Salone del Podestà: a method to improve the acoustics and the accessibility of a historical Hall using removable interventions.

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The Podestà Hall is the largest and most luxurious part of the architectural complex located in Piazza Maggiore in Bologna and owns an ancient past. Currently, however, during special events that take place inside, the acoustic is poor and accessibility is not optimized to ensure easy fruition for the disabled. This paper investigates a method that could improve the acoustic of a Hall in which the aesthetic could not be changed. Using simply wooden vertical panels, acoustical plaster, seats and low frequency absorbers attached to a temporary structure, it has been possible to improve STI index and ISO 3382-1 parameters as C_{50} and reverberation time. This simple and removable intervention, mixed to the broader analysis of paths and solutions for all the visitors, also for those on wheelchair or blind, can be used in a lot of historical building. It respects structures and surfaces, guaranteeing, at the same time, the fruition and the enjoyment of spaces for all the audiences.

Keywords: Acoustics, Removable intervention, Temporal Design, Universal design, Inclusion.

1. Introduction

The architectural complex composed of the Palace of the "Podestà", "Re Enzo" and the "Capitano" is located in one of the most appreciated squares of Italy and owns an ancient past. Currently, however, its environments are not accessible to the public, except during special events such as food and wine festivals, congresses and cultural initiatives, mainly concentrated in the Podestà Hall, the largest and most luxurious part of the complex. In spite of its natural, historical predisposition to aggregation, being the first fulcrum of the administrative and legal life of the city of Bologna, during the aforementioned events, one of the great problems is the lack of a sufficient acoustic in the Hall. Hence the idea to design an appropriate solution to make one of the most prestigious and refined environments in the city, a place of better communication, culture and entertainment. The acoustical intervention process began whit a software simulation. Using simply wooden vertical panels,mounted on wheels, acoustical plaster, seats and low frequency absorbers attached to a temporary structure, ISO 3382-1 parameters C_{50} and reverberation time reached right values for the speaking, moreover STI index became "excellent" through the first rows of the parterre and "good" in the others. Moreover, the acoustic intervention divided the Hall in three different parts, backstage, parterre and services area to improve the organization of the enclosure. This approach leads to a broader analysis: the improvement of the acoustic aspect is related to accessibility and enjoyment of the spaces for the audiences. The result is the public opening, the respect for disabled and the compliance with the current fire regulations. Hence, mobile platform and LOGES system (tactile-plantar paths applied on the floor) have been studied and used in order to guarantee the fruition of the complex and the Hall for all, included people on wheelchair and blind visitors.

Figure 1: The Podesta Hall in Bologna.

2. Measurement

The Podestà Hall has a rectangular $61 \times 13,30\ m$ shape. The floor is in marble, surrounded by a $1,90\ m$ height frame of the same material. Above the frame, the walls are covered by plaster, frescoed by A.De Carolis in the early twentieth century. For this reason, they are smooth and devoid of majestic decorations and stuccoes, with the exception of numerous pillars protruding from the wall, creating a beautiful architectural effect. Three sides have large windows, for a total of 12, which have an automatic curtain, made of a low absorbing plastic material. The vault of the Hall is in a common white plaster, unless the ventilation plant is actually made of drilled holes in the plaster).

Table 1: Characteristics of the Hall. S is the sum of all the surfaces of the hall.

Feature	Symbol	Value
Width (m)	W	13,30
Lenght (m)	L	61,00
Height (m)	H	12,30
Volume (m^3)	V_{Hall}	10000
Total surface (m^2)	S	3600
Number of seats [4]	n	480

On the day of the measurements, the Hall was unoccupied and lacking of any kind of furniture and seats. Only five operators and the essential instruments were inside. The omni microphones array was set as a rectangular grid, where each receiver was 8 meters distant from the closer, exception for a central row which, obviously was 4 meters from the two sides of the rectangle. In order to avoid measuring potential modes, the grid was no centred in the room, but slightly moved towards a side. All the microphones were 1,2 meters height from the floor, where ears of a seated listeners normally are. 2.

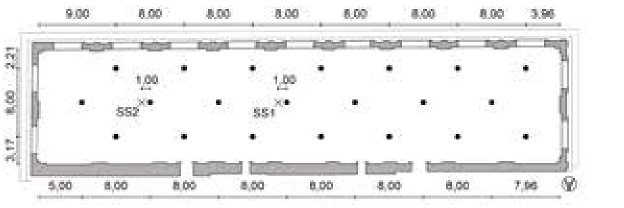


Figure 2: Source (" × " symbol) and receiver (" • " symbol) positions in plan.

An omnidirectional source (dodecahedron radiating a ESS signal) was employed and moved twice, in positions SS1 and SS2, on the central row. The latter was near one of the two short sides of the hall to simulate the position of one hypothetical orchestra and to have a great gap, in meters, from the last receiver, in order to study how Sound Strenght, G, varies with the distance from the source. However, ISO 3382-1, [2] defines that source positions should be located where the natural sound sources in the room would typically be located and a minimum of two source positions should be used. The height of the acoustic center of the noise source should be 1,5 meters above the floor.

A second measure was done placing the microphones along a circular path with radius 1 meters and centred on SS1 3, where noise source was.

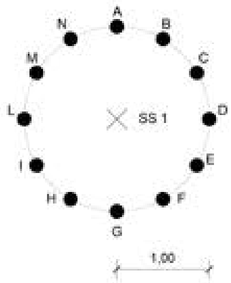


Figure 3: Setting for noise source calibration in situ. Receivers has been placed 1 meters from the source,placed in SS1, following a circular path around the source.

The purpose was to obtain waves at a fixed distance and not much effected by surface reflections, in direct field, useful to calculate sound strength parameter G as:

$$
\begin{aligned}
G &= G_{rel,(meas)} - G_{rel,(10m)} && (dB)\\
G_{rel,(10m)} &= G_{rel,(situ,\ 1m)} - 20 && (dB)\\
G &= G_{rel,(meas)} - G_{rel,(situ,\ 1m)} + 20 && (dB)
\end{aligned}
\tag{1}
$$

where:

$G_{rel,(meas)}$, is the relative Sound Strenght measured in the hall, in each microphone position 2;

$G_{rel,(situ,\ 1m)}$, is the relative Sound Strenght measured inside the same hall, but 1 meter from the noise source 3.

2.1 Results

The results,shown in table 2, present the acoustic parameters, in octave frequency bands, measured inside the Podestà Hall in Bologna.

The reverberation time measured in Podestà Hall is, as predictable, too high for both musical and lecture events. The hard surfaces of the Hall reflect the waves and a great reverberation, due also at the enormous volume of the enclosure, occurs. T_{30} mean values, averaged over all the source position for each octave frequency band, are listed in 4.

In graph 5 measured sound strenght, after source calibration, and predicted values from Barron [3] and Sabine [11] theories are illustrated. From Sabine curve it clearly appears that, due to the geometric shape, volume and materials of the Hall, the diffuse component is prevalent over the direct one. The sound decay concerns only few meters from the source, where direct

Table 2: Acoustic parameters measured inside Podestà Hall. Two source position SS1 and SS2 have been analysed. The subscripts "M" indicates the middle frequencies, 500 - 1000 Hz, "3" represent values averaged over the central octave bands, 500 - 1000 - 2000 Hz.

Source	EDT_M (s)	$T_{30,M}$ (s)	$C_{50,3}$ (dB)	$C_{80,3}$ (dB)	$T_{S,3}$ (ms)	G_M (dB)	STI
$SS1$	8,80	9,19	- 8,80	-6,90	529	13,0	0,34
$SS2$	8,79	9,16	-9,63	-7,23	519	12,5	0,34

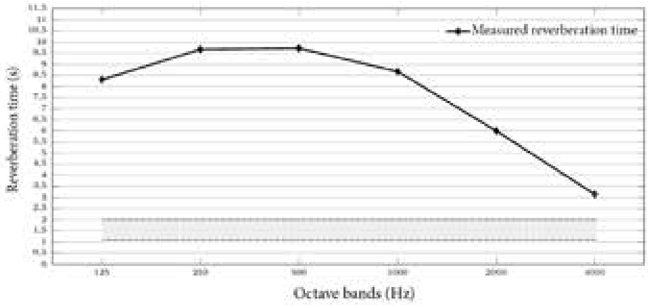


Figure 4: T_{30} mean values averaged over all the source-receivers couples for each frequency band. The graph shows the typical trend of reverberation time due to bigger values at low frequencies and smaller values at high frequencies of absorption coefficient, but the peak recorded at medium frequencies is not advantageous.

field occurs; 5-6 meters far from the source, it becomes linear due to great reverberation.

The same trend could be observed from Barron's curve. The absorption of the enclosure is so low that even in the bottom of the hall G values are similar as those close to the noise source. Measured values of G follow mainly the trend theorised by Sabine appearing quite uniform through the hall.

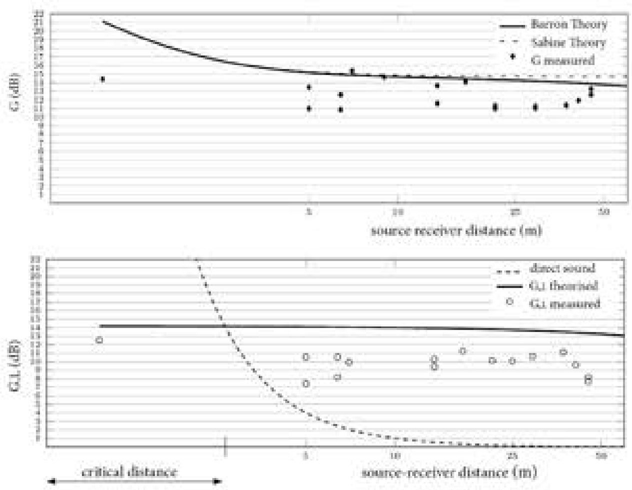


Figure 5: The graph show G parameter measured, the direct sound component predicted from Barron revised theory and how much the parameter $G\ late$, measured, contribute to reach the total level of sound strenght. It proves that the current sound field is reverberant, cause $G\ late$ component is very similar to the total level.

In current conditions it is quite impossible to organize even a simply speech because the acoustic in the Hall is poor.

First of all, the reverberation time has to be reduced. Various solutions could be used e.g. baffles hanged on the ceiling, absorbent curtains or panels attached on the walls. However, in the case of Podestà Hall, the historical aspect must be considered in the acoustical design. The walls have been frescoed in the last century by A. De Carolis, so no one absorbent material can be attached. Curtains currently installed have low absorption coefficient for each octave band, changing them could be very expensive and it could modify the aesthetic aspect of the room. Nevertheless, the vault could be treated with an acoustical plaster cause it lost its historical value. Since 1969 it is covered by a common white plaster, cause frescos of De Carolis have been damaged and removed.

Great absorption of the energy radiated in the space could be also obtained from the right choice of the removable seats. Due to its great extension, the Podestà Hall could host a parterre counting 480 seats [4]. Taking account of the fire safety regulation [5], the seats have to be organized in three different parts composed by 16 seats par row, for a maximum of 10 rows. Each part should be distant, from the closest, at least 1,20 meters in order to guarantee the correct outflow of audience.

2.2 Low frequencies absorber

Given that acoustical plaster, seats and clothes of audience have great absorption in middle and high octave bands, in order to reduce energy in low frequencies the physics of membrane absorbers could be used. In this study particular plastic pipes have been investigated whose membrane, due to a sound pressure difference on the inside and the outside, vibrates reducing energy focused in lower bands as 125 and 250 Hz [6].

As structural support, of the membrane absorbers, it could be simply employed a removable lightweight metallic american truss, that could be also used to support the lighting and the line array. The size of the installation would result in being contained, in order to not influence too much the aesthetic of the Hall.

2.3 Partition of the space and Clarity improvement

The words pronounced, as the notes of a music played, would not be distinguishable from each others if Clarity parameter [2] would not be $+1dB < C_{50}$ [11]. Vertical wooden panels,

Table 3: Absorption coefficients α and scattering assigned to the materials inside "Odeon" in order to simulate the results of intervention. All the values have been chosen from existing tables,[7, 10, 9, 8, 6].

Layer	description	Scattering	α absorption coefficient					
			125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
stage	hardwood	0,10	0,32	0,43	0,12	0,07	0,07	0,11
seats	unoccupied	0,70	0,70	0,76	0,81	0,84	0,84	0,81
vault	acoustic plaster	0,10	0,17	0,36	0,66	0,65	0,62	0,68
wooden panels	hardwood	0,05	0,32	0,43	0,12	0,07	0,07	0,11
wooden diffusers	hardwood	0,70	0,32	0,43	0,12	0,07	0,07	0,11
asborber pipes	plastic	0,10	0,6	0,65	0,52	0,4	0,23	0,10

mounted on wheels, which dimensions could be chosen to be easily transported with a little truck (panels $2,50 \times 0,60\ m$), could be used to make two little wall, as shown in figure 6. The ones behind the last row would have a high scatter coefficient to better diffuse the sound. Panels would subdivide spatially the Hall taking additional advantages. First of all, a backstage could be realised in order to create an area reachable only by the staff through the Eastern entrance of the Hall. Moreover an area for the audience could be set on the opposite side of the room, in which people could enter from the Western door.

In the middle, the parterre area would, thus, be enclosed among these two removable wooden walls. Its dimensions could change in function of the number of seats expected, proving that this installation could be very flexible. The use of wooden panels, could also increase first reflection [11] from the stage and focus the sound as much as possible in the audience area, as shown in figure 9.

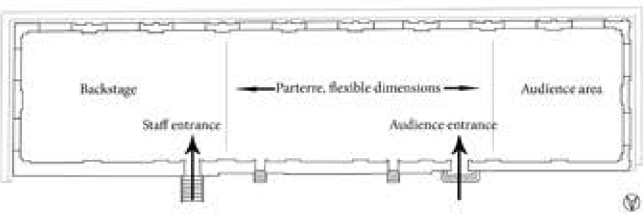


Figure 6: Partition of the space among backstage, parterre, audience area. The dimensions of installation are flexible as function of the number of seats expected.

2.4 Discussion

The intervention simulated, with Odeon software, lead to an improvement of the acoustic of the Hall, reducing the reverberation time and increasing, on the contrary, Clarity and STI index [1].

As illustrated in figure 8, after the intervention the reverberation time would become similar to an ideal range of its values, thought for the speech intelligibility [12]. Even if it is not perfectly equal to this range, this result could be defined satisfying. The volume of the Hall is very large and the intervention is restricted to few devices in order to not modify the Hall as much as possible. Also simulated values of C_{50} and STI index confirm that intervention would be effective.

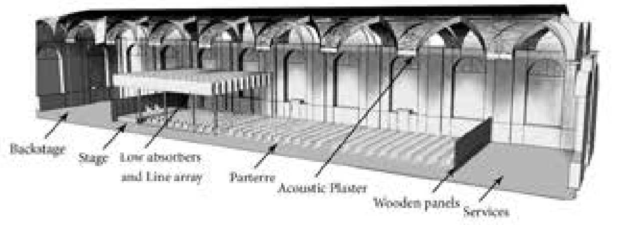


Figure 7: Intervention strategy in order to improve the acoustic inside the Hall. Vertical wooden panels allows to demarcate parterre area and to focus the first reflections of sound. The loudspeaker radiate the energy mainly toward the audience increasing clarity and intelliggibility, while seats, acoustical plaster and low absorbers reduce the reverberation time of the Hall.

The graph 8 shows that the solutions presented in this paper are able to both greatly reduce the reverberation time within the room and to attribute it higher values at low frequencies than the medium and high ones: a typical trend that could be found in a concert halls. In additiond this trend provides a good level of bass ratio, useful in conferring sound richness. The capacity to reduce T_{30} at low frequencies is entrusted to low absorbers, which intervene in a fairly narrow of bands without affecting high frequencies. In this simulation the pipes were extended 10×20 meters, to enclose the first block of seats and part of the second, figure 7, but these dimensions could be modified according to the number of seats needed and available funding.

Dividing the space into three parts, lead to an improvement of Clarity. As shown in figure 9, parameter C_{50}, suitable for describing the amount of first reflections inside the Hall, becomes positive only in the parterre area. This proves that, in addition to an aesthetic effect, the use of wooden vertical panels, 2,50 meters high, allows the first reflections, in the audience area, to increase, especially in the rows far from the stage, and not to disperse the sound into all the volume. This result was also achieved thanks to the help of a line array, hanged on the american truss, which can emit the sound along a main direction (related to its directivity).

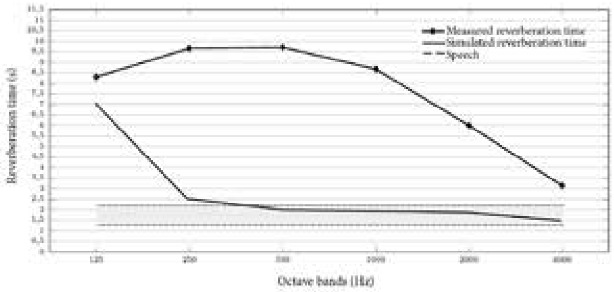
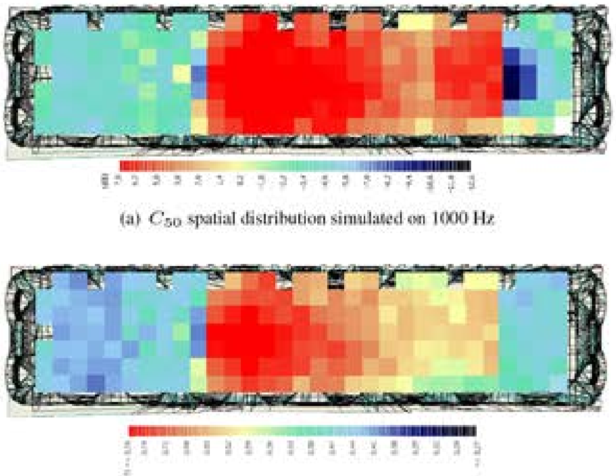


Figure 8: The graph shows that using acoustical plaster, seats and low absorbers, T_{30} is reduced in all the octave bands and it becomes similar to the ideal range [11] for the lectures. These values are referred to unoccupied Hall.



(a) C_{50} spatial distribution simulated on 1000 Hz

(b) STI spatial distribution simulated in the Hall

Figure 9: $C_{50,3}$ parameter simulated with "Odeon" software, after the CAD installation have been created. The source employed has been a line array, hanged 3 meters above the stage on the american truss. Inside the parterre and on the stage, the parameter reached the desirable value [11] for a lecture. STI index became good in the majority of the seats, excellent in the first rows close to the stage. As result, all the people would understand the words pronounced during the lecture as opposed to the current situation.

Table 4: Comparison between current values and simulated ones."M" indicate middle frequencies,500 - 1000 Hz, while "3" refers to the values averaged over 500 - 1000 - 2000 Hz.

	$T_{30,M}$ (s)	$C_{50,3}$ (dB)	STI (average)
Current	9,19	-9.2	0,36 (Poor)
Ideal range	$\simeq 1,3$	$> +1\,dB$	Good-Excellent
Result	1,72	+4,8	0,68 (Good)

Due to the intervention on the acoustic of the Podestà Hall, more cultural and musical initiatives could take place and, with them, a bigger flow of users. At this point, it is important to pay the right attention to aspects and dynamics of fruition, to guarantee to all people the same quality of visit.

3. The hall for all: the Universal Design

Inclusion is a way to live, to feel and to perceive the reality that surrounds us and that it concretizes with thoughts, languages and actions in the contexts of life of people. Space becomes, therefore, an inclusion factor, because, according to its accessibility level, it can include or exclude disabled people: through some spatial characteristics, such as the presence of barriers or some types of architectures, society consolidates the exclusion of a category of people. To prevent it from becoming a source of discrimination, it is necessary to act on its design because "space has to adapt to people, not the opposite" [13].

In architectural terms, the concept is very simple: to build paths that can be for everyone. This is the purpose of Universal Design: movement for human rights, related to development and architecture, which demands creating environments and consumer goods for the largest variety of users.

The name "Universal Design" was born in 1985, thanks to the American architect Ronald Mace: he described it as design of products and environments for everyone as much as possible without any need of adaptation, without distinction of age, sex, and ability. From the words of Mace itself: "The built world does not fit perfectly to anyone. Sometimes we have problems with the space we live in or the products we use. And designers are used to think of a mythical normal group, but in fact this group does not exist. Each individual is unique and, as a group, also the human species appears quite different" [14]. Designing accessibility means not only looking at the aesthetic aspects, but to pay attention to the human being and his needs, respecting his "diversity-uniqueness" [15].

In 1997 the logic of universal design was explicit in seven basic principles:

- fair use.
- flexible use.
- simple and intuitive use.
- perceivable information.
- fault tolerance.
- containment of physical effort.
- measures and spaces for approaching and using.[16]

Italian legislation, about public and private spaces, conceptually allows and suggests to own the principles of the universal design that coincide with the people pursuit of opportunities and the strengthening of individual freedom.

In fact, D.M. 236/89 and D.P.R 503/96 identified criteria of design for accessibility, visibility and adaptability for different environments and indicated technical standards that respond to different performance requests. DPR 503/96 (Article 4), about historic buildings and areas, shows the need to make accessible paths to people with low motor and sensory ability.

Figure 10: Architectural barriers have become an important topic to the Italian laws.

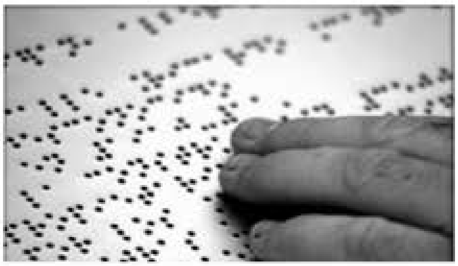


Figure 11: The inclusion begins with language: the braille system allows blind people to get every kind of information.

3.1 The restoration: the courtyard and the internal paths

Hence, treated the acoustic aspect inside the "Salone del Podestà", there will be the need to restore the inner courtyard, located at the ground floor, between the "Palazzo del Podestà", of "Re Enzo" and "del Capitano", in order to make the floor smooth and homogeneous.

This operation will improve its look and, at the same time, make the experience more enjoyable and comfortable for all. First, specific diagnostic analysis should be used to find out the nature of the material and subsequently clean it with controlled blasting, using sand under controlled pressure. Then, the restoration will be complete by restoring gaps with ethyl silicate, the most suitable for this type of intervention.

For people on wheelchairs, new interior paths would allow the use of elevators and the main access. For those who are completely or partially blind, there will be, at the beginning of each path and room, the appropriate directions to guide them to the spaces of the structure: tactile maps, color signals, and so on.

Finally, for deaf visitors, there will be panels to show information to allow them to enjoy completely the visit. The first problem faced in the design of the internal paths of the complex, once conceived as accessible to all, is the distinction between the environments accessible to tourists and those that are not. All the rooms used by AlmaWelcome employees inside the building are all on the top floor. Then it is necessary to make the complex's using simple and enjoyable for both groups without interfere with each other.

The key to the solution lies in the elevators. There are two of them: both recently built, just to respect the laws previously mentioned, are located one on the east side, towards Piazza Re Enzo, while the other faces directly on the inner court. So, in a perspective of inclusion, the idea is to make the beginning of the path to visit the main entrance, on Piazza del Nettuno, because of its useful ramp. Once inside the court, wheelchair users will have access to the lift, located beyond the sandstone pit, while other visitors will be able to proceed along the monumental staircase. At the same time, the last floor will be accessible to the employees thanks to the east entrance, without crossing the flow of tourists.

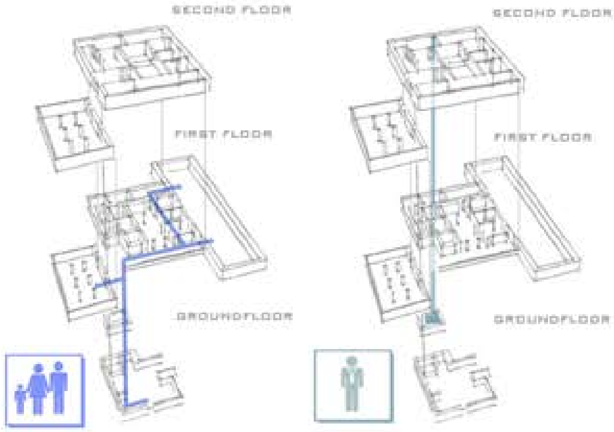


Figure 12: Internal paths: visitors and employees.

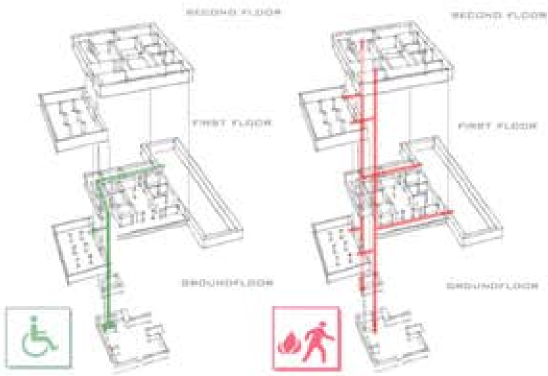


Figure 13: Internal paths: wheelchairs and fire exits.

The visitors to the first floor through the staircase will walk through the lodge and, before accessing the "Salone del Podestà", will find on the left a desk with wardrobe service for the storage of clothes and objects in the back room. Those who have used the elevator will be on the north side of the complex, but will simply go over the desk dedicated to them. Then they will follow a short "L" path, crossing two rooms, and, at the end of it, will find the steps with a lift platform to access the Salon. Once visited the great ambient, the path will continue through the lodge, or returning to the elevator, ending the visit to the Hall of the Acts.In fact, the two rooms to be accessed from the Hall on the east side are included in the project of valorization with two different destinations.One of them, the largest, becomes an integral part of the visit path as Gift Shop / refreshment area; the other one, having direct access to the Salon, will be an instrument store and dressing room for musicians on particular events such as cultural initiatives, once improved the acoustic of the Salon.

The last floor, almost entirely occupied by AlmaWelcome offices, will host, in a separate project, workshops for children in the Hall of King Enzo.

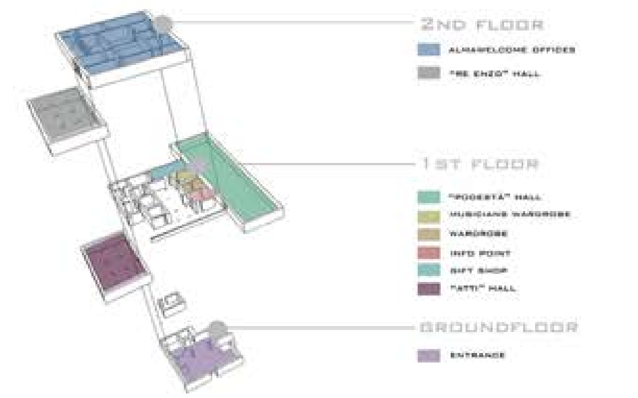


Figure 14: Proposed functional diagram for the new spaces.

The problem with the blind visitors is the most complex one. The complexity lies mainly in the fact that the techniques for communicating information to people with visual disability are still subject to study, refining, and research.

First, we have to understand what to communicate to the blind visitor. We have to select the information, opting for a simple and immediate language, to bring it back to the appropriate tools such as tactile maps. Here is the layout of tactile signage:

- entry point: at one side of the ramp, there will be a tactile-plantar path (the LOGES system) that guides the visitor to the inner courtyard, in correspondence of a low frequency acoustic signal indicating the entrance;
- entrance of the courtyard: there will be a map containing essential information about the internal courtyard and the shape, in plan, of the space in which the user is moving (it will be like a square). Finally, the indication of the steps, on the left, to reach the first floor, described with a section up to the Hall of the Acts and Podestà Hall;
- on the floor of the courtyard: it will be applied to the ground a special gum path that leads to the steps and to the elevator, on the opposite side of the courtyard, allowing the visitor to choose the most appropriate way to reach the top floor;
- the Hall of Acts: there will be the name of the room and a section with details, such as its particular shape, then, to the right, the presence of the lodge and, at the end of it, a wardrobe on the left and the entrance of the Salon on the front;
- entrance of the Hall: there will be the name of the salon, the plant, and the section to indicate its beauty and finally one brief description of its frescoes;
- exit of the Hall: the gift shop will be indicated over the steps and, on the left, the lodge and the end of the visit, in the Hall of Acts. Obviously, there will be also the indication of the toilets, over the gift shop.

Figure 15: Second floor: the LOGES system.

For deaf people a series of panels placed inside the complex will report information about the construction, its spaces and the historical-artistic details that characterize it. This could be helpful also for less impaired visitors. For users with cognitive disabilities, a much simpler and more comprehensible communication channel will be probably represented by figures.

The idea, at least in embryonic form, is to help them using a language such as "comic strip", which helps this kind of visitor to interiorize immediately, through basic and recognizable forms, the information.

This solution could have a dual function: to communicate to disabled people, but also to inform, with the use of illustration, tourists who do not speak Italian or English. In fact, one of the most insidious barriers is just the language. Hence, thanks to this solution, a better exchange of knowledge and culture will take place, helping both types of visitors.

4. Conclusions

Given that reverberation time has been reduced, while first reflections increased, the intelligibility index of speech, STI, became good or excellent as proved in figure 9, where is illustrated the value of simulated parameter. This condition allows audience to understand the words pronounced by the speakers. The advantage of this installation is its flexibility and reversibility. In this paper only one arrangement has been investigated, even though they could be various. Just think about wooden vertical panels and seats. Related to the number of seats needed, it would be easy to make the parterre smaller because panels are movable, due to their contained height. Moreover, it is clear that great reduction of reverberation in the middle and high frequencies is due to acoustical plaster, so having lower number of seats, or different kind of upholstery, would no influence too much T_{30}. This condition is essential because release the acoustic aspect of the Hall from the seats that could vary among the company which produces or rents them. The structure too, made through some american truss, could be easily assembled and dismantled and its dimensions are connected to the shows. Even if the choice of inflated pipes, might be conflicting with the aesthetic aspect of the Hall, it represent an intervention efficient, temporary and completely reversible.

Lastly, this intervention cannot exist without its subsequent use. Culture, more than anything else, is precious and necessary. This is why Universal Design was born: to guarantee its fruition and survival.

This is why this broader analysis: inclusion is an important issue, that should follow every intervention, creating connection and equality between its users.

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