

space from its human context, it transforms into a precisely geometric, three-dimensional space with precise measurements (Borie & Denieul, 1984).

Thanks to geometry, we were able to represent architectural space for years. History has noted down that we quickly moved from simplistic hand drawings to more complex and computerized drawings, merely made possible by the advancement in technology. (Scheer, 2014).

There are two ways to analyze space according to the evolution of theories on architectural space and its ties to human experience, particularly those connected to ambiences: a very reasonable approach that ignores humans and concentrates on physical space actors known as "quantitative," which is defined by objectivity and is based on measurements and quantifiable values of the environment. The second is about the human being and his acts in space, and it is founded on qualifiers that can be used to define space and hence its subjectivity (Chelkoff, 2018).

The fields of investigation in architecture and urban planning have been enriched with the emergence of new research methodologies linked to environments. This is likely to set advancing research paradigms for this new emerging field, and giving it more empirical perspective. (Grosjean & Thibaud, 2001).

The definition of space linked to ambience had made it possible to reconcile the qualitative and quantitative aspects of space. This reconciliation boosted observations on tools of space representation that can handle not only the geometric but also the sensual aspects of the architectural space, moving from computer-assisted drawing tools (Autocad, Archicad) to computer-assisted design tools. (Pellegri, 2015), and the palettes of analysis related to the environments.

New digital softwares now portrays architectural space in a variety of ways, including scaled dimensions, climate files, settings, orientations, and materials. These elements bring the

representation of space extremely realistic; we're no longer talking about general modelling, but architectural space representation.

Through the use of visualization, we seek a new definition of architectural space that supports both its geometric aspect and its sensory actuality. Using a topological approach to space, we'll see if topology can characterize architectural spatiality just through discontinuity relationships.

1.1. The relationship between typologies and visuals when it comes to ambiences:

The importance of the concept of ambience had been highlighted in many types of research works where the researchers' objective was to clarify it. The problematic question is to figure out the basic foundations of the very notion in a way that´s explicit and consequently erase the less clarified components. In a very broad sense, it is a question of listening to the senses, which will thus contribute to the construction of the environment in which man lives and practices his activities. (Thibaud, 2002).

These various fields of problematizations linked to the notion of ambience, correspond to what Thibaud (2002) had named "conceptual levers", which will allow all researchers to position themselves about the type of environmental research, these are as follows:

- The ambience is indivisible: the ambience can be characterized by its degree of predominance. It can only be seized in its entirety.
- It will articulate between the intensive and extensive character.
- The ambience is immediate: the ambience calls for a motor style that gives it a specific character. It is attached to the body which requires a joint between the pre-reflective and reflective ducts.
- The ambience is omnipresent: an ambience is characterized by the dynamics of variations to which it lends itself to. This is an affirmation of the introduction of the background and the thematic plan of the interpretive activity that will correspond to the theme.

- The ambience is diffuse: the ambience has an individual character; it is different to the scales according to which it has been identified. It is imperative in this case to associate the order of perception by articulating it with the order of feeling (its cognitive slope).

The choice of methodology specific to each research refers to the adoption of a research posture with a clear methodology. The methodological process to be chosen by the researcher would fairly lead to more or less relevant results.

The typology of the ambiences may vary according to the methodological choice, but also their sensory aspect which is presented in the form of two typologies: i) of the seen ambiences: luminous, and ii) of the not seen ambiences: sound, thermal, olfactory, tactile,... this typology does not change anything with the definition of the ambience, but the seen (luminous) ambience is often easier to detect and to analyze. Although in situ measurements can be made on all types of ambiences with measurable signal, they do not give us a visible image of their (abstract) character, and it is often the user who helps us to decide (qualitative opinion).

If we receive information through several senses, our brain is more likely to choose those that have a visual nature (which we receive through the eye) from where the absence of ambiguity in the seen (luminous) environment. (Nudds, 2004; Bonnet .G, 2005)

An ambiance which is not visible would mean creating its image in the architectural space; in case the ambience source fails the image, then its state would fill the gap.

Software simulation aids in the creation of a model that is very near to reality, allowing to visualize the ambience (Bouchlaghem et al, 2005). This visualization supports the physical environment of the space (Degen, 2017). However, the user becomes an important component of spatial reading (Siret & Woloszyn, 1998).

The field of ambient visualization has made a lot of progress; visualization converts data into images that can be used to explore, identify, and study it. We can create successful visualization rules by relying on human perception.

Visualization as a discipline has become imposing by the rapid development in computer science. Computer graphics being the objective of study, it has helped improve in so many ways the procedures in teaching and learning (D'Alba, 2012).

Even though there is a large amount of visualization software available, it is not made available to designers and has only been studied by academics.

1.2. The act of displacement and topology:

Although it is old in architecture (Kantor, 2005), and like geometry, Topology first developed in the area of architecture as a response to a century-old urban problem, the famous problem of the seven bridges of Königsberg (Corcuff, 2007; Bonnin, 2010) , then came a change of topological classifications of architectural structures (Ibrahim, 1997).

Many researchers were interested in the role that topology can play beyond theoretical considerations (Emmer, 2013), the application of topology as a tool for the analysis of architectural space and, not just a tool for conceptual modelling, has become more than necessary for topology to contribute to a conceptualization of architecture as a closed space in motion (Aish, 2018).

It is noteworthy that from a theoretical viewpoint, the recognition of topology as a principle of contemporary architectural design has meant that architects often seek to emphasize topological properties to produce a form which includes three entities: i) continuity, ii) openness, and ii) deformability (Lojanica & Dragisic, 2018; Paul & Borrmann, 2009). Topology has been used in architectural design for a long time, its use has increased in contemporary architecture (Dapogny et al, 2017).

It should be noted that the path of the construction had often been considered linear, starting from the starting point down to the finishing line, topology intervenes as a modification at the level of the initial plan, twists, turns, flyovers, ... this intervention makes architecture homeomorphic that has to develop from the straight line (Liang et al, 2013)

The establishment of two trends has resulted from the emergence of the topological tendency in contemporary architectural philosophy. The first is the deconstructivist architectural movement. They aimed to represent the diversity and heterogeneity of our age's physical and cultural settings using formal ways of discontinuity based on the formal conflict approach (fragmentation, diagonal, juxtaposition, and opposition). The modern avant-garde architects who are seeking to merge architecture with mathematics constitute the second trend. Topological theories inspired by mathematics have yet to yield a theory suitable for topological architecture. Nonetheless, one might speak of a topological movement in which architects, both theoreticians, and practitioners, i) speak or ii) adapt to conceive their projects solely through the lens of mathematics. Topology, from their perspective, is merely a mathematical solution to an architectural problem (Di Cristina, 2001; Chapman, 2002).

We have determined that topology is defined as the act of displacement following a temporal period based on what Di Cristina (2001) offered as a definition. The body's dynamic movement crosses time, establishing consecutive locations along a route (duration). Once created, this point becomes an event.

As a result, it is thought that topology can be defined etymologically using two terms: i) transformation, which relates to deforming and metamorphosis; and ii) continuity, which refers to a continuous movement with a geometric origin.

While morphological and typological characterizations of space are common in theoretical reflections on architectural space, topological characterization of space is uncommon, and when it is used, it is frequently related to a parameter of spatial composition. We investigated the existence of topology in the three ambience typologies on which we intend to develop this work to learn more about them.

We reference work on luminous topology, which is defined as the interaction between space and light, as an example. The "bay effect" or "opening" exhibits this relationship, which

is characterized as: i) space/light continuum, ii) object light, iii) light total of a sequence of objects, and iv) surface (Biron, 2008). Biron developed the shadow-light effect from a manner connected to Lassence to produce additional possibilities of topology of light from the shadow, and it provides a very solid theoretical basis for this reflection (Biron, 2008).

The sound topology which has long been present in works on "the cybernetic city," is based on complementarities of the designer's reflexion. First in macro between the agglomeration and its environment, and then in micro between the diurnal and night periods. The musical world's description of sound topology declares that sound topology is a revealing notion of the discontinuities or stops in sound compositions materialized by a void at the level of the solfeggio, which is a space of whole share for musicians (Schöffer, 1972).

In architectural works dealing with architectural and urban space, the topological approach to sound has not been mentioned. However, we discovered that when it comes to methodology, the notion of the route is frequently found in numerous research works that deal with sound. The alteration of the auditory ambience materializes the route and often decomposed in sound sequences or discontinuities (Defreville, 2005; Sahraoui, 2006; Boubezari & Bento Coelho, 2004, 2012; Yang et al, 2015).

The term "thermal topology" is defined by thermologists as a notion that indicates the material's thermal equilibrium. It refers to the continuous fluctuations in temperature in a particular material, where each temperature is assigned a name depending on whether the flow is vertical or horizontal (the substance's chemical composition remains the same, but each area is assigned a temperature) (Grégoire & Kumbaro, 2013; Ramalingom, 2017; Chevalier, 2018).

However, we have not found any work in architecture or urbanism that deals with this concept. Therefore, according to physicists, we may confirm that thermal topology relates to temperature fluctuations along a single line, which can be a route in macro (If we change the scale).

1.3. The ambience *and the* ambience*s in the museum route :*

If all suggests that the route as a journey is geometric, it is subjected to various evaluations throughout the scientific study, making it a Spatio-temporal aspect. (Beaudoin, 2016)

We have chosen the work of Maria Saraiva (2001) on purpose; because, she very well presented the ambiance in the museum space moderating two aspects: i) the located ambience: putting emphasis on the visitor, the ambience will exist in a precise space and/or it is perceived during the time of a visit, ii) the conceived ambience: putting emphasis on the intention of the designer to create this ambience, and his intuition at the time of the realization, the ambiences then become controlled by the designer.

She cites two types of ambiences that can be found in all museums which are: i) the ambient objective is the traditional presentation aimed at enhancing the exhibited object, this ambient is part of the spatio-temporality of the object and is based on the aesthetic or emotional experience between the visitor and the object, ii) the ambient functional: it covers all the spaces visited by the visitor inside the museum, before and after the visit. In terms of topology of space whereby the route makes its passage, the variety of the ambient is often considered in its plurality. These spaces are counted to offer visitors some perspective experience and by then influence their choice or the exhibition sequences to visit. it is more about spaciotemporal dominance which is included in the programme (route designed) and even after the realization (signage, before the announcement...). Being characterized as the first ambient of the dominant spatiotemporal, the existence of dominant sensory inherent to both the visitor and the route integrating and orienting all sensory modalities.

The museum route is the most basic structure of museum design, and because of that, a successful museum design should rest on a successful museum route. Because of its polysemy, defining the concept of the route would be hard to settle. Let´s read LAROUSSE's (2009, p. 356) definition: "it is the way or path followed to move from one point to another." The term

"common sense" in Larousse definition has a wide range of interpretations. This demonstrates the term's intricacy.

In some studies, the route is used to represent both bodily and spatial movement. Others refer to it as a design-visit interaction. After the route has been set, the simple act of moving begins to make sense.

The sum of studies carried out on the notion of the route are generally quite diverse (Krier, 1988). We shall cite for this purpose the general and urban cases in particular A.Borie et al (1984) and P.Panerai et al (1983), We've found that several different sub-typologies are linked to the same typology cited by these authors.

In the case of museums, we refer to the circulation principles that have been devised following their structure (Mariani-Roussset, 1996). The "linear" route is necessary; the "labyrinth" route has no traffic limits, and the "centered" route allows visitors to take their way. We find Ching's approach to be quite fascinating; route typologies vary, but the most well-known provide a clear and consistent spatial relationship among these routes: linear, radial, spiral, network grid, and eventually composed (Ching, 2019).

Mariani (2000) developed a typology that is very complete when combined with the one proposed by Jean Davallon, which is based on the three stages of display: conception (thought route), placing in the exhibition (suggested route), and visit (lived route).

With the development of technology, museums have seen the birth of museography, which allows us to judge the success of a museum according to its exhibitions, the number of visitors, and their satisfaction. Museographers place the journey at the center of all their interventions within the museum space, and based on the tour guide, they determine the animated or non-animated effects that should accompany the visitor throughout their visit. If they start to introduce fixed sound sources for each exhibition space, they try to keep the same intensity and frequency of the human voice. (Martinez, 2003)

Contrary to popular belief about signals in the museum, Meyer finds that sound guides the gaze, sound perception supports visual perception, creating a continuum to which we can add well-being as linked to the thermal, olfactory, or other ambiences (Meyer, 2013; Corbel, 2003) .

Our work is part of the new scientific museology, where the visitor's well-being is taken into account; in the meantime, putting the exhibited art objects at the center of all reflections. The aim of this research is to explore the ambiences of museum spaces, considering their spatial dimensions by means of the notion of "topology", which is a recurrent aspect in the architectural production of our era. It is a question of demonstrating that a topological characterization of the architectural space is completely possible. It will not be subordinated only to the user, but to the whole of the ambiences present within the architectural space. Furthermore, the notion of sequence and route has brought more intelligibility of architectural space. Despite the research paper´s theme focussing on architectural space, the ambiences, the course and the exhibits objects; on the other hand, we shall cover the notion of discontinuities: referred as topologies. Our objective so far is to demonstrate their existence within the museum space and likely initiative more continued research in this long field of work. Our very concern lately is to explore the dynamics of light, sound and thermal ambience.

2. Methodology and case

2.1. Theoretical interpretation:

According to pigeon (pigeon, 2013) a person has to feel the route by becoming aware of what surrounds their body; this awareness would lead to a deeper comprehension of architectural space. A person may learn to adjust his surroundings while deciphering the amount of information to be found in the space.

J Cousin's usage of the bubble in his works can adequately define the links involving a man and his environment, both during and after the journey. It has no defined dimensions or shape, but changes its spatial route in response to the body's movements. It joins the body at a

set distance, although it can extend, widen, or compress itself based on the context and its spatial perceptions. The direction in which the user moves through the environments, however, has an impact on their perception.

Following the definition of the topology and applying its consistency to the interior properties of the location, we state a fact of the interior portion through which a person´s body moves (route), and the period is the only thing that comes to mind. In other words, the dynamic body movement that generates points of intersection along the route that will need to be considering as "sequences." (Fig 01)

[Figure 01 near here]

Figure 01: Definition of the sequential analysis for the lighting, sound and thermal ambiences according to the museum route

The sequence in this case study is defined as a series of purely environmental events that lead to a transition from one sequence to the next. The change in atmosphere distinguishes this transition (Saraoui et al, 2011, 2018). The sequence can be luminous, sonorous, or thermal.

2.2. Sequential analysis, analysis model, and visualization:

In addition to the graphic file, all written references, images, analyses, or comments that have already been made must be submitted for each case study.

2.2.1.3D modelling:

The modelling in our work will create a reduced model of our case studies, these models will have the same architectural details, characteristics of materials, climatic file, orientation, and context or immediate environment.

The following elements were also chosen to be reproduced using the layering technique:

- A blue line denotes the museum route.

- The source: in the case of the luminous ambience, the axes of the bays indicate the source of light in the space by the red color, in the case of the sound ambience, the location of the sound source, which will represent the position of the tour guide, and in the case of the thermal ambience, the variations of mean radiant temperatures (respecting the conditions of thermal comfort).

- The sequences: for the light sequence, the area denoted by the axis of a bay operated in the wall and whose boundaries are determined by the neighborhoods of the axes, of the same route, positioned midway between the bay of the sequence in question, is specified. In the case of sound, the piece of the architectural space is part of a route and may be defined by the presence of a sound source at a human height.

Thermal sequences can be viewed on the simulation grid results as a function of the route line, or each color change corresponds to a temperature change, resulting in thermal topologies.

The scale models of all the case studies with all the details mentioned above including the immediate context are reproduced using Autocad and Archicad.

The environment plays a critical role in the methodological principle. In case of seen environment (Luminous), the sequential analysis which highlights topologies is quite satisfactory, and the visualisation conducted by simulation would manifestly help in confirming the data. We have come to the conclusion that the sequence criteria are dispersed in the following order : (Fig 02)

[Figure 02 near here]

Figure 02: methodological principle

We have gathered all the parameters and variables to be analysed throughout the modelling of our theoretical conceptualization variables are meant to influence all at once the quality of the

light, sound and thermal environment within a pathway sequence (Baker & Steemers, 2002; Boudier & Guibert, 2006).

Variables intended for lighting ambience, i) conformation: Materials, morphology, ii) bay: type, lighting, orientation, position, inclination, shape, size, glazing, glazing complement. For the sound ambience, i) conformation: geometry, materials, ii) sound: the sound source, sound wave characteristics (diffusion and transmission), wave characteristics according to incidence surfaces. As for the case of thermal ambience, i) conformation: materials, orientation, type of route, ii) temperature: winter, mid-season, summer.

It should be mentioned that each type of environment was studied separately with the data analyzed statically using STATISTICA 7 software.

2.2.2. The simulation:

The purpose of simulation in this project is to visualize the topologies and explore their characteristics. When it comes the case of the luminous environment, the visualization by simulation will confirm the resulting luminous topologies. In our research we chose to export the model under Ecotect v5 then Radiance. In this regard, we cite the proposal case of the Salzburg Historical Museum, in figure 03 the sequences of the resulting light topology and in the table the visualizations of some parts to confirm the discontinuities in the day when the flow of visits is the highest (Table 01).

[Figure 03 near here]

Figure 03 : the sequences of the luminous topology.

Table 01: simulation of some parts of the route by Radiance

[Table 01 near here]

We will be using the Ecotect v5 program for sound and thermal ambiences. By simulating the sound and thermal sequences, we will be able to see them; however, this step is more than necessary for describing the sequence.

In Case of the sound ambience, the sound source is taken as a guideline in the process of visiting the space. We will give it the height as tall as an average human being in the software we´re utilizing. Then we track its movement through spaces. However, diffused sound wave is taken as a picture to be compared to the rest of the points.

In table 02, we will be presenting the discontinuities of the sound sequences for the case of the proposal from the Salzburg Historical Museum.

Table 02 : Museum sound sequences in the Salzburg Historical Museum

[Table 02 near here]

We have carried out a simulation on thermal ambience. Three distinctive periods ranging from the most unfavourable down to the most expressive periods of the thermal viewpoints are given separate time slots in the day, namely: Winter (am, noon, pm), summer (am, noon, pm) mid-season (spring / autumn (am, noon, pm). Abbreviations are intentionally being used to simplify results reading (WM/WN/WA, SM/SN/SA, MSM/MSN/MSA).

It is noteworthy that the deduction of the thermal sequences is made by drawing the line of the course, in connection to the museum, and by considering each color of temperature as a sequence. While indeed considering the Salzburg Historical Museum for the noon period in summer (Fig 04); there is no variation in color throughout the route, which means that the route constitutes a single sequence of 18°. Whereas in the morning, the same season will have 08 sequences of 18° and 07 sequences of 16°.

[Figure 04 near here]

Figure 04 : Thermal sequence differences between hours of the same season

Regarding thermal discontinuities (Table 03), we have summarized summarize them for the case of the Salzburg Historical Museum proposal as follows:

Table 03 : Thermal simulation for the most unfavourable periods of the year.

[Table 03 near here]

2.2.3. Estimation of discontinuities:

Provided that a sequence of several shots performed on the same urban landscape will have breaks in between shots; the breaks being the change in elements perceived in the visual field, then the quality of the urban sequence is to be weighed by how much inter sequence continuity is released. In case no break in occurring, therefore the details at a new sequence will be as similar as old one.

The estimation of discontinuity is subjected to the change in ambiance. We tried to identify the existing situation mostly used in contemporary museums which are related to the three typologies. These discontinuities are likely becoming our theorical basis for future designs in proposing topologies that best respond to the nature of the museum and exhibited objects.

From a mathematical stand point, topological problems related to the order of differential geometry are solved this way: one or two variety spaces would translate as a MAP; in case of more than two, it would be an ATLAS. Compared to architectural space, the sequences of each type of ambiance would tell us more about the dominant type of ambience in the sequence found in each museum. Such experiment would likely match the data of each sequence: first combining two sequences of ambient panorama, i) **Combined sequences (light-sound) ii) Combined sequences (light-thermal), iii) Combined sequences (thermal-sound).** Secondly, establishing what makes the three types of topological sequences correspond and finally deduce sequences with a compound ambient topological character.

The thematic addressed in this article is meant to be such a theoretical basis for a much more consistent study project we have had already started. It basically highlights the sequential analysis with its pending results. We intend to be adding more findings in the coming article.

2.3. The study corpus:

There´s a myriad of varieties in the classification of museum typologies, however, the museum architectural space design is based on characteristics related to a few essential parameters. First, the museum is considered to be a building. Second, its pathway represents a key element in the design. Third, its exhibition space (sensory aspect of the visitor).

The historical evolution of museums has reported that during the Renaissance and quite earlier a museum had had a limited function: a little space set up in temples, castles or other buildings to preserve and exhibit art objects. However, the Baroque period saw a complete shift on how a museum should look like. Modern museum, particularly, the notion of white cube in 20th C has had much influence on its evolution.

Late 20th Century up to this day, architectural trends have led to the emergence of specific types of museums. For instance, the symbolic museum came with the notion of conveying specific message about its hosting city. Literature review has denoted that architects came with three existing realities: i) the revival of the monumental tradition, ii) the search for an affinity with the historical landscape; iii) the fascinating virtuality.

As a result, there are numerous museums in nowadays that serve this purpose. Shapes, colors, and functions are all different, likewise, the sort of exposure.

Our research is focussing on museums that fit several criteria, this includes: i) same historical timeframe, ii) the aim to construct architectural work with daylight, which we name it as "luminous purpose," and iii) the quantity of information presented (speech, text, graphics, images...).

Being designed to work with natural light has an impact on the project's orientation, materials, and colors,...all of which have an impact on the thermal environment, and the corpus of study will contain thirty European museums. (Table 04).

The use of sound and thermal ambiences is explained by the fact that the museums we chose were all built between 1980 and 2008, a period defined by the impact of sound and thermal-based museography enterprises on museum design and implementation.

The route of contemporary museum is sometimes not given a thought by the visitor whose primary concern is the works being exhibited. This is quite the opposite for Tayac Museun, Jean Tingley, Jawish museum in Berlin where the route is more important than the works exhibited.

A route that qualifies as modern or contemporary has to be very animated with quite varied topology, in a sense it cannot be autonomous, although the external form might be very simple or basic, the route inside may have plans and inclined ramps. Architects made use of very rigid forms having spatial robustness that would ensure animation and allow the creation of interesting relationships with the outdoors. Topologies of routes are related to the architectural anatomy of the building, not to the stylistic tendency.

Table 04 : Case studies

[Table 04 near here]

According to the typology proposed by R. Gregory (2008), it could be that a building belongs to three or four types of classification. Such is the case of the Young Museum by Herzog and de Meuron, a building of extraordinary refinement, which has the merit to be cited in several books. It is conceived as a series of deformed bands, clearly constituting a variant of the linear organisation. It´s tower is treated in that way to comply with the urban grid of san fransisco, deserving to be analyzed among other superimposed plans.

As a separate object of investigation, it is rather to be interpreted as a good sculptural adaptation to the urban landscape. At last, there´s a focus on courtyards in trying to define what is ultimately a simple orthogonal stell box.

This leaves researchers to proceed under their own reading of plans to organize their projects. Our study corpus falls into this type of typology while the historical evolution and the targeted public criteria are not of prime concern. In other words, we mainly favour the architectural aspect: plans, sections, elevations, and all architectural details.

3. Results and discussions:

3.1.The luminous topologies and their visualizations :

3.1.1.The discontinuity of orientation 85%:

For example, the Athens Museum follows a straight route. The first graph displays a segment of the route, illustrating how the surface illumination curves cross from one series to the next, ranging from 400 to 1900lux for the west direction at 15h. Because of the route's linear design. The curves are in ascending order due to the route's linear shape (time or attendance, very high in summer).

The second graph depicts a section of The Alvdal Museum's linear route (Tab 05), where it can be observed that there is no consistency between the sequences due to differences in the orientations of the openings, highlighting the discontinuities of orientation in this case study.

Table 05: Example of discontinuities in orientation

[Table 05 near here]

3.1.2. the discontinuity of the type of lighting 80%:

To highlight the discontinuities of the type of lighting, we took the case of The Paris Natural History Museum for a centered route and the time of attendance of 14H00 in April (Tab 06), we found that for the first graph containing just the zenithal lighting, the curves of the surface illumination are parallel, this refers to the continuity character of the sequences.

In the second graph, the lighting levels are very variable between the successive sequences, this is due to the existence of several lateral bays throughout the course.

Table 06: Example of discontinuities of the type of lighting

[Table 06 near here]

3.1.3. The discontinuity of Bay size 63%:

The graph for this case study shows part of the route in the Musée De Quai De Branly (Tab 07), where the size of the bay varies throughout the route. We, therefore, notice growing stability of surface illumination at the ceiling and floor level, however, at the level of the sequence wall, the values are very variable and it is thanks to this value that the discontinuities in the size of the bay are identified.

Table 07: Example of discontinuities of the bay size.

[Table 07 near here]

3.1.4. The discontinuity of bay position 40%:

In the Sammlung Goetz museum and for the first graph, we notice that on the ground floor, the curves are parallel, this is due to the absence of discontinuities. For the graph of level 01, in the first three sequences we notice that the curve of the surface illumination of the wall is in a decreasing direction, this refers to the existence of discontinuity of the position of the bay which occupies the high part of the wall, for the rest of the sequences, the bay is located in the middle of the wall and this reduces the surface illumination at the level of the wall of the sequence (Tab 08).

Table 08: Example of discontinuity of bay position.

[Table 08 near here]

3.1.5. The discontinuity of the proportion of the bay about the wall or ceiling43%:

The curves in the first graph are all variable, indicating that there is a discontinuity in this section of The Jewish Museum of Berlin (Tab 09). Stability is present in sequences 03 and 04 of the second graph. The lighting curves are varied throughout the rest of the sequences, In the case of The Bilbao Museum, this describes the discontinuities in the proportions of the bay.

Table 09: Example of discontinuity of the proportion of the bay.

[Table 09 near here]

3.2. Thermal topologies and their visualizations :

3.2.1. Thermal discontinuities for adverse winter periods :

There are several types of winter discontinuities, they are of a percentage of 40% for the whole season. It is around 47% for all the case studies for the coldest winter mornings, as in the case of The Musée Du Quai De Branly competition. For the midday period, the discontinuities present a percentage of 50% in all the case studies, we cite the case of Bonnefanten Museum, Maastricht, The Netherlands. For the afternoons of the coldest days the discontinuities present 50% of the case studies, as in the case of the Museum KUNSTHAL; Rotterdam Netherlands (Tab 10).

Table 10: Thermal discontinuities in the winter season

[Table 10 near here]

3.2.2.Thermal discontinuities for adverse mid-season periods:

For the mornings of the mid-season days the discontinuities are 73%, we quote as an example (Tab 11) the case of The Historical Museum Of Salzburg, for the midday period the percentage of the discontinuities is around 77% as in the case of the Museum DE MAXXI in Rome, for the afternoons of the mid-season days the discontinuities present 77% of all the corpus.

Table 11: Thermal discontinuities in the mid-season

[Table 11 near here]

3.2.3. Thermal discontinuities for adverse summer periods:

These discontinuities are present in 77%, distributed over the three periods of the day as follows (Tab 12): the discontinuities of the morning period 80% we cite for this purpose the case of the Museum of Modern Art and Architecture Stokholm, for the same season in noon period the percentage is 80% as in the case of KUNSTHAL; Rotterdam Netherlands. And

finally, for the afternoon period, the percentage is 80% as in the case of Sammlung Goetz Museum.

Table 12: Thermal discontinuities in the summer season

[Table 12 near here]

3.3. Sound topologies and their visualizations:

3.3.1. The discontinuities of orientation:

The sound source is linked to these types of discontinuities, which tend to keep the same characteristics throughout the museum route by changing orientation. As for the physical characteristics of the architectural museum space, they will play a major role in the variation of the sound ambience.

One example is the Acropolis Museum in Athens (Table 08), where the sound sources are not oriented in the same way. This will contribute to the birth of orientation sound topologies.

3.3.2. Direction discontinuities:

The fluctuations that affect the directions of the sound source throughout the journey are strongly related to direction discontinuities. These sound sources generally obey the same direction of the route in question; however, they remain free to change in several sequences.

The sound direction discontinuities change along the course; in some situations, like in the case of the Jean Tingley Museum, the direction of the sources completely follows that of the route. (Table 08)

3.3.3. Reverb discontinuities

It's the presence of many sound reflections along the same route whose character is variable from one sequence to another. We will then talk about reverb discontinuities.

One example is the case of the Maritime Archaeology Museum designed by Alberto Campo Baeza where reverberation is present in certain sequences but not others, and even when it is there, it varies (Table 08).

3.3.4. The discontinuities of useful (reflected) sound :

The analysis of the sound wave allowed us to detect the characteristics of the useful sound which is in our research the reflected sound, it also allows us to highlight the limits of the sequence. The discontinuities of the useful sound are related to the variations which affect the environment of the conformation of the sequences.

Sometimes the useful sound wave remains in the geometric shape of the conformation as was found in the case of the American air museum; the useful sound wave fully respects the geometry of the conformation (Table 08). Sometimes it exceeds the limit of the simulated sequence towards the outside or towards the neighboring sequence, thus not respecting the limit of the conformation such as in the case of Hergé de Potzamparc (Table 08).

3.3.5. The Refraction discontinuities:

It should be noted that in some sequences of the route, sound waves undergo a break characterized by a change of angle as soon as they touch the walls, this break manifests itself by a change of directions, subject to a discontinuity related to the composition of the wall. This we will identify as discontinuities of refraction.

An example of refraction by the interior walls is the North Jutland Art Museum or internal refraction (Table 08).

3.3.6. The Direct sound's discontinuities:

The presence of sound-modifying materials or impediments that hinder sound from being transmitted from the emitter (guide) to the listener (visitor), generates what we call discontinuities related to direct sound. Depending on the intensity, these discontinuities can be strong, medium, or weak.

We can cite the case of the Grenoble Museum of Fine Arts or the direct and practically loud sound in most of the sequences.

3.3.7. Sound boundary discontinuities :

The properties of the conformation when the sound is above or below the audible limits are related to the discontinuities of the sound boundaries. This will demarcate the audibility zone's boundaries.

We will cite the example of the Maxxi museum (Tab 13) where we note the absence of sound boundaries in some sequences such as Sequence 04 and their presence in others such as Sequence 02.

Table 13: Examples of sound discontinuities

[Table 13 near here]

3.4.Discussions:

3.4.1.Signals, route and ambient topologies.

We have come to the conclusion by following topological rules used in all the software that takes into account the topology aspect. Our findings have established some correspondences as follows: I) Regarding the superposition between two ambient topologies: Perfect superposition, Partial superposition by union, Partial superposition by subtraction. II) In case of more than two varieties: Global partial superposition, Global perfect superposition.

3.4.1.1. the correspondence between the luminous and sound ambience :

we obtained two typologies: i) the presence of luminous discontinuities of the size, the shape and the position of the bay refer to the presence of sound discontinuities of direct, useful and masked sound, ii) the presence of luminous discontinuity of the proportion of the bay corresponds to a presence of sound discontinuities of reverberation, direction, and orientation.

[Figure 05 near here]

Figure 05 : Multivariate correspondence between luminous and sonorous discontinuities.

We took the historical museum of Salzburg and After the superposition of the sequence analysis for the case of light and sound ambience, we noticed that for both cases presented in

the figure, the two sequences overlap. For the following light parameters: size/shape/position and the following sound parameters: direct/useful/masked, it is noticed that the yellow color that overflows for the case of the sound sequence is related to other analysis parameters that are the transmission of the wave.

Regarding the Bonfenten museum, the sound sequence can be superimposed on several light sequences, and it cannot be considered as an overlay.

In the museum of Kansthal, we have noticed an overlap in the very first sequence, the rest of the sequences bear no relation.

3.4.1.2. the correspondence between light and thermal ambience

we obtained two categories: i) the presence of light discontinuities of size, shape and orientation of the bay, correspond to a presence of the following thermal discontinuities: S. M/S.N/S.A/MS.A, ii) the absence of the discontinuity of the proportion of the bay refers to a presence of thermal discontinuities MS. A/MS.M/W.N/W.A.

Regarding the Salzburg Museum, the thermal sequences are perfectly superimposed on the luminous sequences because of the morphology of the space and the type of lighting which is zenithal.

We noticed the existence of thermal and luminous discontinuity by superposition in the MAXXI Museum, where we move for the same type of lighting, from a thermal sequence of blue color to a thermal sequence of orange color, then to a succession of the same typology of sequences (materializing the continuity).

[Figure 06 near here]

Figure 06 : Multivariate correspondence between luminous and thermal discontinuities.

3.4.1.3. the correspondence between the sound ambience and the thermal ambience:

we noticed two categories: i) the presence of the sound discontinuities of; direct sound, useful sound, echo, and the sound boundary. The absence of the discontinuities of direction, parasitic transmission and refraction, would return to a presence of the thermal discontinuities of S. M/S.N/S.A/MS.A, ii) the presence of the sound discontinuities of the masked sound with an absence of the discontinuities of orientation and reverberation, return to the presence of the thermal discontinuities of W. M/W.N/W.A / MS.N.

We take as an example the historical museum of Salzburg for the sequence 01,02, 03, we have a total superposition of the sound and thermal sequence, the yellow color which overflows is due to the discontinuity of transmission of the sound wave of the sequence.

We notice that the morphology of the conformation has a great influence on the nature of the sequences.

[Figure 07 near here]

Figure 07 : Multivariate correspondence between sound and thermal discontinuities.

We can also quote the case of prehistory museum of Paris and the Beyler Reihn museum where we notice that the course is considered as both as thermal as well as a sound sequence (except for the variable of transmissions). The limits of the conformation also draw a limit to the sound and thermal sequence.

Regarding Hergé Museum on the ground floor, the sound and thermal sequences overlap perfectly, this is due to the fact that there is not a great variation in temperature which causes the absence of thermal discontinuities, and therefore, only mentioned sequences overlap (except for the discontinuity of transmission).

3.4.1.4. the global correspondence according to the ambience analyzed and the type of route :

We have come to the conclusion that in the museums where the route is of linear form, the ambient topology is present by: i) the luminous topologies related to the position of the bay and its proportion in the wall, and ii) the sound topologies related to the orientation, the direction, and the reverberation. For museums where the route is centered, there is only one ambient (thermal) topology which corresponds to the thermal topologies of the winter season, and to that of mid-season in the morning and noon period. The ambiental discontinuities in the linear routes are rhythmic, and we do not feel the abrupt changes of ambiences. The exposed objects often stand in a linear way, however, in a discontinuous sequence they are gapped so as to create free passages for visitors to circulate.

For museums with a labyrinth or mixed route, the ambient topology is composed of three topologies: i) the luminous topologies which are related to the size, the shape, and the orientation of the bay, plus the type of lighting, ii) the sound topologies which are related to the masked sound, the direct sound, the useful sound, the echo, and the sound boundary, iii) the thermal topologies of the summer season and of the afternoon period for the mid-season.

The Ambiental discontinuities in this typology are quite varied and the rhythm is hard to establish, even though the centred route displays it. However, any abrupt change in ambiences of a route sequence would mean the appearance of discontinuity, therefore, the ambiance will come in a totally different shape.

Sequences of discontinuity in a labyrinthine route are chosen by architects as a space to display the works of art, which is more or less corresponding to the perceptible side of ambiences. Sometimes a feeling of discomfort in a sequence is induced by the architect designer for a specific reason.

3.4.2. ***The Intentions of the Architect and the Influence of the Stylistic Tendency on the resulting Discontinuities:***

3.4.2.1: Reading the stylistic tendency

It is very simple to categorize museums according to the stylistic intentions (Basso Peressut, 1999), but this does not add any value to our ambient topology research. Moreover, many writers claim that the contemporary conception of museums began with the works of the Guggenheim of Salzburg, which is a very unique project with a very unique conception where the connection between different rooms is made by a mixed route. The snag is that the project does not offer a specific external image because it is anchored in the ratchet. The Bilbao Guggenheim will be mentioned because its exterior is more expressive. This means that the project's image is not only important, but it also determines the museum's role.

According to the conceptual intentions of the architect and in accordance with the definition of the topological approach, we could be classifying the museums of our corpus into two categories depending on the discontinuity results: i) the first one is seeking mathematical answers to architectural form problems, be it the essential feature of the new avant-garde. This type of architecture conveys the geometric topological message through its external form in all its unique splendour. Most of its projects deal with rehabilitation of urban fabric whether in decline or new neighbourhood, for instance, Gallego De Arte Center. ii) the second one is seeking the creation of forms that express heterogeneities in our world of current ideas through mathematical topology. This is basically the movement of the deconstructivist architects whose talent is to display the continuous transformations in the original form. Thus, making the museum project a message carrier, particularly highlighting the effects of chaos as in Bilbao, Vitra Museum and the Jewish Museum in Berlin.

In order to study the luminous ambience in both typologies, we have successfully compared Ara Pacis of Richard Meier, that belongs to the new avant-garde, with the Maxxi Museum of Zaha Hadid. However, by comparing the ambient landscape of the luminous sequence at the new avant guard museum entrance, the state of the light spectrum is totally different from the

peak which is corresponding to a punctual zenithal light embedded as a uniform luminance of the entrance bay. On the other hand, Zaha Hadid Museum showed a spectrum of several peaks which would suggest the existence of several values of high luminance in the same route. By the way, the zenithal lighting constitutes the dominant element.

Table 14: Comparison between the luminous spectrum of luminance in two examples of the corpus study (avant-garde/Ara Pacis, Deconstructivist/ Maxxi Museum)

[Table 14 near here]

We summerize all these details by saying that the peak in the graph of Meier Museum would correspond to a single dominant sequence displayed in the photograph, i-e, the zenithal lighting. On the other hand, the type of lighting in Zaha Hadid´s graph showed a variety that corresponds to the existence of several discontinuities.

3.4.2.2. Impact of the ambient topology on the exhibited museum objects and the museology as a whole and limitations of the research:

Basso Peressut (1999) compares the effect created by modern museum design to that which can be instant or long-term. In our corpus, we found that the deconstructivists' sought-after ambient topology had an immediate effect on the visitor. This is owing to the building's powerful outward form; nevertheless, the visible articulation within appears rough, and all the emotions associated with the show will come later. The Guggenheim in Bilbao, for example, is a step forward in terms of marketing. However, in most new avant-garde museums, the effect is not immediate; in most cases the form is very basic, the details inside are designed in a very precise way, each element plays a very important role in the exhibition. The museum appears simple, and it is the effects produced that the visitors will discover during their movements within the building by rejoicing in the mystical tone that attracts the visitors' attention. For this aim, we will take the example of the Kunsthaus Zumthor museum, which is far from being a marketing museum (Basso Peressut, 1999) and has achieved an edifying level of sobriety through its plain character.

The ambiental topologies resulting from the superposition of several topologies are indeed very present in the museums of the new avant-garde. The passage of an ambiental sequence to another is made in a linear way, that is to say, without discontinuities. In the deconstructivist museums or of ambiguous forms, the ambiental topologies exist in a punctual and discontinuous way, this means that the superpositions are perfect in the parts where the architectural conformation constitutes itself a sequence of the museum route.

Back to the types of environments cited by Maria Saraiva (2001) in point 1.3 above: i) the objectal environment, ii) the functional environment, we can say that our research takes into consideration both types, except that in this article we will not present the results of the quantitative part. In the end, the consideration of the museum environment through its sequences places the physical signal at the center of all the reflections. In contemporary museums the impact will be immediate on the visitor who is the user on the move as well as the object exposed in a given sequence.

We have noticed, for example, that among the museums that represent a linear route especially the museums of the new avant-garde of our corpus, with ambient topologies that overlap almost perfectly, the exhibited object is placed in the center yet the route makes its turn. This means that all the luminous sequences that follow each other will have the same spatial characteristics, same case is observed for thermals too. We have observed that the sound sequences will not be affected as much, since the sequence where the object is exposed constitutes a single sound sequence (the guide will speak only once at the beginning or at the end of the sequence. For the objects exposed in other sequences, the museographers had positioned them in such a way that the influence of direct daylight and heat does not deteriorate them, therefore they are in perfect linear sequences.

[Figure 08 near here]

Figure 08 : Linear route and disposition of the works of art in the museum of the Ara pacis.

Regarding the museums of the deconstructivists like the MAXXI museum, the discontinuities of the sequences create very perceptible contrasts for the visitors. The exposed art objects do not follow in any case the sequences. The work of the museoraphs follows the effects of light studied, creating a duality of sharing the quite varied sequences and, on the other hand the architectural space which is exposed.

[Figure 09 near here]

Figure 09: Mixed route and disposition of the artworks in the MAXXI museum.

This work that we have elaborated builds the concept of topology that remains objectively and subjectively very linked to the museum space, however, we cannot be satisfied with just this analysis to theorize. The fieldwork will constitute a logical continuation to develop this new way of reading the space through the ambiences. The graphic file does not inform us about the position of the works of art, the photos constitute crucial information for our study, however, the survey and the work in situ, with the taking of measurements will allow us to better define the ambient topologies, which in this case will have significant values.

Conclusion:

This study allowed us to emphasize the importance of visualization in the representation of architectural space in general, and the concept of ambience. The more realistic a software could be, the better is the experience of working through. The advancement in technology has brought about a plethora of softwares offering a wide range of options.

Thanks to the notion of ambience, we try to make the architectural space a link between the subjective and the objective, thus trying to reduce its ambiguity.

As a concept relating to architecture, topology has long been used by urban planners. All attempts to define this concept, however, refer to mathematics, leading us to conclude that a specific definition for architecture has yet to be developed.

Architects' interpretations on the definition of topology all refer to movement along a set route and during a specific time period. Then, using the principles of route and sequence, we must create our definition.

The definition of topology is closely linked to the notion of the route. This linking idea has spurred our choice to work on museums. In museums, the notion of the route is often highlighted from the design phase. To begin the sequence analysis, about thirty European museums were chosen based on a number of criteria.

Although the physical aspects of the ambiences can be classified as similar, this allowed us to identify a significant difference between the research of seen ambiences such as the luminous ambience and the analysis of unseen ambiences such as the sound and thermal ambience. The visualization phase of the analysis phase of the unseen ambiences is critical because it allows an environment that is visually difficult to define to become visible and limited in the architectural space. The study's conclusions, which in our case were based on a sequential analysis, are completed and supported by the perceived ambience.

In both cases, the visualization allows the topological ambient sequences to be materialized. We were able to make a preliminary sketch of the definition of this ambient topology. Whether it is light, acoustic, or thermal, the topology corresponding to discontinuities in the ambient event in question is obtained by theoretical reading. In the case of the luminous ambience, the topology is represented by variations in the spatial features or the bay's course. In the case of sound ambience, the topology corresponds to the change in the parameters of the sound wave as a function of space and the position of the visitor guide along a given route (sound source in movement). for the thermal ambience although it is not very materialized by the visualization, it corresponds to the change of temperature in a given route. We may claim that this reading is still of theoretical order, despite the fact that it has been statistically proven. We want to confirm it with field study that will involve a commented route and measurements.

As a result, topology in an architectural setting might produce a new spatiality. The findings of this study will aid our understanding of spatial ambiences. The results can be used to create a computer programming interface that evaluates the sequence's nature and type of topology.

The use of simulation in luminous topology may complete or confirm the luminous topologies resulting in effect. However, simulation applied for invisible ambiences is a must because it allows good visualisation to the extent of palpability. In our work, the simulation was of great importance (as the work had been done on book examples), it allowed us to make the topologies more visible, to calculate them and to detect their limits in the conformation. However, the simulation alone cannot replace the in-situ analysis which can be accompanied by measurements, and makes the results much more accurate.

Finally, we were able through this research to confirm our assumptions, thus responding to the problem posed in the abstract. This research will allow us to explore new horizons in the fields of scientific research. In order to refine, deepen and improve our achievements we propose as future research:

- To create an interface allowing data input from similar museums to obtain the topology types existing for each.

- To Match the quantitative results of the simulation with an in situ measurement campaign to confirm the topologies. hence to be able to provide information about the optimal location of art objects across ambient topologies.

- To propose for the future design of museums the topologies that best correspond to each type of museum and museography work.

Références :

Aish, R., Jabi, W., Lannon, S., Wardhana, N., & Chatzivasileiadi, A. (2018). Topologic: Tools to explore architectural topology, Conference: Advances in Architectural Geometry 2018 At: Chalmers University of Technology, Gothenburg, Sweden.

Baker, N., Steemers, K. (2002). Daylight design of buildings. Ed. James & James (science publishers) Ltd, 35-37 William Road, London, NWI 3ER, UK.

Basso Peressut, G. L. (1999). Musées. Architectures 1990/2000. Edited by : Actes Sud.

Beaudoin, J. M. (2016). Évaluation de parcours d'exposition: une approche par indicateurs spatiaux et temporels. La Lettre de l'OCIM. Musées, Patrimoine et Culture scientifiques et techniques, (165), 24-31. htsatps://doi.org/10.4000/ocim.1658

Biron K. (2008). Dynamique Forme/Lumière Exploration du processus de création de l'espace architectural par modèles maquettes/images, NOVEMBRE 2008.

Bonnet .G (2005) ,Rayons sonores et ondes de lumière ?publié sur http://culturesciencesphysique.ens-lyon.fr/ressource/RaySon.xml le 18/04/2005 consulté 22/08/2015

Bonnin, P. (2010). Pour une topologie sociale. Communications, 87, 43-64. https://doi.org/10.3917/commu.087.0043

Borie, A., & Denieul, F. (1984). Méthode d'analyse morphologique des tissus urbains traditionnels, Collection Etudes et Documents sur le patrimoine culturel, UNESCO.

Boubezari M, Bento Coelho J. (2004). Ambiance et espaces sonores, espace et société n°115, Ed Harmattan.

Boubezari, M., & Coelho, J. L. B. (2012, September). La topographie du paysage sonore-Un outil descriptif et prédictif des ambiances sonores. In Ambiances in action/Ambiances en acte (s)-International Congress on Ambiances, Montreal 2012 (pp. 247-252). International Ambiances Network.

Bouchlaghem, D., Shang, H., Whyte, J., & Ganah, A. (2005). Visualisation in architecture, engineering and construction (AEC). Automation in Construction, 14(3), 287–295. doi:10.1016/j.autcon.2004.08.012

Boudier, A., & Guibert, E. (2006). Cours d'acoustique. Techniciens supérieurs son 1re année, 2007.

Chapman, M. (2002). Giuseppa di Cristina (ed.), Architecture and Science–(London: Wiley-Academy, 2001).

Chelkoff, G. (2018). Expérimenter l'ambiance par l'architecture. Ambiances. Environnement sensible, architecture et espace urbain, http://journals.openedition.org/ambiances/1558 ; https://doi.org/10.4000/ambiances.1558

Chevalier, L. (2018). Prémices de l'optimisation topologique des échangeurs de chaleur. : http://hdl.handle.net/2268.2/4501

Ching, F DK. Architecture: forme, espace, organisation. Editions Eyrolles, 2019.p 256-291

Corbel, C. (2003). L'intégration du sonore au musée. Quelques expériences muséographiques (No. 16, pp. 73-81). Infolio Editeur/Ateliers d'ethnomusicologie.

Corcuff, M. P. (2007). Penser l'espace et les formes: l'apport des opérations effectuées dans l'analyse (géographie) et la production (architecture) d'espace et de formes à la définition et à la conceptualisation des notions d'espace et de forme (géométrie) (Doctoral dissertation, Université Rennes 2).

Cousin J. (1980). L'Espace Vivant. Introduction à l'Espace Architectural Premier. Ed. Le Moniteur, Paris.

D'Alba, A. (2012). Analyzing visitors' discourse, attitudes, perceptions, and knowledge acquisition in an art museum tour after using a 3D virtual environment. The University of North Texas.

Dapogny, C., Faure, A., Michailidis, G., Allaire, G., Couvelas, A., & Estevez, R. (2017). Geometric constraints for shape and topology optimization in architectural design. Computational Mechanics, 59(6), 933-965. https://doi.org/10.1007/s00466-017-1383-6

Defreville B. (2005). Caractérisation De La Qualité Sonore De L'environnement Urbain : Une Approche Physique Et Perceptive Basée Sur L'identification Des Sources Sonores. Acoustique [physics.class-ph]. Université de Cergy Pontoise, 2005. Français.

Degen, M., Melhuish, C., & Rose, G. (2017). Producing place atmospheres digitally: Architecture, digital visualization practices, and the experience economy. Journal of Consumer Culture, 17(1), 3-24. https://doi.org/10.1177/1469540515572238

Di Cristina G (2001), Architecture and science, published by Wiley academy, Great Britain.

Emmer, M. (2013). Topology from Art and Math to contemporary cities, AUSART Journal for Research in Art. 1 (2013), 1, pp. 255-264.

Goulette, J. P. (1999). Sémantique formelle de l'espace. Application au raisonnement spatial qualitatif en architecture. Intellectica, 29(2), 9-34.

Grégoire O, Kumbaro A. (2013). Introduction aux modèles industriels pour les écoulements liquide-gaz, Laboratoire d'Etude de la Thermique des Réacteurs, Cours diphasique industriel, Université PARIS VI,2013.

Gregory, T. R. (2008). Architecture and Interior Design for 20th Century America: Photographs by Samuel Gottscho and William Schleisner. Reference Reviews.

Grosjean, M., & Thibaud, J. P. (2001). L'espace urbain en méthodes. Editions Parenthèses.

Ibrahim M. H.(1997) A Typology of Building Forms, J King Saud Univ., Vol. 9, Arch. &Planning, pp. l-30.

Kantor, J M (2005). A tale of bridges: topology and architecture. Nexus Network Journal, 2005, vol. 7, no 2, p. 13-21. https://doi.org/10.1007/s00004-005-0020-4

Krier. R. (1988).(Architecturale composition); Newyork, Rozzeli Academy Edition, 1988. https://robkrier.de/architectural-composition.php#page-001.

Kurmann, D., Elte, N., & Engeli, M. (1997). Real-time modeling with architectural space. In CAAD futures 1997 (pp. 809-819). Springer, Dordrecht. DOI: 10.1007/978-94-011-5576-2_59

Liang, J., Zhang, M. Y., Xu, X. L., Li, J. W., & Huang, L. D. (2013). Topology Theory Application in Exhibition Design. In Applied Mechanics and Materials (Vol. 357, pp. 289-292). Trans Tech Publications Ltd. https://doi.org/10.4028/www.scientific.net/amm.357-360.289

Lojanica, V., & Dragisic, M. (2018). The topological principles in the contemporary architectural design process, International Journal of Novel Ideas: Mathematics.

Maria Do Rosario, F. C. (2001). L'environnement sensible dans les musées à caractère ethnologique (Doctoral dissertation, Université de Nantes).

Mariani-Roussset S, (1996), la méthode des parcours dans les lieux d'exposition, l'espace urbain en méthode, p29-p45. Editions Parenthèses.

Martinez, L. (2003). Oyez! le son s' expose (No. 16, pp. 83-94). Infolio Editeur/Ateliers d'ethnomusicologie.

Meyer M. (2013), la communication par le son dans les musées et les expositions, revue le son dans les musées. doc.ocim.fr/LO/LO004/LO4-P.PDF consulted the 13 /06 /2017

Nudds, M. (2004, June). II—the significance of the senses. In Proceedings of the Aristotelian Society (Hardback) (Vol. 104, No. 1, pp. 31-51). Oxford, UK: Blackwell Publishing Ltd.

Panerai, P., Demorgon, M., & Depaule, J. C. (1983). Analyse urbaine. Marseille: Parenthèses.

Parsaee, M., Parva, M., & Karimi, B. (2015). Space and place concepts analysis based on semiology approach in residential architecture: The case study of traditional city of Bushehr, Iran. HBRC journal, 11(3), 368-383. https://doi.org/10.1016/j.hbrcj.2014.07.001

Paul, N., & Borrmann, A. (2009). Geometrical and topological approaches in building information modelling. Journal of Information Technology in Construction (ITcon), 14(46), 705-723.

Pellegri, G. (2015). Survey and Drawing Representation of Architecture and Environment: Different Teaching Approach for Architects and Engineers. Procedia-Social and Behavioral Sciences, 174, 4090-4095. doi: 10.1016/j.sbspro.2015.01.1159

Pigeon J.R. (2013), Entre-Espace, Essai (projet) soumis en vue de l'obtention du grade M.Arch. École d'architecture Université Laval 2013

Ramalingom, D., Cocquet, P. H., & Bastide, A. (2017, May). Optimisation topologique des échanges thermiques dans un canal vertical asymétriquement chauffé. In Société Française de Thermique. https://hal.univ-reunion.fr/hal-01618696

Sahraoui N. (2006). L'identité sonore de la Médina de Constantine La qualité acoustique de l'espace urbain, Permanences et changements, mémoire de DEA.

Saraoui S.Belakehal A., Attar A. et Bennadji A., (2018) , Analysis and Visualization of the NewArchitectural Spatiality: Light and Sound Topologies in Museums. Actes de

ZEMCH 2018, (ISBN978-0-7340-5486-9) 29/01/2018-01/02/2018, Melbourne, Australie, pp.89-105.

Saraoui. S, Belakehal. A (2011), Parcours et séquences : des éléments fondamentaux pour une lecture topologique spatio-lumineuse de l'espace muséal. Actes de la conférence BASC'2011,

Scheer, D. (2014). The death of drawing: architecture in the age of simulation. Routledge. https://doi.org/10.4324/9781315813950

Schöffer, N. (1972). La tour lumière cybernétique. Art Book Magazine Distribution.

Sfintes, A. I. (2019, February). Architecture and Anthropology. Working in between Concepts. In IOP Conference Series: Materials Science and Engineering (Vol. 471, No. 7, p. 072027). IOP Publishing. doi:10.1088/1757-899X/471/7/072027

Siala, A., Allani, N., Halin, G., & Bouattour, M. (2016, September). Donner du sens à l'espace architectural. Vers une intégration de la dimension sensible de l'architecture dans les pratiques BIM. In SCAN'16: Séminaire de Conception Architecturale Numérique. https://hal.archives-ouvertes.fr/hal-02549200

Siret, D and Woloszyn, P (1998), 'Ambiances architecturales et urbaines – Du complexe au simplexe', in Adolphe, Luc (ed), Les cahiers de la recherche architecturale 42/13 - Ambiances architecturales et urbaines, Parenthèses Editions, Paris, pp. 49-55

Thibaud, J. P. (2002). L'horizon des ambiances urbaines. Communications, (73), 185-201.

Von Meiss, P. (1993). De la forme au lieu: une introduction à l'étude de l'architecture. PPUR presses polytechniques.

Wilhoit, E. D. (2016). Organizational Space and Place beyond Container or Construction: Exploring Workspace in the Communicative Constitution of Organizations. Annals of the International Communication Association, 40(1), 247–275. doi:10.1080/23808985.2015.1173526

Yang, Z., Gao, F., Shi, X., Lin, X., Gao, Z., Chong, Y., & Zhang, B. (2015). Topological Acoustics. Physical Review Letters, 114(11). doi:10.1103/physrevlett.114.11430

Zevi, B. (1984). Apprendre à voir l'architecture. Ed. de Minuit.GUAR

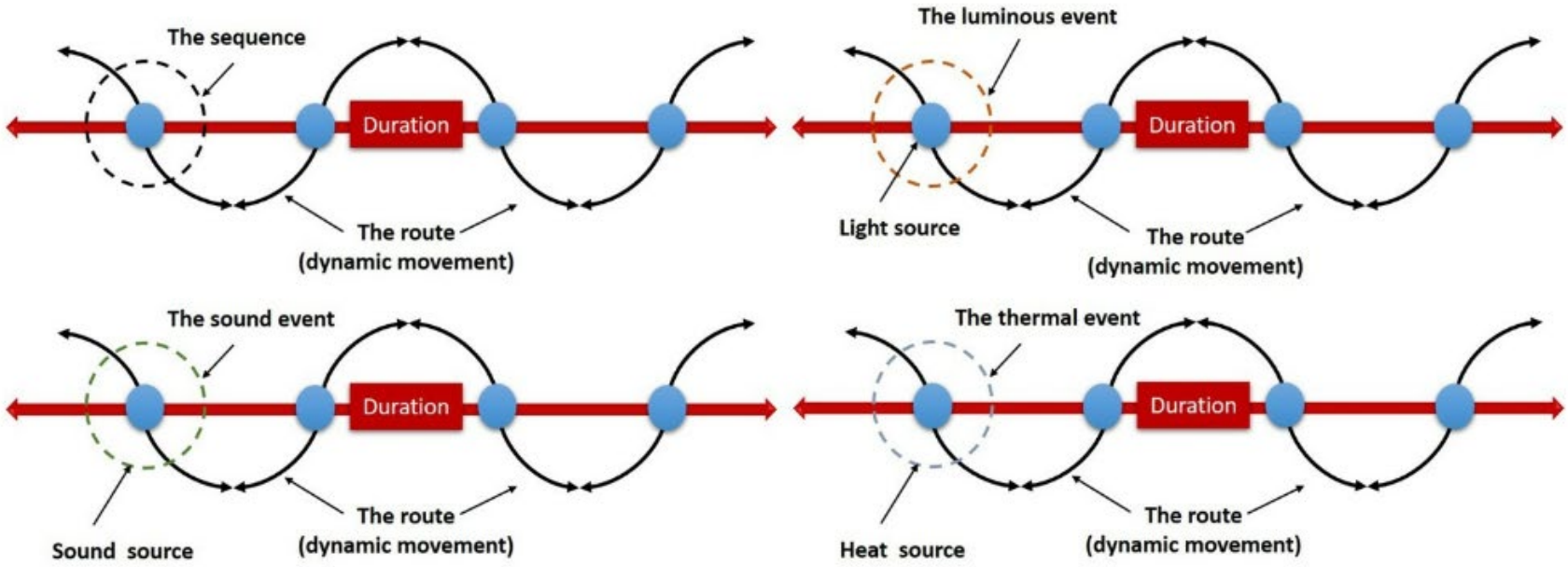


Figure 1. Definition of the sequential analysis for the lighting, sound and thermal ambiences according to the museum route.

Figure 2. Methodological principle.

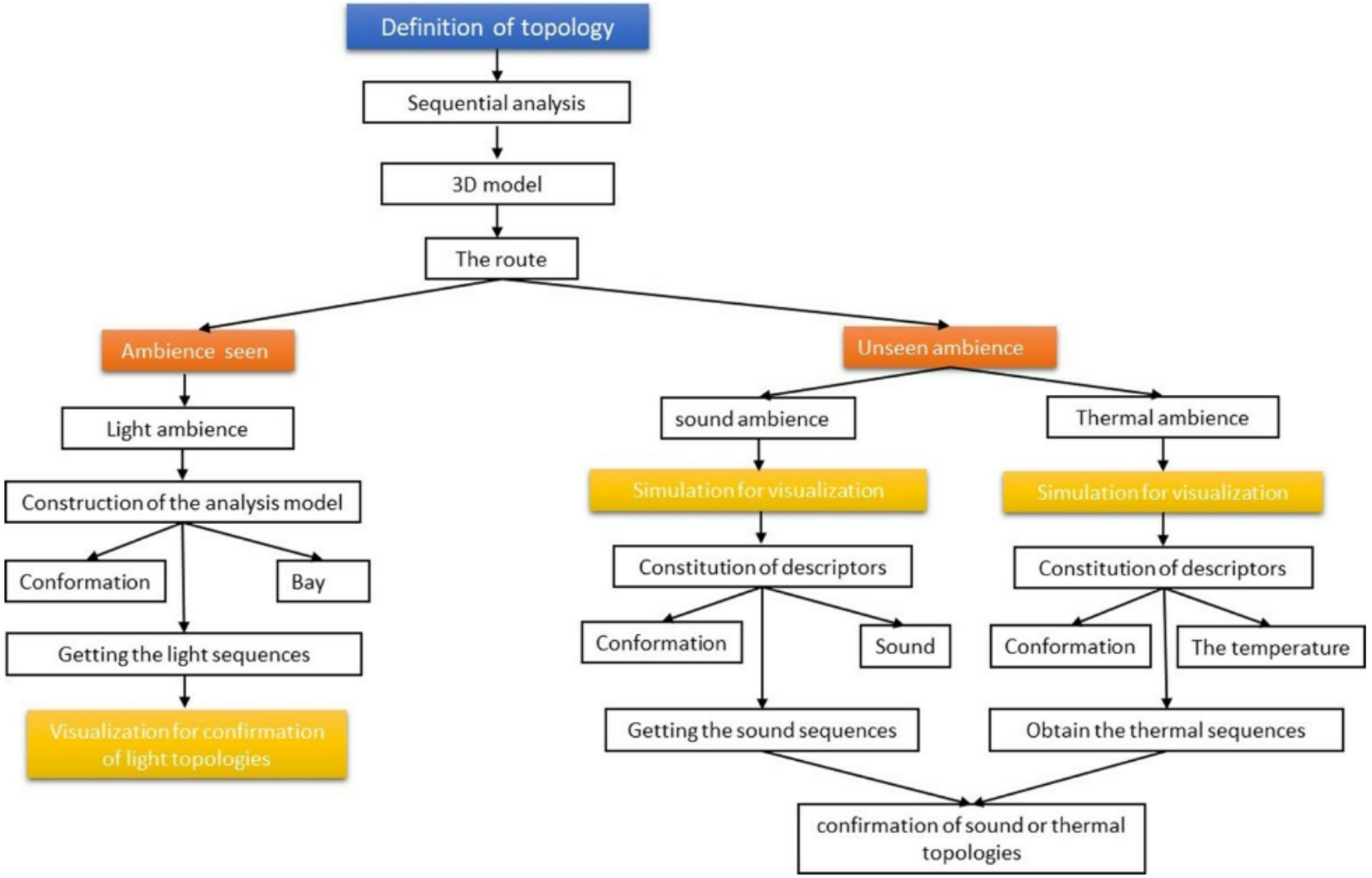


Figure 3. The sequences of the luminous topology.

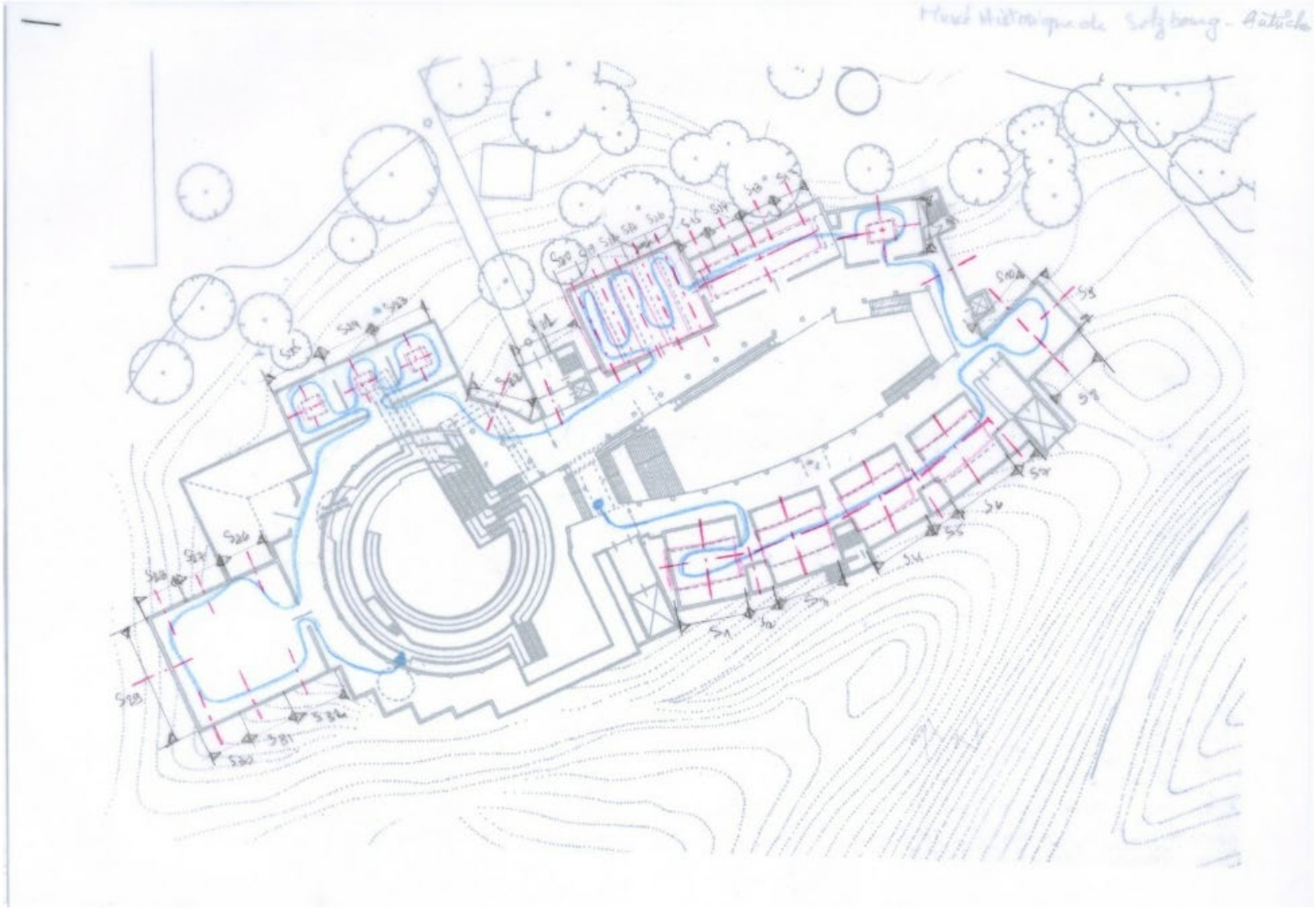
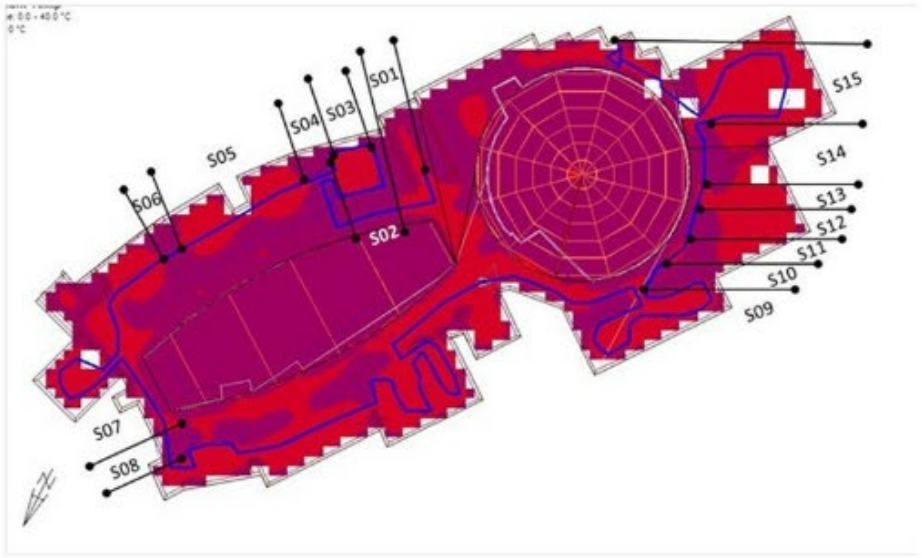
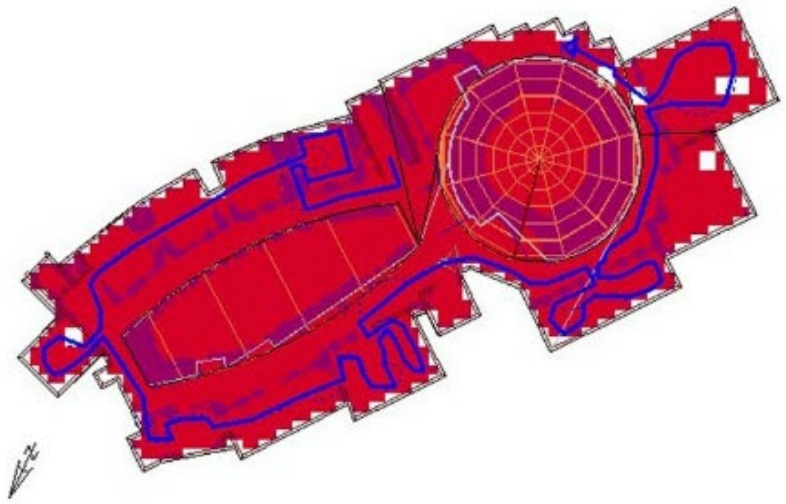


Figure 4. Thermal sequence differences between hours of the same season.



Morning



Noon

Figure 5. Multivariate correspondence between luminous and sonorous discontinuities.

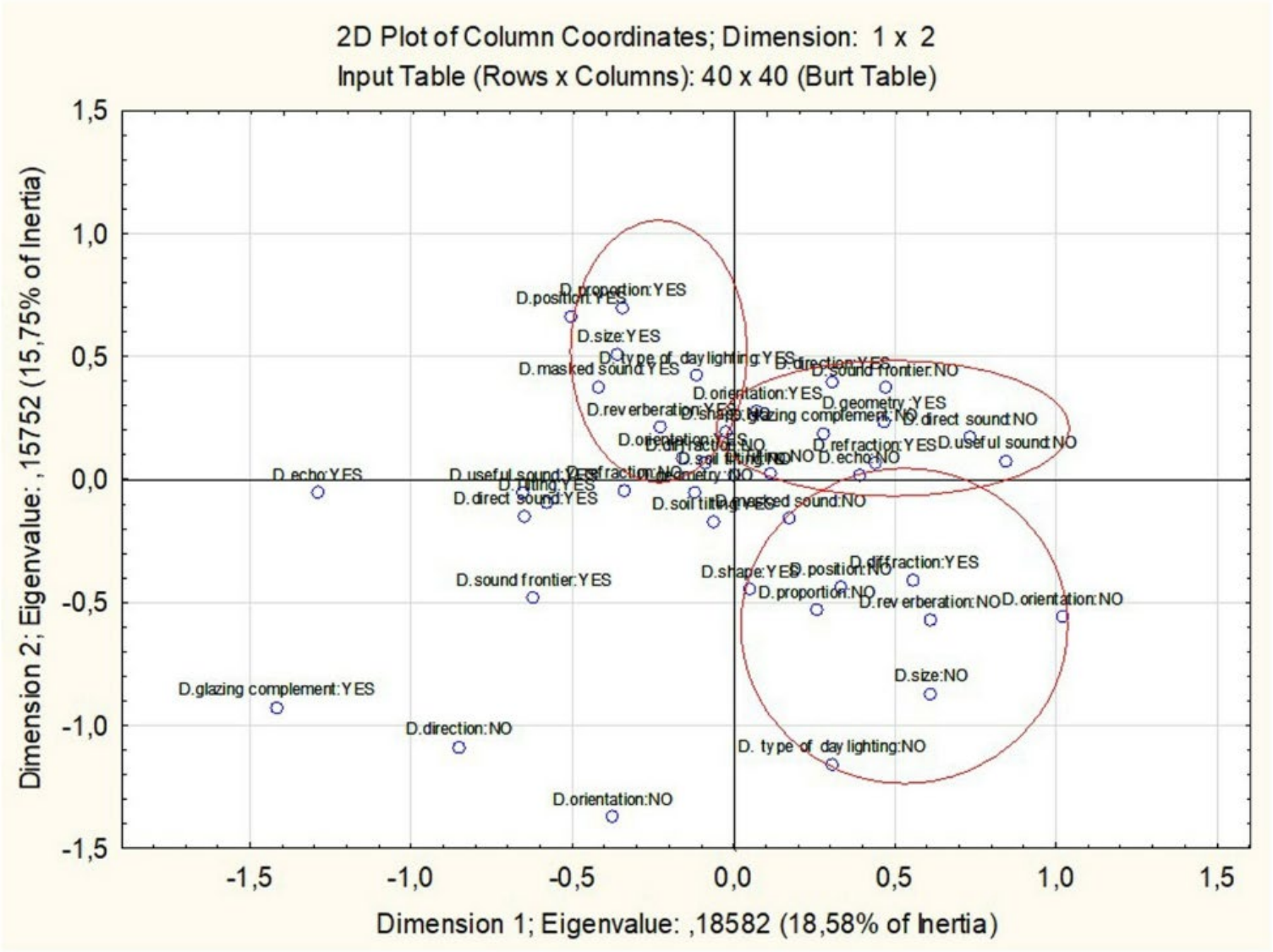


Figure 6. Multivariate correspondence between luminous and thermal discontinuities.

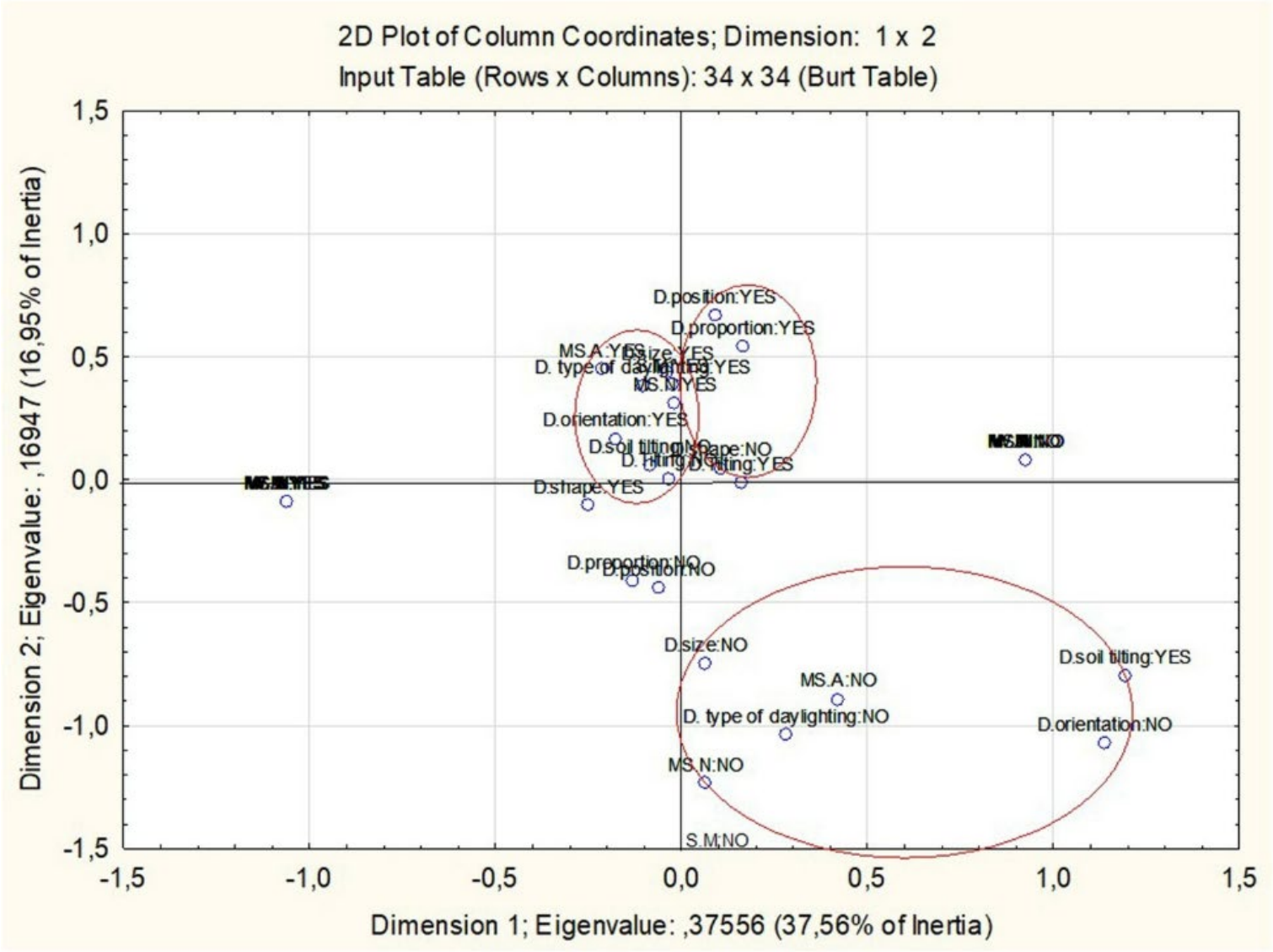


Figure 7. Multivariate correspondence between sound and thermal discontinuities.

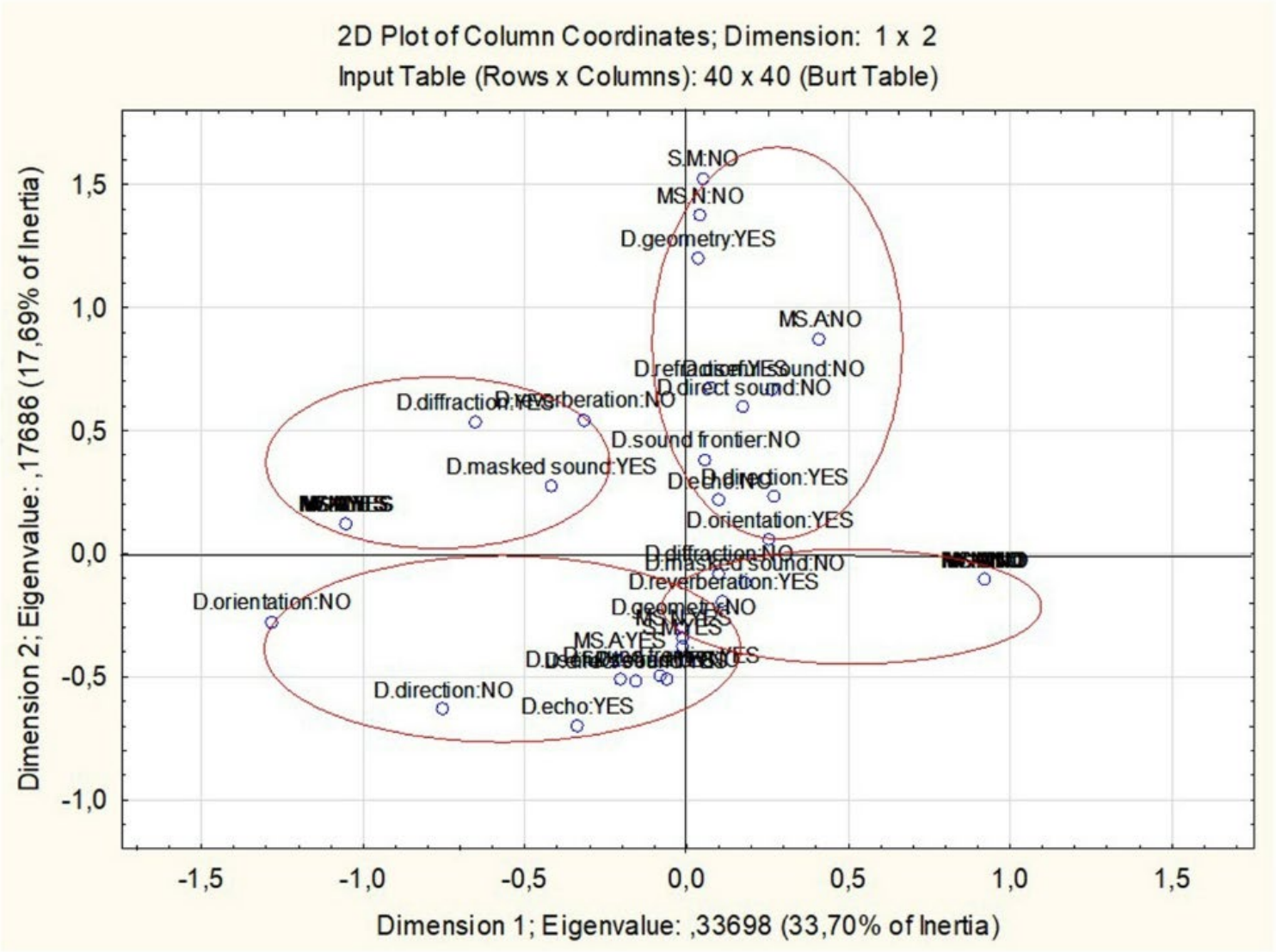


Figure 8. Linear route and disposition of the works of art in the museum of the Ara pacis.

Figure 9. Mixed route and disposition of the artworks in the MAXXI museum.

Table 01: simulation of some parts of the route by Radiance.

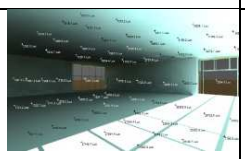
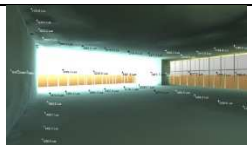
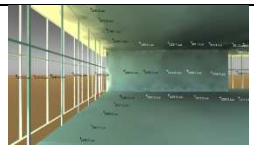
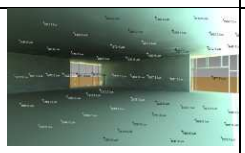
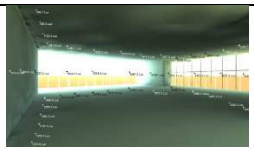
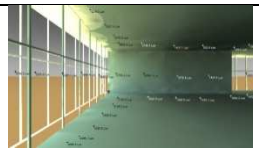
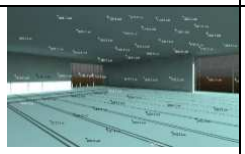
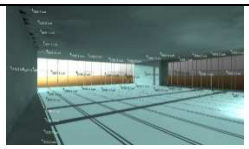
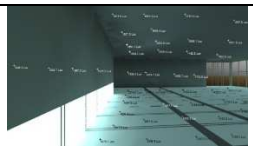
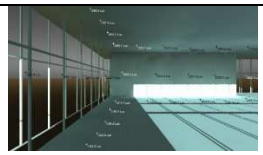
Time of attendance 13H	Space Discontinuities	Indoor and bay discontinuities	The bay's shape discontinuities	The bay's shape and character discontinuities
21 March				
21 June				
21 December				

Table 02 : Museum sound sequences in the Salzburg Historical Museum

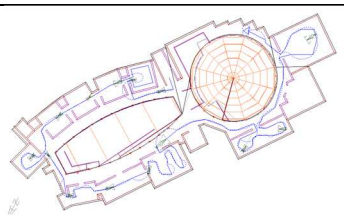
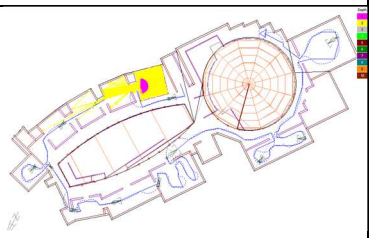
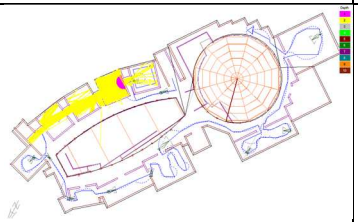
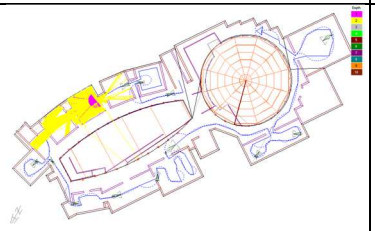
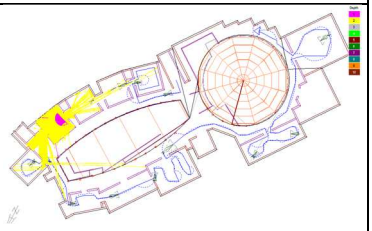
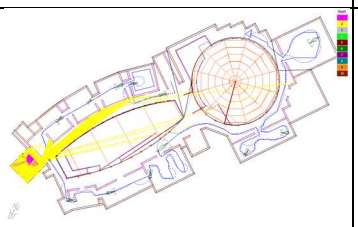
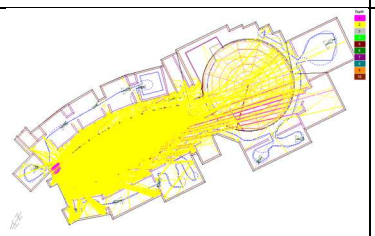
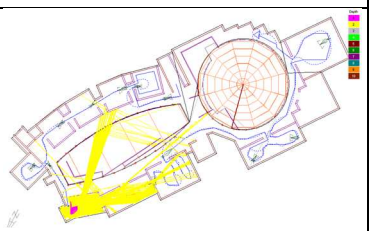
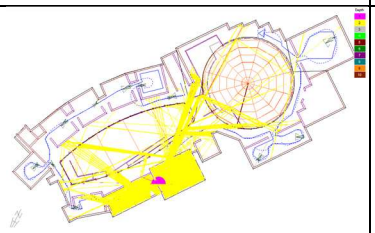
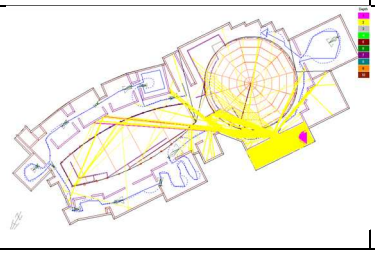
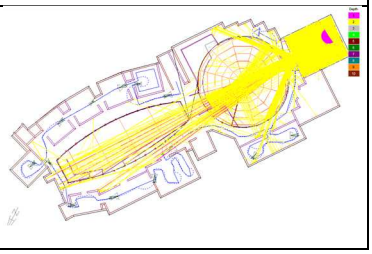
Sequences	**Sources**	**S01**	**S02**
Results			
Sequences	**S03**	**S04**	**S05**
Results			
Sequences	**S06**	**S07**	**S08**
Results			
Sequences	**S09**	**S10**	**S11**
Results			
Sequences	**S12**	**S13**	**S14**
Results			

Table 03 : Thermal simulation for the most unfavourable periods of the year.

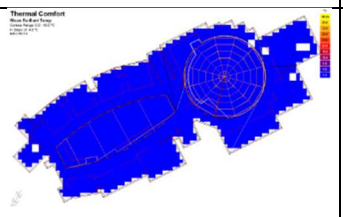
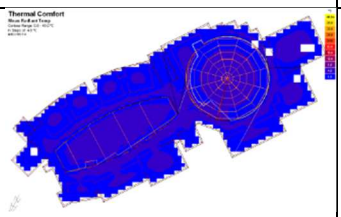
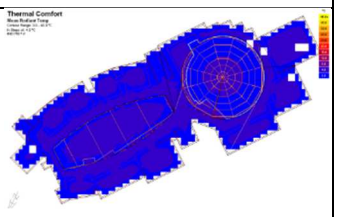
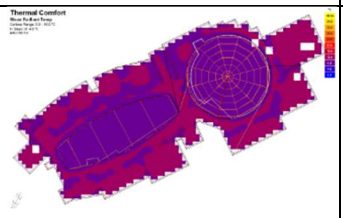
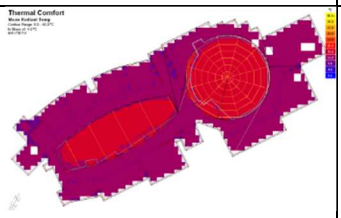
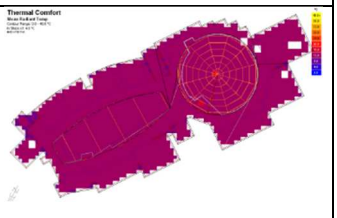
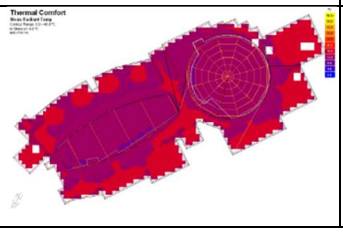
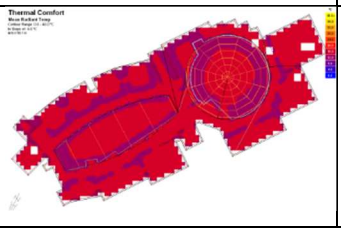
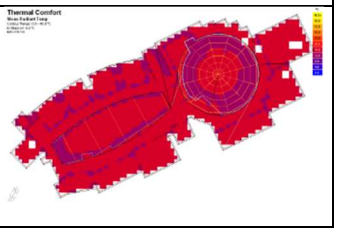
	Morning (am)	Noon	Afternoon(pm)
21 December			
21 March/21 September			
21 June			

Table 04 : Case studies

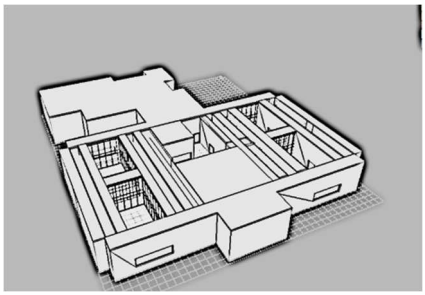
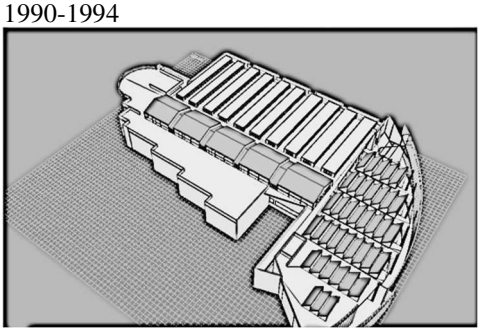
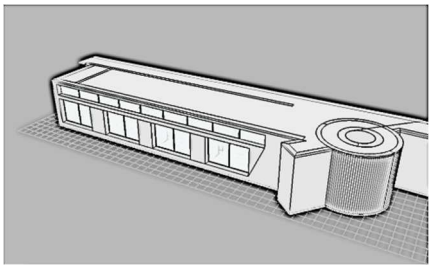
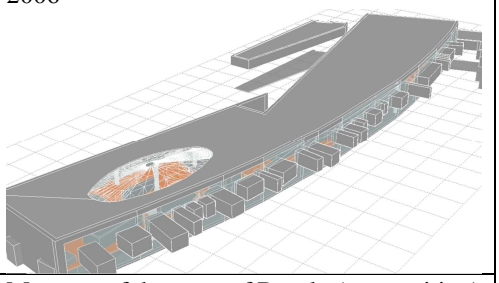
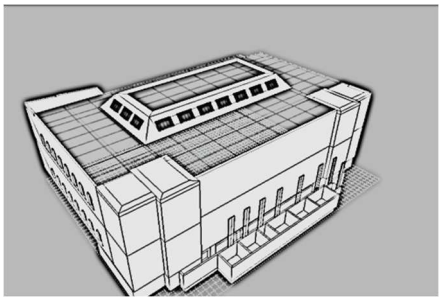
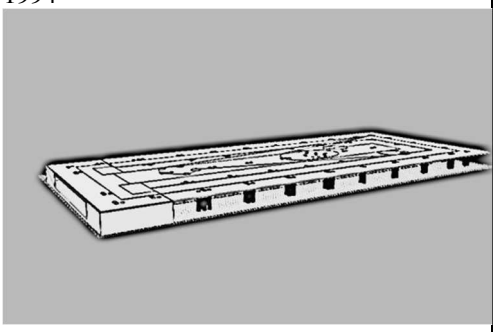
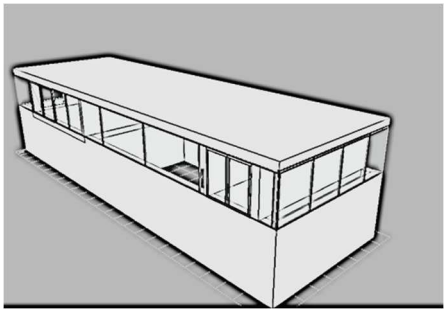
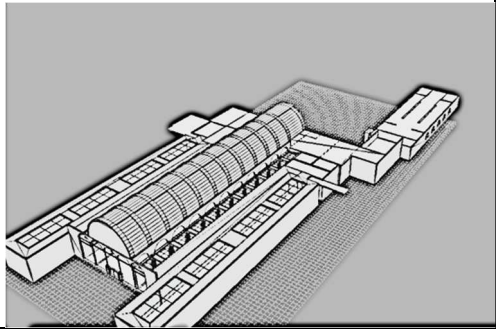
N°	Museums	N°	Museums
France			
01	Departmental Museum of Prehistory Roland Simounet 1981 	02	Museum of Fine Arts of Grenoble. Olivier Félix-Faure, Antoine Félix-Faure et Philippe Macary Lorenzo Piqueras. 1990-1994 
03	National Museum of Tayac Jean-Pierre Buffi 1994-2004 	04	Museum of the quay of Branly Jean Nouvel 2006 
05	Museum of Natural History Paul Chemetov et Borja huidobro 1991-1994 	06	Museum of the quay of Branly (competition) Rudy Ricciotti 1994 
Germany			
07	Museum of SAMMLUNG GOETZ Munich Jacques Herzog et Pierre de Meuron 1989-1992 	08	Humbuguer Bahenhof museum ,fur Gegenwart Josef Paul Kleihues 1988 

Table 04 : Case studies

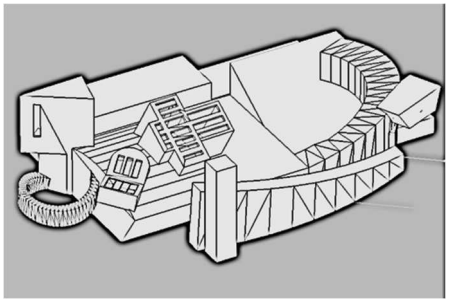
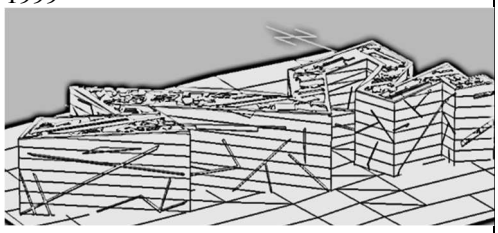
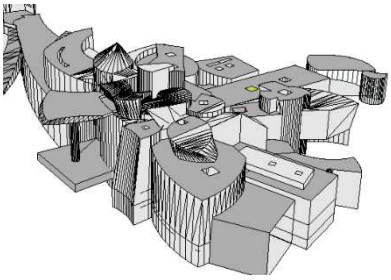
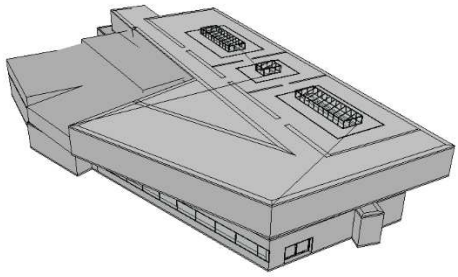
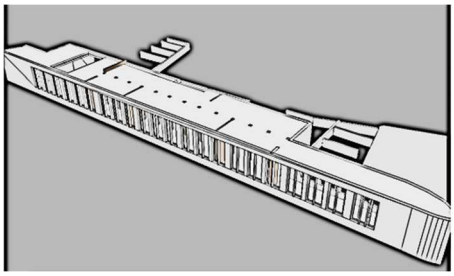
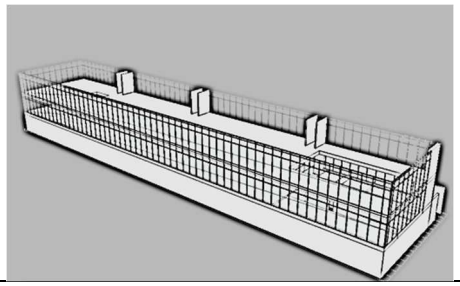
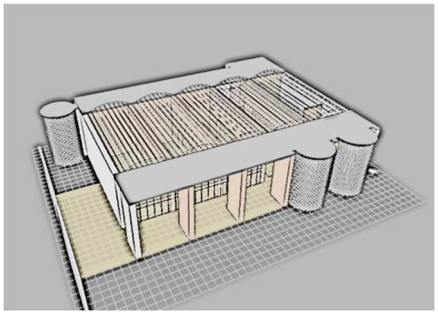
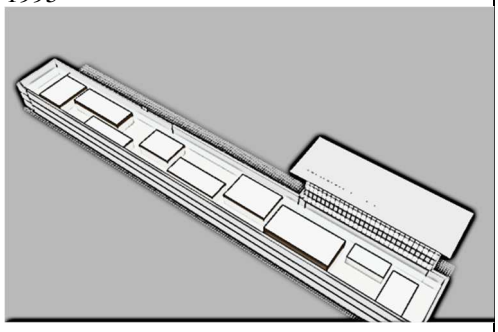
09	Vitra design museum Frank Gehry 1988-1989 	10	Berlin Jewish Museum Daniel Libeskind 1999 
Spain			
11	Guggenheim Museum Bilbao Frank Gehry 1993 	12	Centro Gallego de Arte contemporaneo Alvaro Siza 1994 
13	Hydraulic museum Juan Navarro Baldeweg 1989- 1992 	14	Museum of Maritime Archeology Alberto campo baeza 1998 
Switzerland			
15	Jean Tinguely Museum Mario Botta 1993-1996 	16	Museum of Swiss Ethnography Hanger, Monnerat, Petitpierre 1995 
17	Beyeler Riehen Museum Renzo Piano 1998		

Table 04 : Case studies

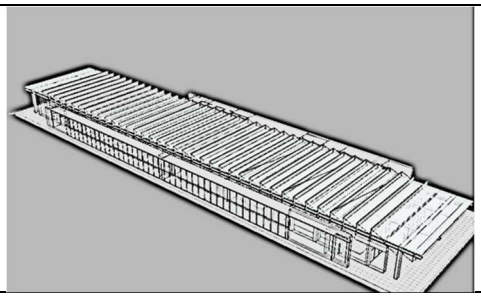
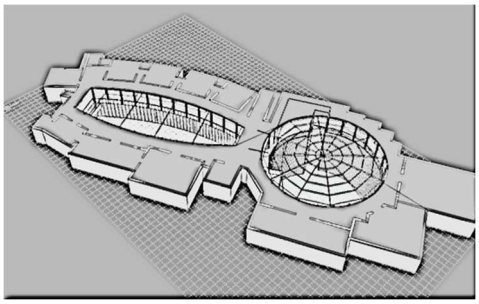
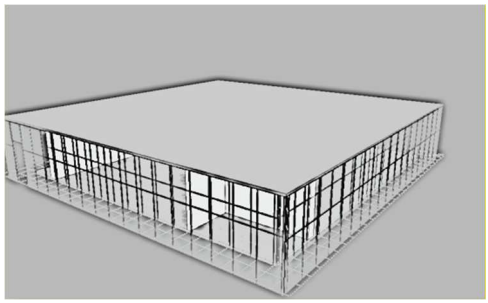
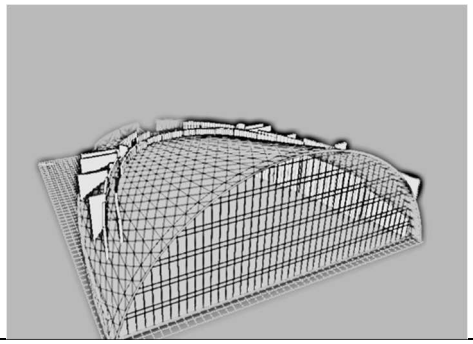
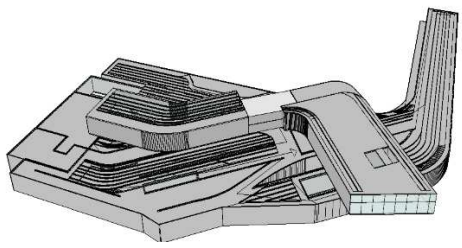
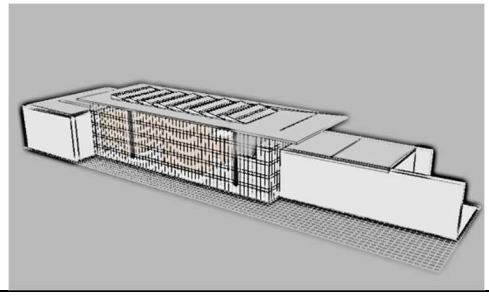
			
Austria			
18	Historical Museum of Salzburg Hans Hollein 1989-1990 	19	KUNSTHAUS BREGENZ museum Peter Zumthor 1990-1997 
Great Britain			
20	American air museum Duxford Foster partners 1993-1997 		
Italy			
21	Museum DE MAXXI Zaha Hadid 2007 	22	Ara Pacis museum Richard Meier & Partners 1995-2006 
Netherlands			
23	Bonnefanten museum,Maastricht Aldo Rossi 1990-1994	24	KUNSTHAL museum, Rotterdam Rem Koolhaas 1987-1992

Table 04 : Case studies

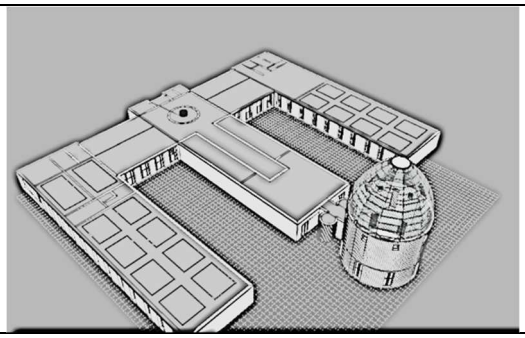
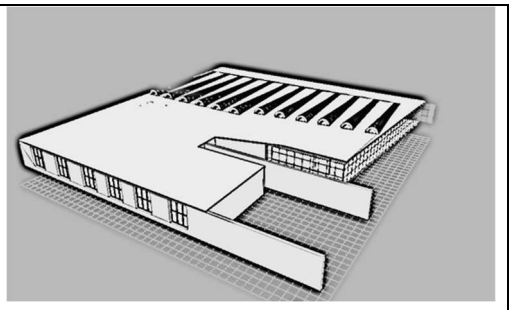
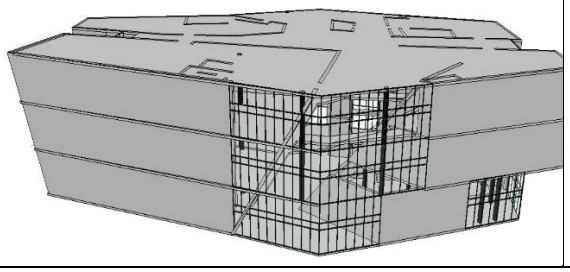
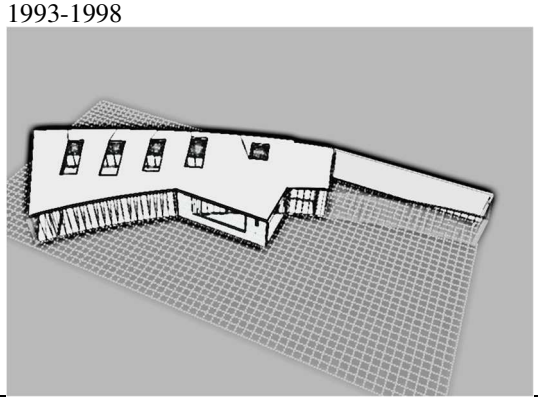
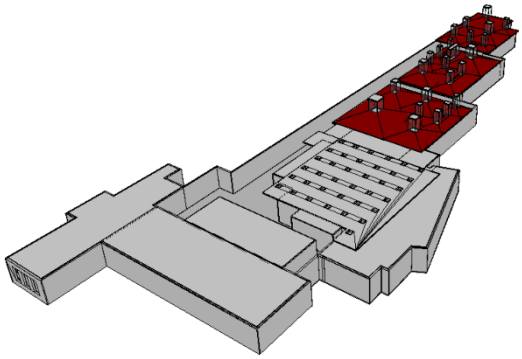
			
Belgium			
25	The Hergé Museum Portzamparc Christian 2006 		
Finland			
26	Museum Nykytaiteen Kiasma, Helsinki. Steven Holl 1993-1998 		
Sweden			
27	The Museum of Modern Art and Architecture Stockholm. Rafael Moneo 1990-1997 		
Denmark			
28	North Jutland Art museum, Alborg . Elissa and Alvar Aalto 1998		

Table 04 : Case studies

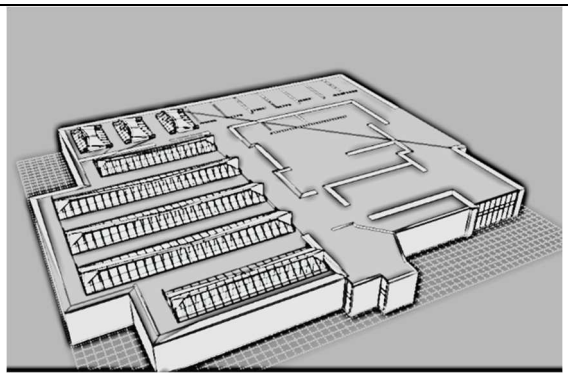
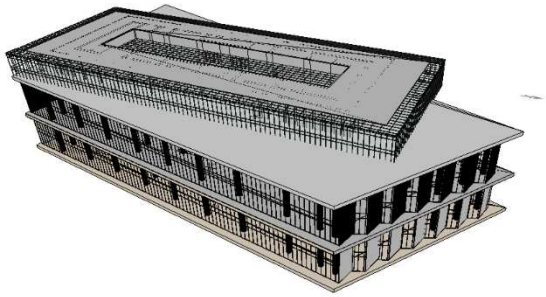
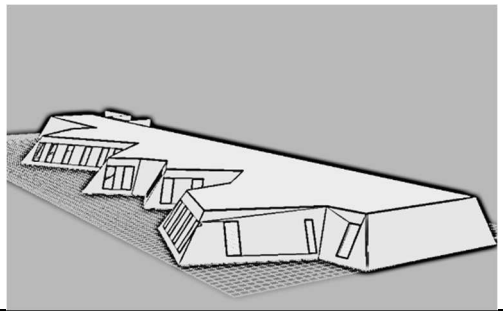
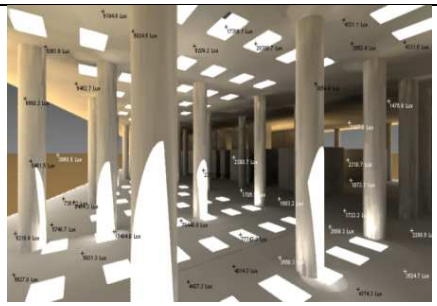
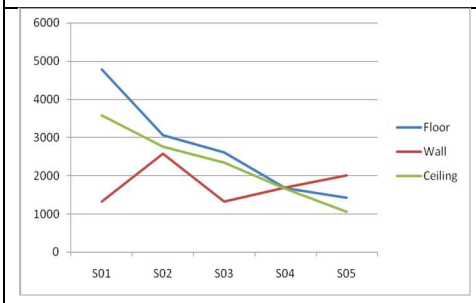
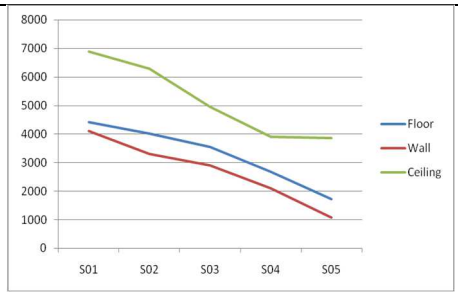
		
Greece		
29	Museum of the Acropolis Athens. Bernard Tschumi 2007 	
Norway		
30	Aukrustsentret museum, Alvdal Sverre Fehn 1993-1996 	

Table 05: Example of discontinuities in orientation.

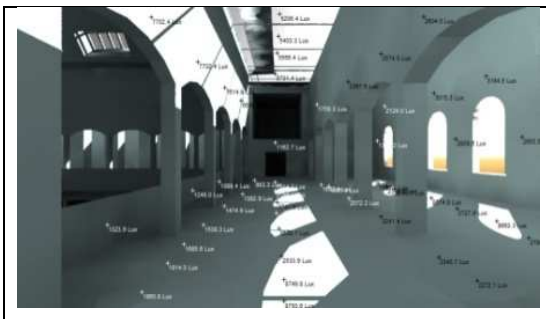


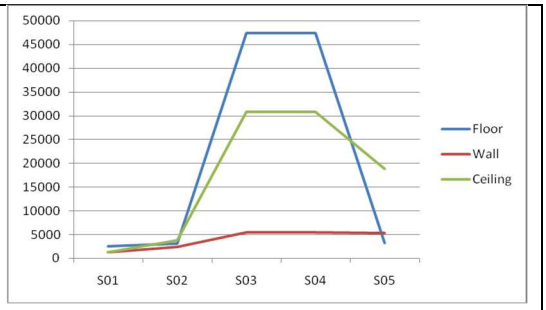




The Acropolis Museum

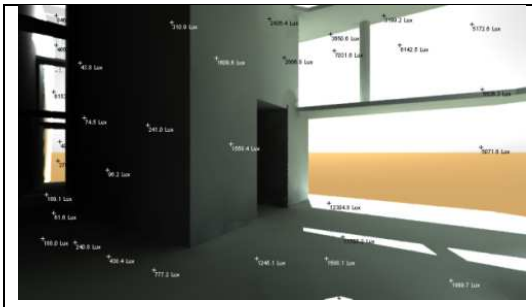
Table 06: Example of discontinuities of the lighting type.

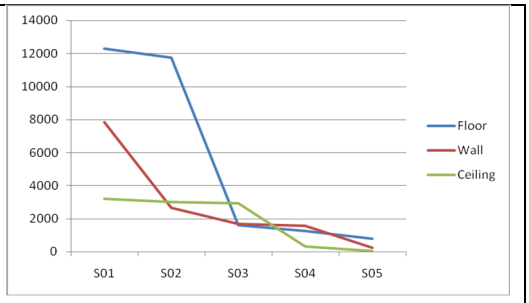




Natural History Museum (Paris)

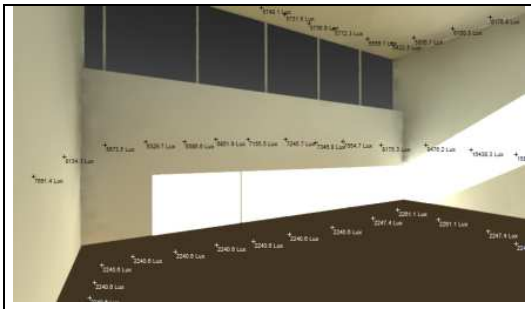
Table 07: Example of discontinuities of the bay size.

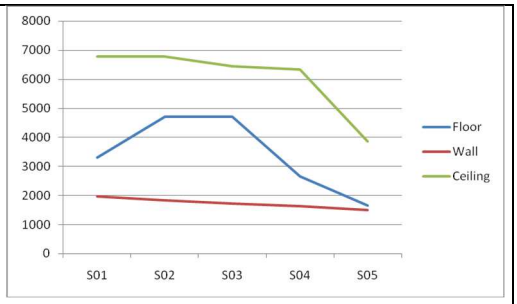




Hergé Museum

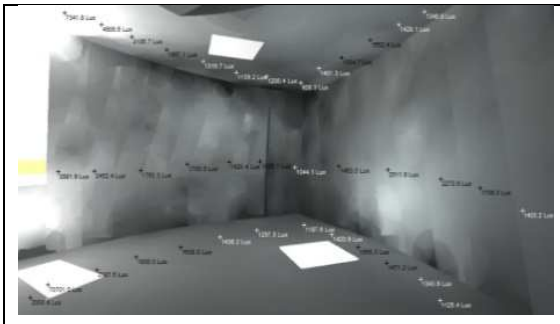
Table 08: Example of discontinuity of bay position.

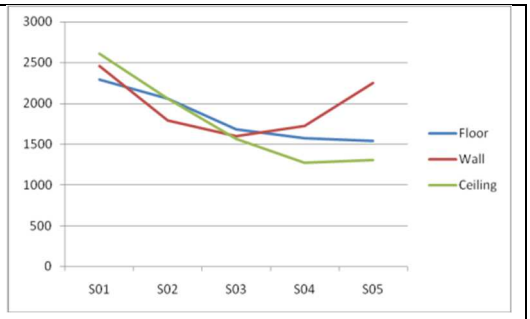




Sammlung Goetz Museum

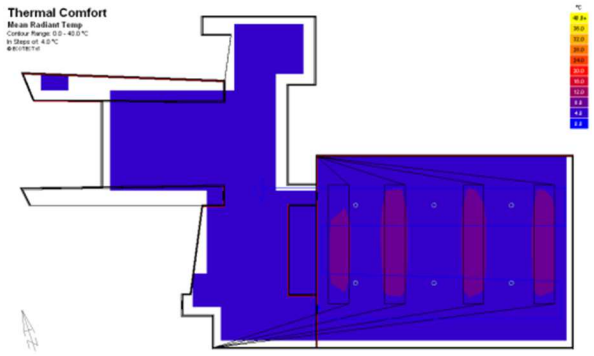
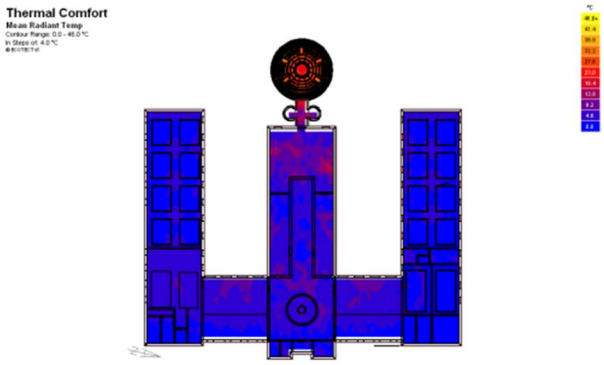
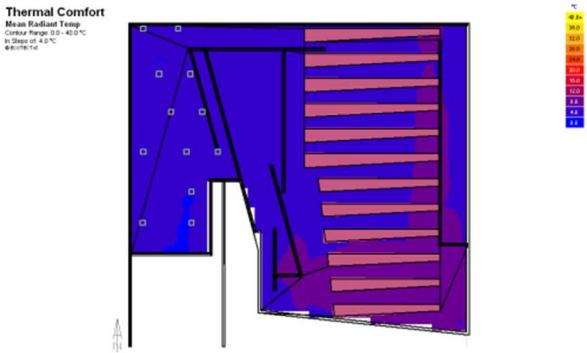
Table 09: Example of discontinuity of the bay proportion.





Bilbao Guggenheim Museum

Table 10: Thermal discontinuities in the winter season

Season	Period of discontinuities	%
Winter	Winter discontinuities in the morning: example of the Rudy Ricciotti MQB Competition 	47%
	Winter discontinuities at noon: Bonnefanten museum,Maastricht,Netherlands 	50%
	Winter discontinuities in the afternoon: KUNSTHAL;Rotterdam Netherlands 	50%
	Winter discontinuities: Hergé Museum	40%

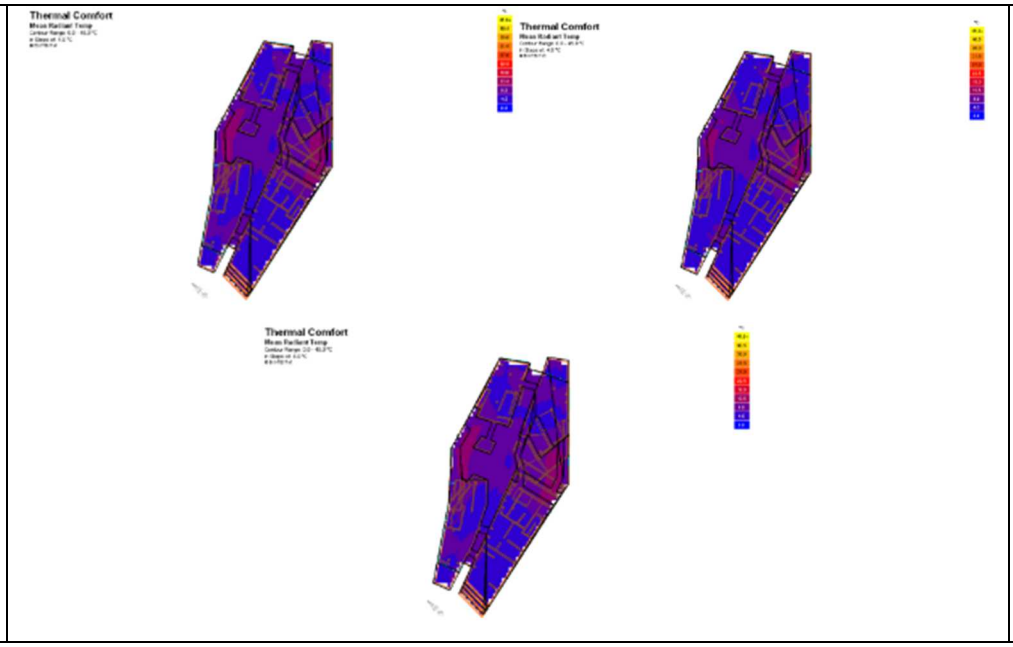

Thermal Comfort
Thermal Comfort
Thermal Comfort

Table 11: Thermal discontinuities in the mid-season

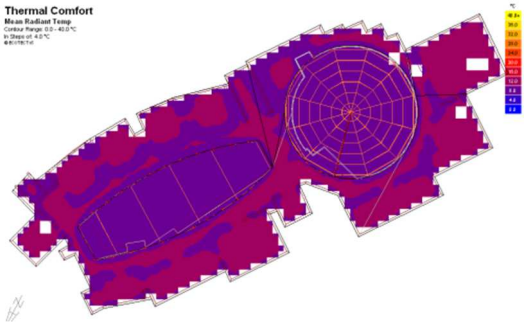
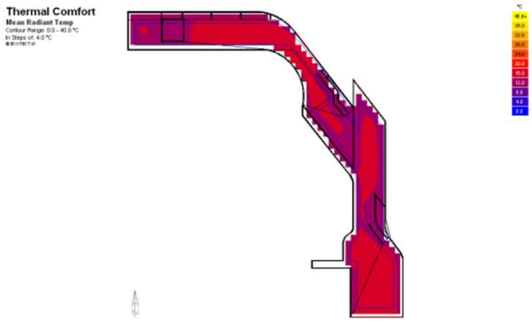
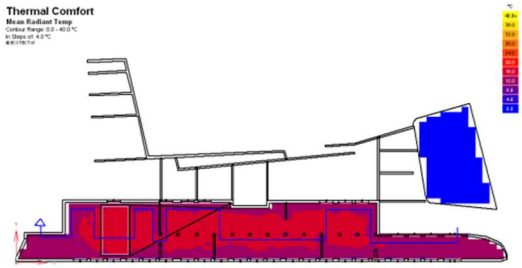
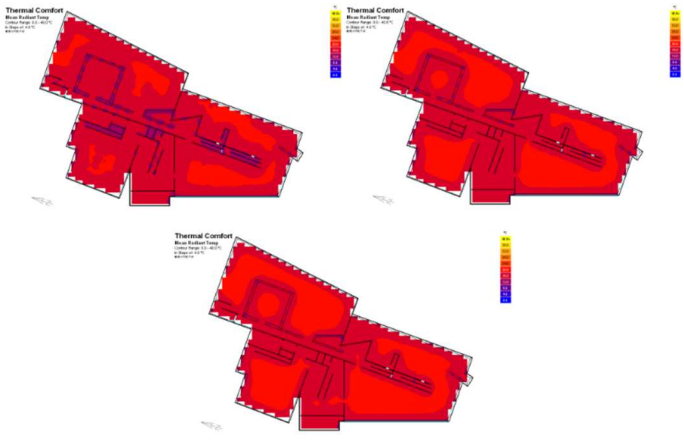
Season	Period of discontinuities	%
Mid-Season	Mid-season discontinuities in the morning: Salzburg Historical Museum 	73%
	Mid-season to noon discontinuities: Museum DE MAXXI 	77%
	Mid-season discontinuities for the afternoon: Hydraulic Museum Spain 	77%
	Mid-season discontinuities: Centro Gallego de Arte contemporaneo 	77%

Table 12: Thermal discontinuities in the summer season

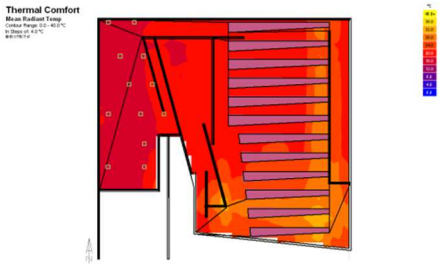
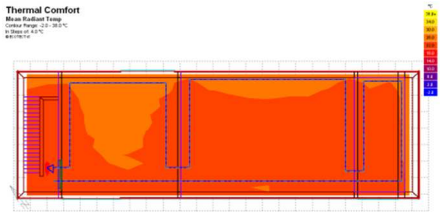
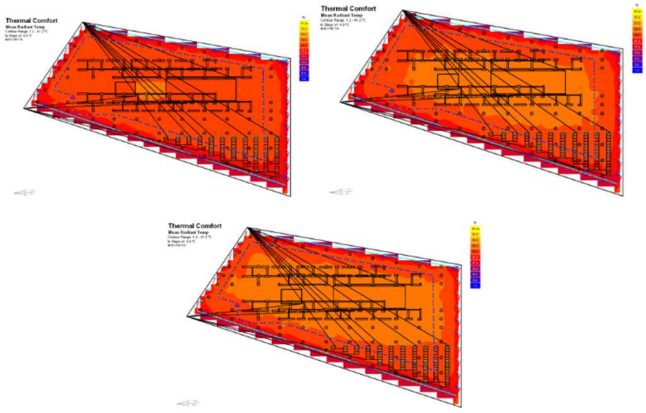
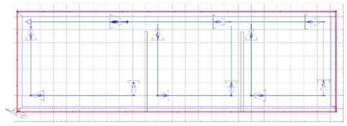
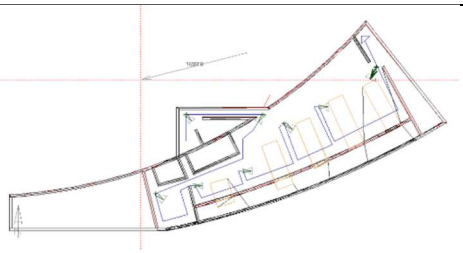
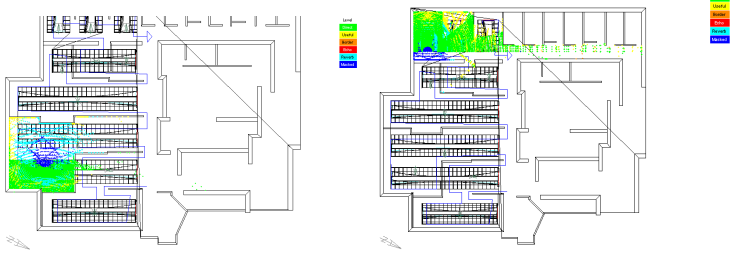
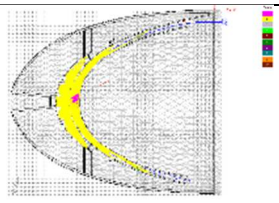
Season	Period of discontinuities	%
Summer	Summer discontinuities in the morning: the Museum of Modern Art and Architecture Stokholm. 	80%
	Summer discontinuities at noon: KUNSTHAL;Rotterdam Netherlands 	80%
	Summer afternoon discontinuities: SAMMLUNG GOETZ Museum 	80%
	Summer discontinuities: the Acropolis Museum 	77%

Table 13: Examples of sound discontinuities

Sound topology	Examples	%
Orientation Discontinuity	 Hergé museum	**43%**
Direction Discontinuity	 Sammlung Goetz Museum  Nykytaiteen Kiasma Museum	**73%**
Reverberation Discontinuity	 North Jutland Art Museum	**77%**
Discontinuity of Useful Sound	 Ara Pacis museum  American Air Museum	**57%**

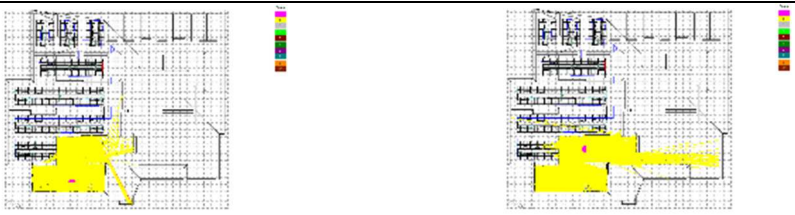
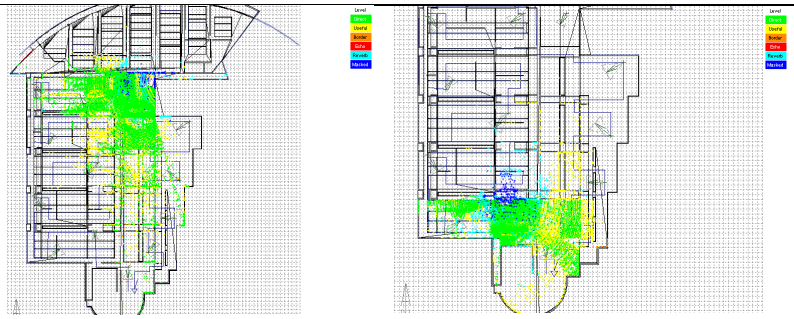
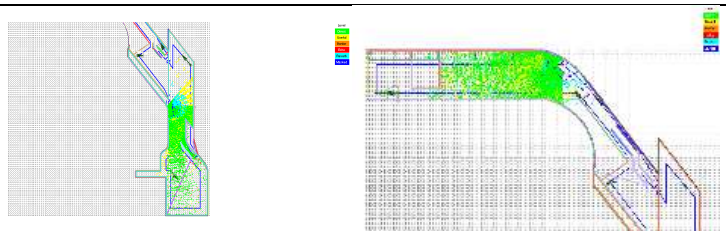
Refraction Discontinuity	 North Jutland Art Museum	**43%**
Discontinuity of Direct Sound	 Grenoble Museum of Fine Arts	**53%**
Discontinuity of the Sound Boundary	 MAXXI Museum	**43%**

Table 14: Comparison between the luminous spectrum of luminance in two examples of the corpus study (avant-garde/Ara Pacis, Deconstructivist/ MAXXI Museum)

The entrance sequence	Light spectrum luminance