(FP7 614100)

# D8.3.1 Application Development: The Teatro Amazonas: Initial Prototype

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# Index:

# 1. Executive summary

This deliverable describes how the structure of Amazonas Theater will be used to install sensors, which measures must be obtained, and how to build a demo to show the system to the public. This deliverable is divided as follows. The first section shows the physical structure of the Amazonas Theater with some floor plans, to depict which parts of the theater will be measured and to list the required sensors to accomplish this job. Section two presents some use cases that have been built to help readers to understand where we are planning to install the sensors. Finally, section three presents how we are going to develop at UFAM the application that will be used as the demo.

# 2. Amazonas Theater Architecture

This section shows the Amazonas Theater architecture with some floor plants to facilitate the understanding of where the sensors will be installed. After that, this section address the equipment and parameters from the theater which must be taken into account in order to control and monitor the environment, as well as the sensors that must be installed to capture ambient information. Finally, some use cases are depicted to help understanding how things are planned to work.

## 2.1. Amazonas Theater Physical Structure

Amazonas Theater was inaugurated in December 31, 1896, and is the most significant architectural masterpiece of the golden period of rubber and main artistic cultural patrimony of the Amazonas state. Normally it is used as playhouse, with regional, national and international artistic attractions. To show the theater physical structure we divided it using the theater plants. Such partition resulted into the following seven parts: showroom, noble hall, dressing rooms, stage, warp, basement and others. The showroom is depicted in Figure 2.1.

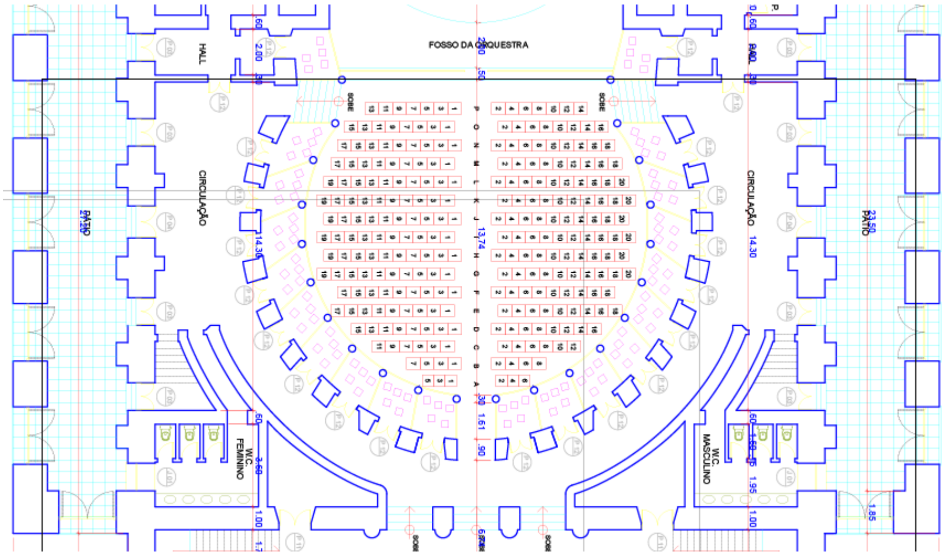

Figure 2.1: Showroom.

The Showroom can support 701 people, distributed among the audience and three floors. It has 266 armchairs at the stalls, 100 seats distributed into 20 spots on the ground, 125 seats distributed in 20 cabins on the first floor, 125 seats distributed in 25 cabins in the second floor and 100 seats distributed in 20 cabins on third floor.  Figure 2.1 presents an overview of the showroom and Figures 5.1, 5.2, 5.3 and 5.4 in the annex shows the floors separately.

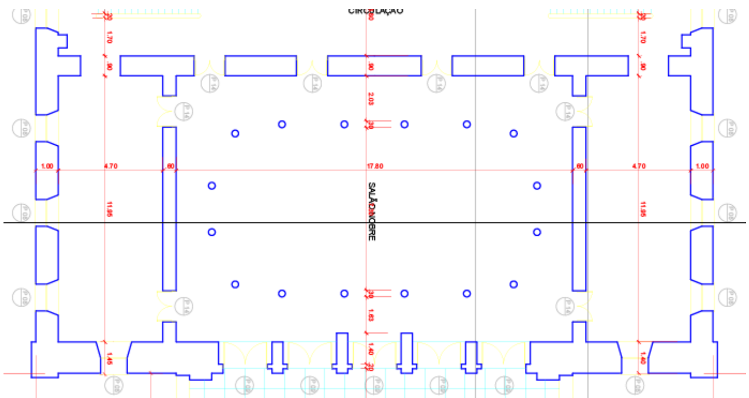
Figure 2.2: Noble hall.

The second part of the theater is the baroque style Noble Hall that can support 200 people. Figure 2.2 shows the noble hall and Figure 5.2 in annex has more details. After we have the dome, that is composed of 36.000 pieces of scales in glazed ceramic and glazed roof tiles coming from Alsace. It was acquired in the Koch Frères House in Paris. The ornamental painting is authored by Lourenço Machado. The original colored in green, blue and yellow is an analogy to the exuberance of the Brazilian flag.

Next we have the dressing rooms, which are located on the back of the theater and on the floors. Figure 2.3 shows one part of the dressing rooms and Figure 5.2, 5.3 and 5.4 in annex shows it with more details.

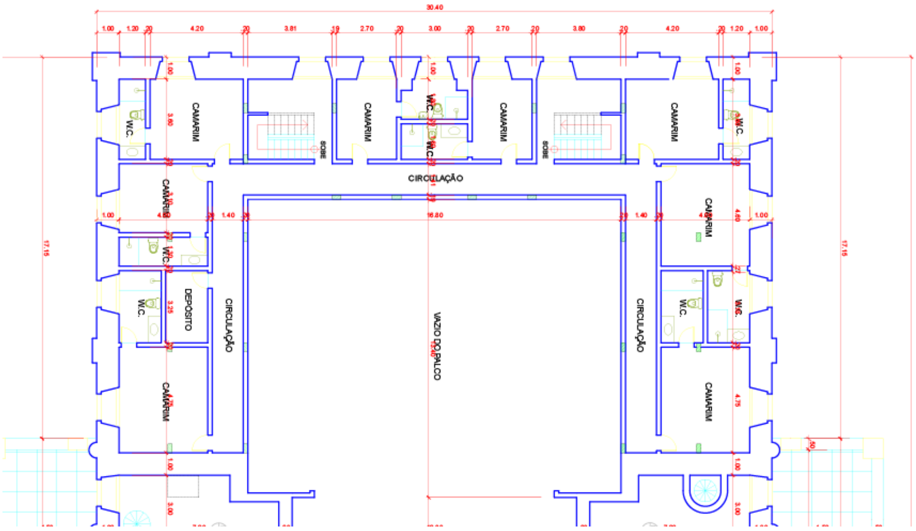

Figure 2.3: Dressing rooms.

The next part of the theater is the stage. Its architecture has a proscenium arch that is 10.50 meters width, 6.40 meters tall, 11.97 meters deep and has a total floor area of 123.29 square meters. Figure 2.4 depicts the stage and Figure 5.1 in annex shows the stage in front of the showroom.

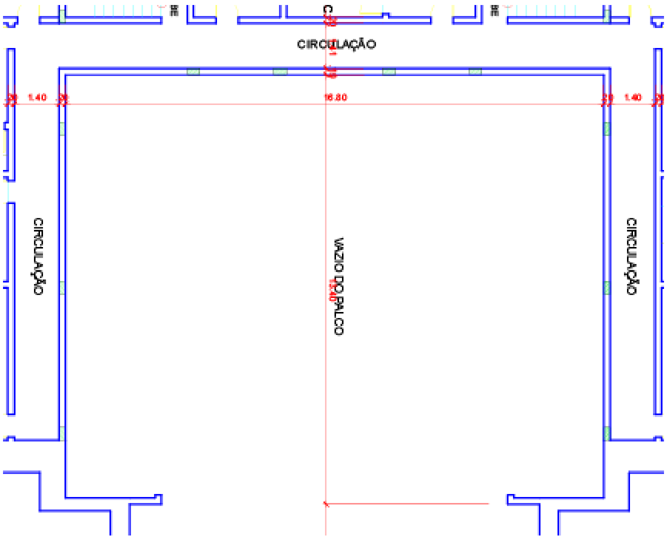

Figure 2.4: Stage.

Next we have the Warp, which is located in the upper part of the theater, where is developed all the driver of scenic pieces. Next we have the Basement of the theater that has power stations, deposits and technical rooms. Finally, the theater has other places such as administration rooms, bathrooms, reception and cafeterias. These places are located in different parts of theater and are most frequented by the staff. Next we will show what we will measure at the theater and how.

## 2.1. Monitored & Controlled parameters and devices

Table 2.1 shows which equipment we will be controlling and monitoring and where they are located.

| Location | Circuit | Measurement point (name) | cable size | Max current | control/monitor |
|---|---|---|---|---|---|
| Dressing Room 1 | breaker 12 | Shower and TV socket | 4mm | 28 A | Control & Monitor |
| Dressing Room 1 | breaker 07 | Lighting and sockets | 4 mm | 28 A | Control & Monitor |
| Dressing Room 2 | breaker 01 | Sockets | 4 mm | 28 A | Control & Monitor |
| Dressing Room 2 | breaker 06 | Fancoil | 4 mm | 28 A | Control & Monitor |
| Dressing Room 25 | breaker 3 | Shower | 6 mm | 36 A | Control & Monitor |
| Dressing Room 25 | Breaker 5 | Lighting and sockets | 6 mm | 36 A | Control & Monitor |
| Dressing Room 27 | Breaker 7 | Shower | 6 mm | 36 A | Control & Monitor |
| Dressing Room 26 | Breaker 9 | Lighting and sockets | 6 mm | 36 A | Control & Monitor |
| Dressing Room 27 | Breaker 15 | Lighting and sockets | 6 mm | 36 A | Control & Monitor |
| Dressing Room 21 | Breaker 8 | Shower | 6 mm | 36 A | Control & Monitor |
| Dressing Room 21 | Breaker 12 | Lighting and sockets | 6 mm | 36 A | Control & Monitor |
| Dressing Room 22 | Breaker 12 | Shower | 6 mm | 36 A | Control & Monitor |
| Dressing Room 22 | Breaker 14 | Lighting and sockets | 6 mm | 36 A | Control & Monitor |
| Dressing Room 23 | Breaker 16 | Shower | 4 mm | 28 A | Control & Monitor |
| Dressing Room 23 | Breaker 18 | Lighting and sockets | 4 mm | 28 A | Control & Monitor |
| Dressing Room 24 | Breaker 18 | Lighting and sockets | 4 mm | 28 A | Control & Monitor |
| Dressing Room 23 | Breaker 20 | Shower | 4 mm | 28 A | Control & Monitor |
| Dressing Room 25 | Breaker 22 | Lighting and sockets of the dressing | 4 mm | 28 A | Control & Monitor |
| Dressing Room 37 | breaker 1 | Shower | 4 mm | 28 A | Control & Monitor |
| Dressing Room 37 | breaker 3 | Lighting and sockets | 4 mm | 28 A | Control & Monitor |
| Dressing Room 38 | breaker 5 | Fancoil | 4 mm | 28 A | Control & Monitor |
| Dressing Room 38 | breaker 9 | Shower | 4 mm | 28 A | Control & Monitor |
| Dressing Room 38 | breaker 11 | Lighting and sockets | 4 mm | 28 A | Control & Monitor |
| Dressing Room 36 | breaker 15 | Shower | 4 mm | 28 A | Control & Monitor |

| | | | | | |
|---|---|---|---|---|---|
| Dressing Room 31 | breaker 4 | Shower | 4 mm | 28 A | Control & Monitor |
| Dressing Room 31 | breaker 6 | Lighting and sockets | 4 mm | 28 A | Control & Monitor |
| Dressing Room 32 | breaker 8 | Shower | 4 mm | 28 A | Control & Monitor |
| Dressing Room 32 | Breaker 10 | Lighting and sockets | 4 mm | 28 A | Control & Monitor |
| Dressing Room 33 | breaker 12 | Shower | 4 mm | 28 A | Control & Monitor |
| Dressing Room 33 | Breaker 14 | Lighting and sockets | 4 mm | 28 A | Control & Monitor |
| Dressing Room 34 | breaker 16 | Shower | 4 mm | 28 A | Control & Monitor |
| Dressing Room 34 | Breaker 18 | Lighting and sockets | 4 mm | 28 A | Control & Monitor |
| Dressing Room 35 | Breaker 18 | Lighting and sockets | 4 mm | 28 A | Control & Monitor |
| Dressing Room 35 | breaker 20 | Shower | 4 mm | 28 A | Control & Monitor |
| Dressing Room 36 | Breaker 22 | Lighting and sockets | 4 mm | 28 A | Control & Monitor |
| Warp | breaker 2 | Reflector 1 | 4 mm | 28 A | Control & Monitor |
| Warp | breaker 4 | Reflector 2 | 4 mm | 28 A | Control & Monitor |
| Warp | breaker 6 | Reflector 3 | 4 mm | 28 A | Control & Monitor |
| Main hall | breaker 6 | chandelier | 4 mm | 28 A | Control & Monitor |
| External Area | breaker 3 | Side reflectors | 6 mm | 36 A | Control & Monitor |
| External Area | breaker 4 | Reflectors of the lawn | 6 mm | 36 A | Control & Monitor |
| External Area | breaker 5 | Reflectors of the statue | 6 mm | 36 A | Control & Monitor |

Table 2.1: Equipment list

In order to monitor energy consumption and save energy we will analyze four parameters considered important. These parameters are:

1. Temperature
2. Humidity
3. Presence/occupation
4. Electrical current

In order to analyze these parameters we need to use sensors to capture the data. As an example, we present the EnOcean technology [1], which is an energy harvesting wireless technology used primarily for building automation systems and Plugwise products that are based on Zigbee wireless network. This suggestion is not the final decision, since it may be changed in the future. EnOcean energy harvesting wireless technology uses its proven interoperable building automation functionality to allow battery less control of smart homes or smart metering systems. Energy harvesting enables wireless smart home solutions to connect self-powered lighting, heating and climate control with domestic appliances via any EnOcean enabled hub or gateway. The gateway allows complete control of building automation facilities via a web-based interface (over TCP/IP) with other backend services or smart grid systems.

Zigbee technology has gained wide adoption particularly in Europe to enable home automation and energy measurement. Plugwise presents a set of devices that can be used to monitor energy consumption in each room and automate the appliances to optimize the energy consumption. Table 2.2 shows a sensors list that can be used at the theater scenarios.

| Product Name | Image | Module Categories | Short description |
|---|---|---|---|
| TCM 300U |  | Wireless Transceiver Module | Transceiver module for programmable system components |
| TCM 310U |  | Wireless Transceiver Module | Transceiver module for gateways |
| TCM 320U |  | Wireless Transceiver Module | Transceiver module for programmable system components |
| STM 320U |  | Energy Harvesting Wireless Sensor | Energy harvesting magnet contact transmitter module |
| STM 332U |  | Energy Harvesting Wireless Sensor | Energy harvesting wireless temperature sensor module - whip antenna, side oriented LRN button |
| STM 333U |  | Energy Harvesting Wireless Sensor | Energy harvesting wireless temperature sensor module - including solar cell, helical antenna and side oriented LRN button |
| HSM 100 |  | Kits and Accessories | Humidity sensor module HSM 100 as extension for STM 33x temperature sensor module |
| PTM 330U |  | Energy Harvesting Wireless Sensor | Transmitter module (card board box) |
| ECO 200 |  | Energy Harvester | Energy converter for motion energy harvesting |
| USB 300U (OEM) |  | Wireless Transceiver Module | USB Gateway |
| Ceiling Mounted Occupancy Sensor - EOSC (OEM) |  | Energy Harvesting Wireless Sensor | Ceiling Mounted Wireless Occupancy Sensor |
| Wall Mounted Occupancy Sensor - EOSW (OEM) |  | Energy Harvesting Wireless Sensor | Wall Mounted Wireless Occupancy Sensor |
| EDK 350U |  | Kits and Accessories | Developer kit for energy harvesting wireless sensor solutions |

| | | | |
|---|---|---|---|
| Plugwise circle |  | Smart plug power sensor | Power sensor and actuator that can be used for devices plugged to electrical outlets. |
| Plugwise Stealth |  | Embedded power sensor | Power sensor and actuator that can be used for devices embedded within the building such as ceiling lamps or embedded outlets. |
| Plugwise Receiver |  | Zigbee transmitter | USB Transmitter that can be used to communicate with Plugwise devices through PCs or gateways. |
| Plugwise Strong 604 |  | Embedded high current power sensor | Power sensor that can be used to measure electrical current at the electrical panels. |
| Plugwise Switch |  | Zigbee switch | Electrical switch that can be paired with Plugwise stealth for switching ceiling lamps. |
| Plugwise Sense |  | Temperature and humidity sensor | Wall mounted temperature and humidity sensors which can be used to regulate the HVAC in rooms. |
| Plugwise Scan |  | PIR and Ligth sensor | Wall mounted PIR and light sensors which can be used to regulate the lighting in rooms. |

Table 2.1: Sensor and actuator list

Taking into account the sensors and the structure of the theater, we can build our system and use the IMPReSS platform. We have planned some scenarios and scenes, which we consider useful and may be used at the showcase, as listed below.

## 2.2. Scenarios

The scenarios proposed in this section are based on a visit to the Amazonas Theater. In this visit, the structure of the theater was studied with the support of an electrician. The following aspects may be pointed out: the theater has an organized power substation that can be used to measure the energy consumption; we also found out that the theater has panels scattered around with diagrams that show what they control. Based on these observations, we could install sensors at the substation and at the panels. Figure 2.5 shows the power station. An example of a panel with a diagram is depicted in Figure 2.6.

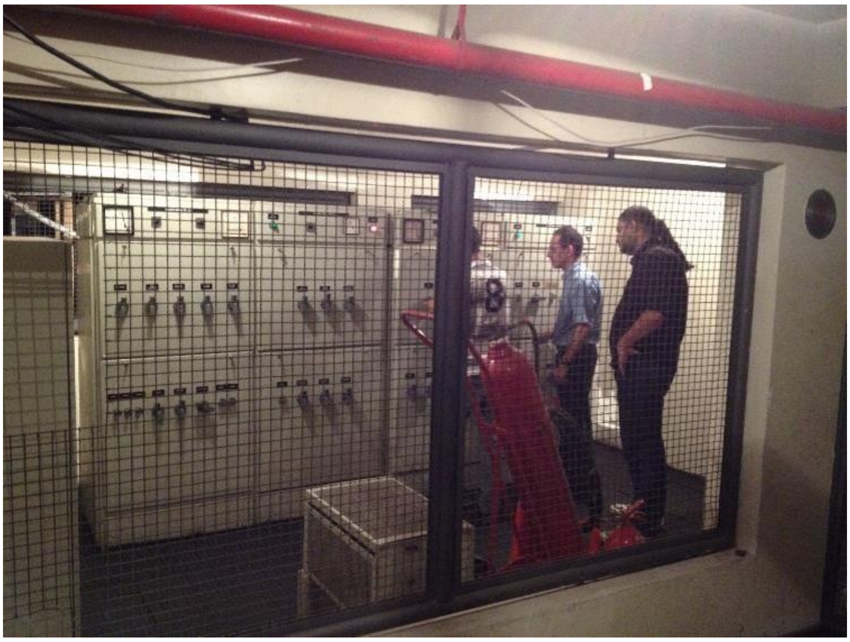

Figure 2.5: Power substation.

Figure 2.6: Energy panel with a diagram.

Therefore, we could, for example, use ECO 200 sensors at the panels instead of spreading wireless sensors in sockets. In the next paragraphs we are going to discuss about the use cases, starting with the Dressing Rooms.

### 2.2.1. Dressing Room

The first use case is the Dressing Rooms. Amazonas Theater has 18 dressing rooms: eight located at the second floor, eight at the third floor and two at the stage. Sixteen Dressing rooms have the same size, the remaining two are a little larger. All of them are equipped with fluorescent bulbs and controls to turn in/off the air conditioner, as shown in Figure 2.7 and in Figure 2.8.


Figure 2.7: Fluorescent light at a Dressing Room.

At the moment, these equipment are on all day long, even if nobody is within the room. Consequently, this leads the theater to spend energy unnecessarily. The goal of this use case is to replace the fluorescent bulbs by LED ones and to install presence sensors. These tasks will certainly allow the theater to save a large amount of energy, since the LED bulbs are more economic and the bulbs and air conditioner will be turned on only if people are present in the dressing room.

In order to prove that the theater will save energy as a consequence of these changes, we plan to apply the following strategy. First, we will measure the energy consumption of the dressing rooms for a period of time. Thus, we plan to use IMPReSS APIs to get a prediction of the amount of spent energy. Finally, we will install the sensors, replace the bulbs, measure the energy consumption again and compare the results to show it at the showcase. We built some scenes to help the understanding, as listed below:

- **Scene 1:** On a particular day, a dance group made a presentation inside the theater. The dance group consisted of 10 people. Therefore they needed to use three dressing rooms to get ready for the ShowTime. They arrived at 16:00 PM and each subgroup entered at the dressing rooms. Firstly the IMPReSS platform detected that people were inside the dressing rooms and with the help of occupancy sensors turned the air conditioner and the ceiling lights on.
- **Scene 2:** That particular day, a member of the dance group stopped in front of the mirror and the IMPReSS platform turned on the side mirror lights.
- **Scene 3:** When a member of the dance group entered the bathroom IMPReSS detected the presence through occupancy sensors and turned the light on and when the member left the light were turned off.

Figure 2.8: Control to turn in/off the air conditioner.

### 2.2.2. Warp

The second use case scenario is the Warp. The total height of the Amazonas Theater scenic box is 14 meters, and the warp is located in its upper part. Figures 2.9 and 2.10 show the warp.

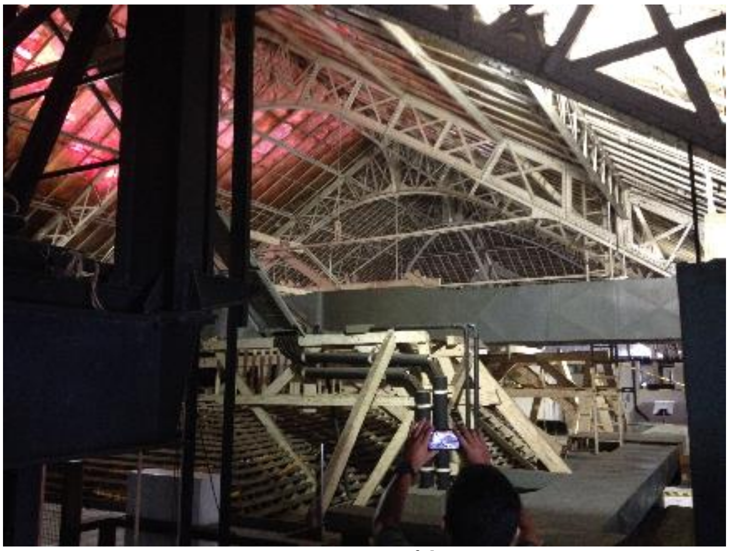

Figure 2.9 First part of the warp.

The theater administration has recently allowed visits in this area. As a consequence, four light reflectors have been installed at the warp, each of them with 380 Watts of capacity. The problem here is that the light reflectors are on all day long. Figures 2.11 and 2.12 show some reflectors.

Figure 2.10 Middle part of the warp.

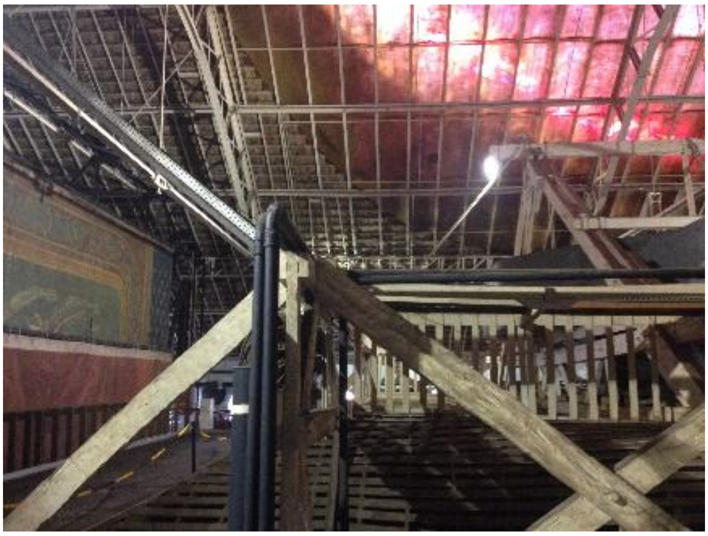
Figure 2.11 Light reflector at the first part of the warp.


Figure 2.12 Light reflector at the end of the warp.

The goal of this scenario is to control the light reflectors by using presence sensors, turning it on or not according to the presence of people. This action will decrease the consumption of energy at the warp.

Focusing on proving that the theater will save energy as a consequence of these changes, we plan to apply the same strategy mentioned for the first case scenario. First, we will measure the energy consumption of the warp for a period of time. Thus, we plan to use the IMPReSS framework to get a prediction of the amount of spent energy. Finally, we will install the sensors, replace the bulbs, measure the energy consumption again and compare the results to show it at the showcase.

Another possibility would be the use of solar panels placed on the roof of the theater to store energy from the sun and to replace the reflectors. This action would also save energy and be measured to show the results at the showcase. Some scenes were made to help the understanding, as listed below:

- **Scene 1:** Adriano, member of a group of visitors, requested to visit the Warp of the Amazonas Theater. When a member of the group of visitors or the guide entered the Warp IMPReSS detected the presence with the help of occupancy sensors and turned the reflectors on, when the group left the visit IMPReSS turned off the reflectors.

### 2.2.3. External Area

The third use case scenario is the external area of the theater. This area includes a theater forefront and a small garden, 12 reflectors with 300 Watts are used in the forefront. The electrician reported that when some specific event happens a company is hired to add at least 12 colorful reflectors to the forefront for adornment, according to the event colors.

The garden also has 6 reflectors with 380 Watts and 6 additional reflectors with 300 Watts to illuminate statues. Figure 2.13 and 2.14 show the forefront and the garden.


Figure 2.13 TAO forefront.

Figure 2.14 Garden reflector.

The goal of this use case scenario is to replace all bulbs with multicolor LED bulbs. This change will allow the operators of the theater to change the color of the lights according to the events, avoiding hiring a company and adding a more economic bulb.

Again, to prove that the theater will save energy as a consequence of these changes, we plan to measure the energy consumption of the external area for a period of time. Thus, we plan to use the IMPReSS framework to get a prediction of the amount of spent energy. Finally, we will install the sensors, replace the bulbs, measure the energy consumption again and compare the results to show it at the showcase. The scenes of this use case are listed below:

- **Scene 1:** On a particular day Amazonas Theater is hosting the philharmonic orchestra. At these special days the front of the theater is adorned with colored lights, using IMPReSS the operator changed the colors of the lights automatically to improve the Theater appearance.

### 2.2.4. Lobby

The last use case scenario is the lobby. Amazonas Theater has a lobby divided into four parts: store, hall, box office and snack bar. The store has three buffs with 25 bulbs each; the snack bar has 2 buffs with 25 bulbs each; the hall has 2 buffs with 40 bulbs each; and the box office has one buff with 6 bulbs. The goal of this scenario is to replace all the bulbs with LED bulbs focusing on saving energy. To prove that this objective will be achieved, we plan to apply the same strategy described for the previous use case scenario.

Given that the sensors will be installed and the scenarios are well defined, we plan to develop an application to the users, which is described in the next section.

# 3. Amazonas Theater System

The System discussed in this section consists of a responsive web application for energy management, which was based in deliverable 8.1 [2]. A draft of the screens will be showed starting with Figure 3.1 that depicts the login screen, this work is not final and may be modified in the future.

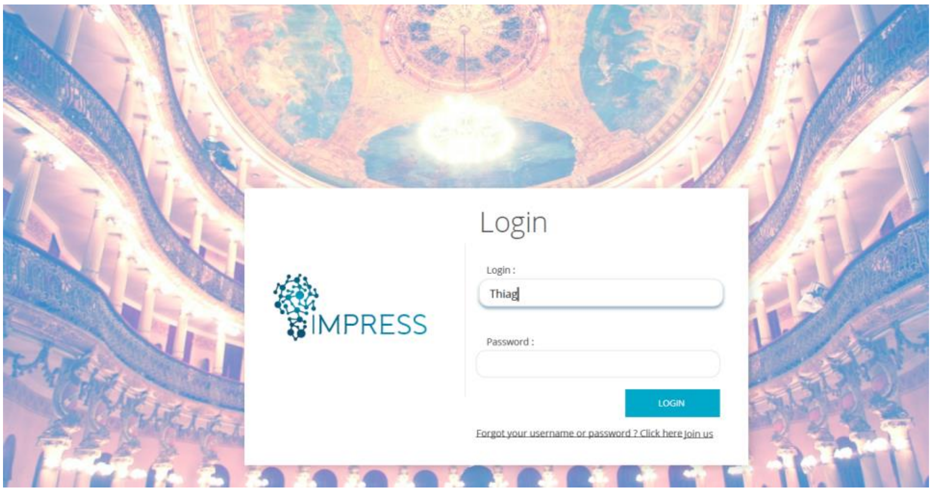


Figure 3.1: Login screen.

At this screen the user will add his login and password to log in and use the web application. There are three kinds of users: public, operator and administrator. The public user will be the visitors of the theater and they will be able to see information about the energy consumption only, the operator and administrator users will be able to see information, turn in/off equipment and add information to the IMPReSS repository. Figure 3.2 shows the home screen.

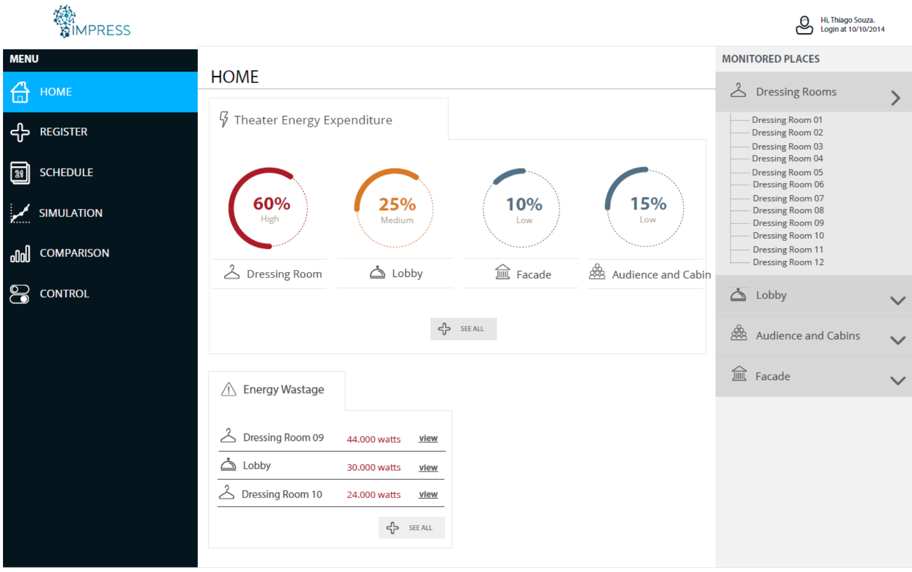


Figure 3.2: Home screen.

At the home screen the user will see the main menu at left and the energy consumption of all the areas being monitored at the theater in the middle. The right side displays a list of all the areas that are being monitored and when the user clicks on it the graphics will be updated to show the energy consumption of the area that was clicked. Figure 3.3 and 3.4 shows an example of a register screen (area in this case) that will be used from the users to add information about areas, groups, devices and others to the IMPReSS repository.

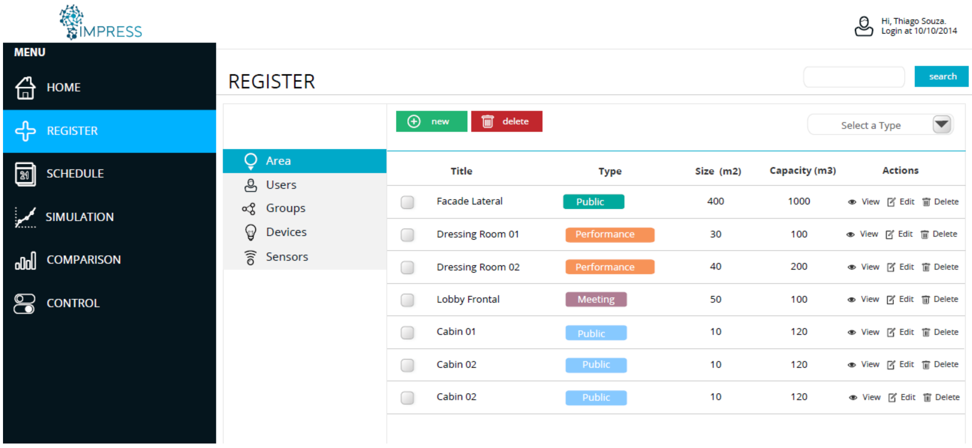


Figure 3.3: Register screen.

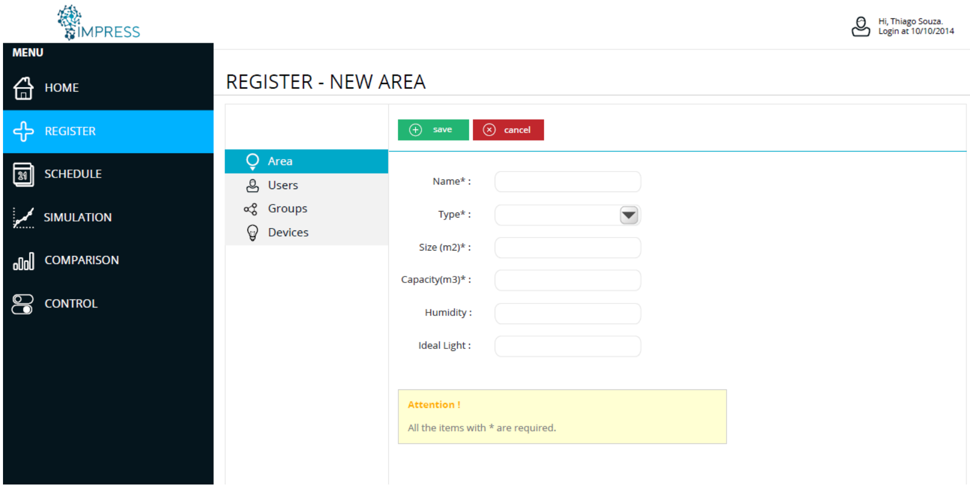


Figure 3.4: Register screen.

Figure 3.3 shows the first part of the register screen. It is a search screen that allows the users to search for specific content that after will be displayed in a grid. By selecting an item the user will be able to update, view or delete the content, finally there is a button called "new" that is used to open Figure 3.4 screen that is used to create content (area in this case) and add it to the IMPReSS repository. The next screen is the schedule screen and is depicted in Figure 3.5 and 3.6.

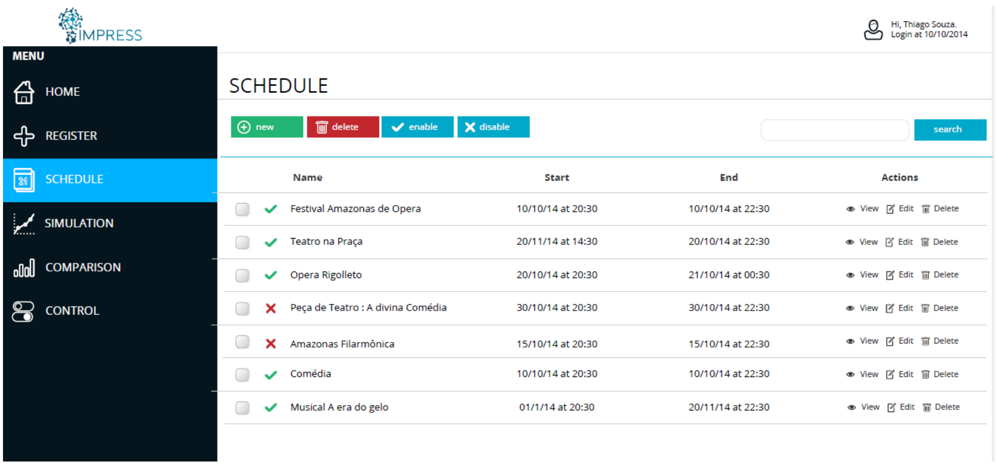


Figure 3.5: Schedule screen.

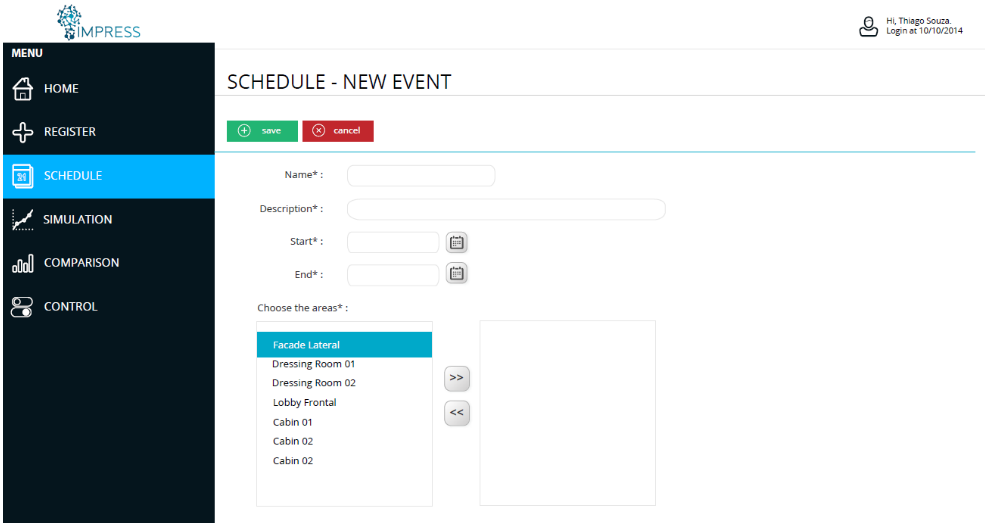


Figure 3.6: Schedule screen.

At the schedule screen the user will be able to make event reservations. Figure 3.5 is the search screen and when clicking on new it goes to Figure 3.6 that will allow the user to create an event adding its name, description, period and the areas that will host it. Figure 3.7 and 3.8 depicts the simulation screen.

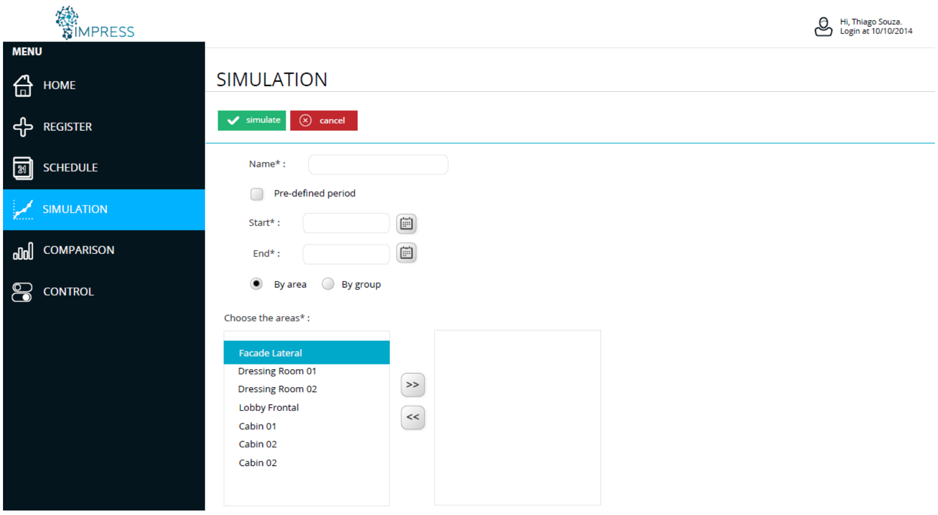


Figure 3.7: Simulation screen.

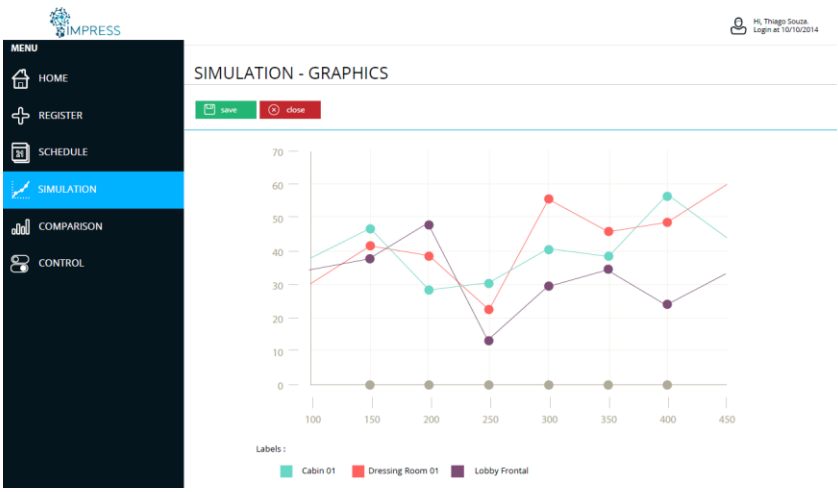


Figure 3.8: Simulation screen.

At the simulation screen the user will be able to add a name, a period and a set of areas or groups to make a simulation. After running the simulation a graphic will be displayed to the user to analyze the results, to run the simulations the application will use IMPReSS data analytics APIs to analyze the data. For example, an algorithm to predict energy consumption may be used. The last screen is the control screen and is depicted in Figure 3.9.

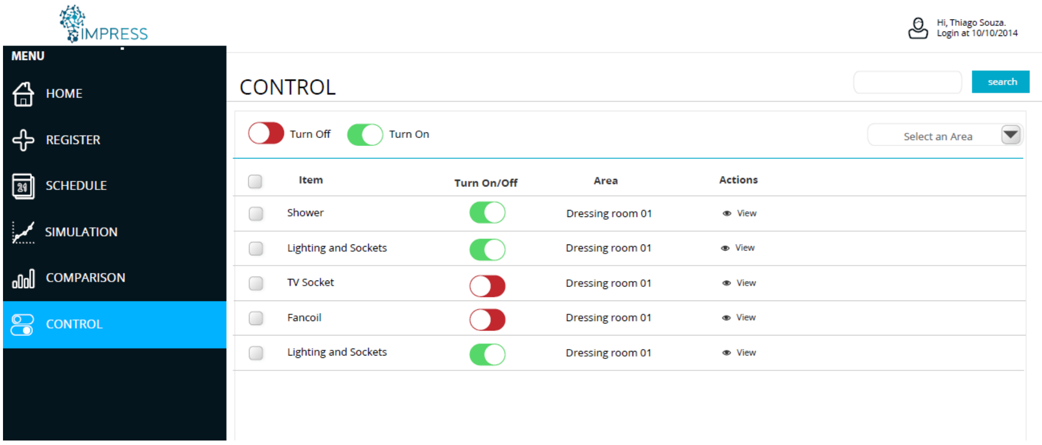


Figure 3.9: Control screen.

At the control screen the user will see a list of equipment and will be able turn them on or off. Besides, a public display application is intended to show to the visitors the energy consumptions and savings achieved by the project as a result of retrofitting the lighting, the use of occupancy sensors, as well as the schedule of the shows. Figure 3.10 shows an example of public display.

Figure 3.10: Public display application at the opera house.

Figure 3.11 shows the IMPReSS components used to develop the public display application. On the lowest layer, the resource adaptation layer, called Resource Adaptation Interface (RAI), provides a unified software interface to communicate with plugwise and enocean devices. Above the RAI, IMPReSS components such as context and data analytics are used to simplify the development of the application logic. The context manager provides rule templates that can be extended to define policy for controlling lighting based on room occupancy, the amount of daylight coming from the window, and the schedule when the rooms are to be used. The data analytic module provide algorithms that can be used to determine the users' occupancy pattern that are useful to regulate the air conditioner so that the rooms can be pre-cooled before the users come into the rooms.

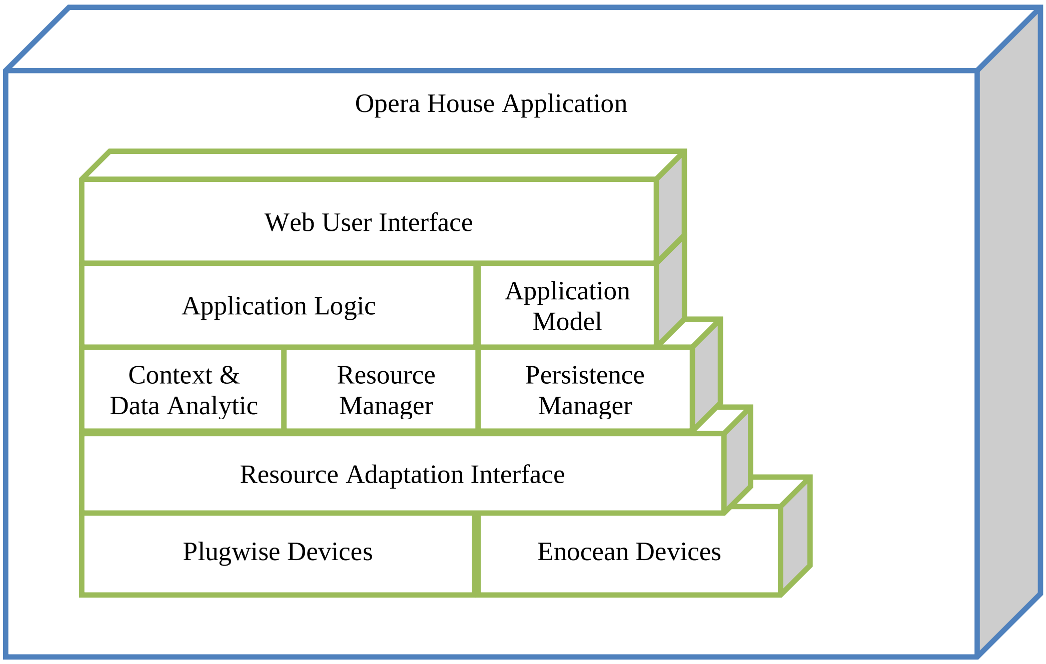


Figure 3.11: IMPReSS components used for the application development.

# References

[1] EnOcean. Available in: http://www.enocean.com. Date Acess: 10/09/2014.

[2] IMPReSS D8.1 Specification of Proof of Concept Applications, 16 March 2014.

# Annex

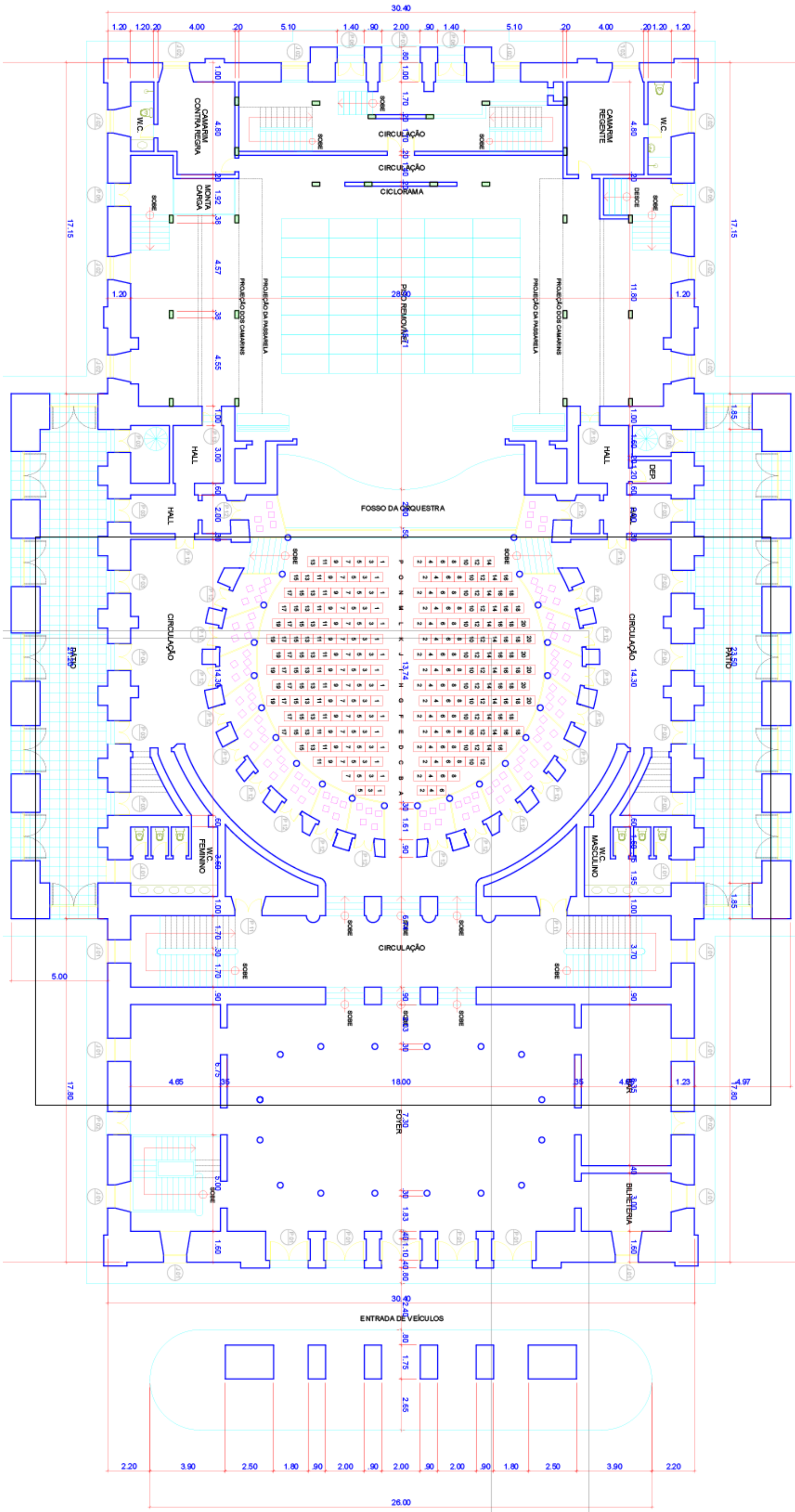


Figure 5.1: Floor Pant of the ground.

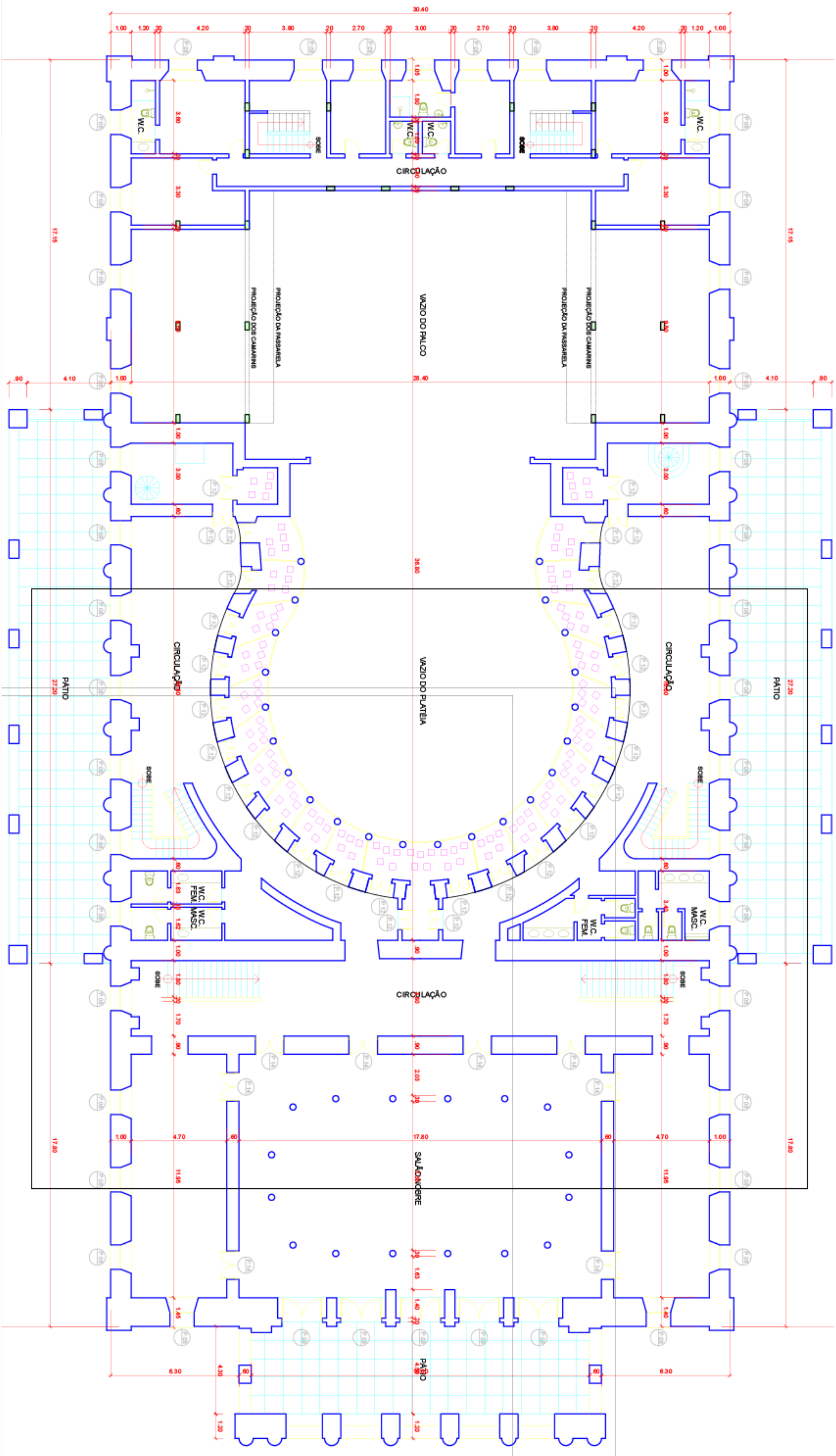


Figure 5.2: Plant first floor.

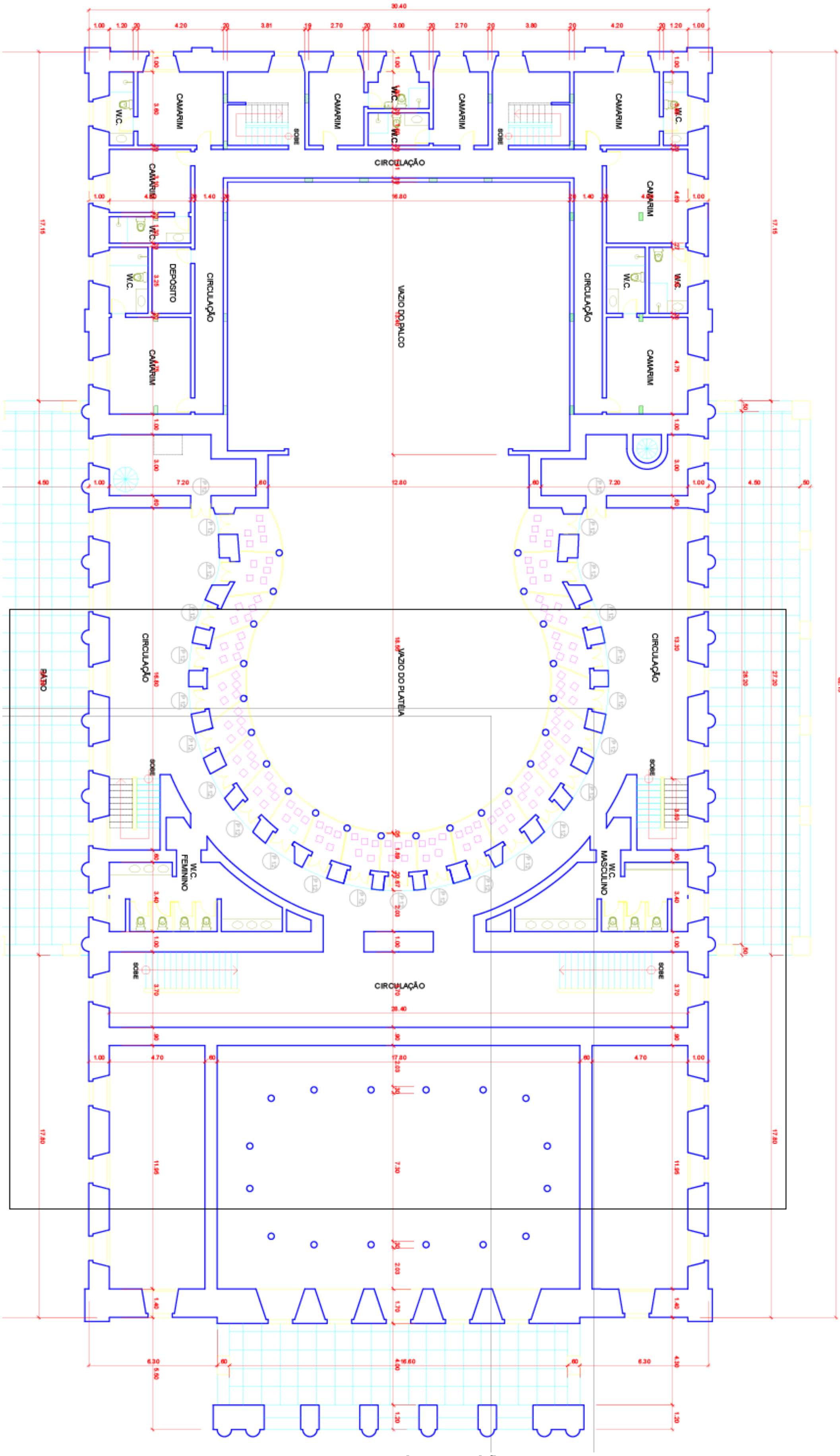


Figure 5.3: Plant second floor.

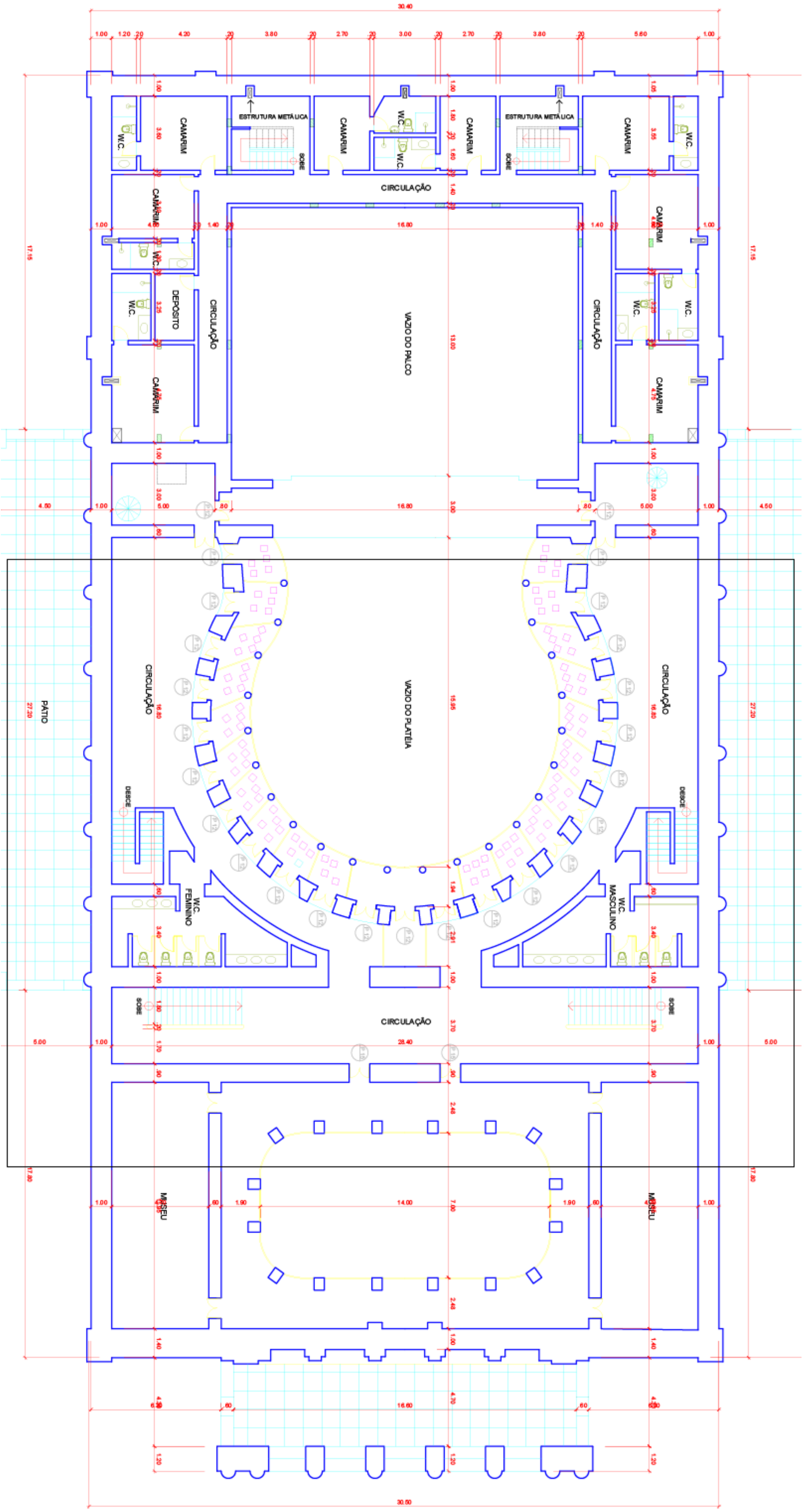


Figure 5.4: Plant third floor.

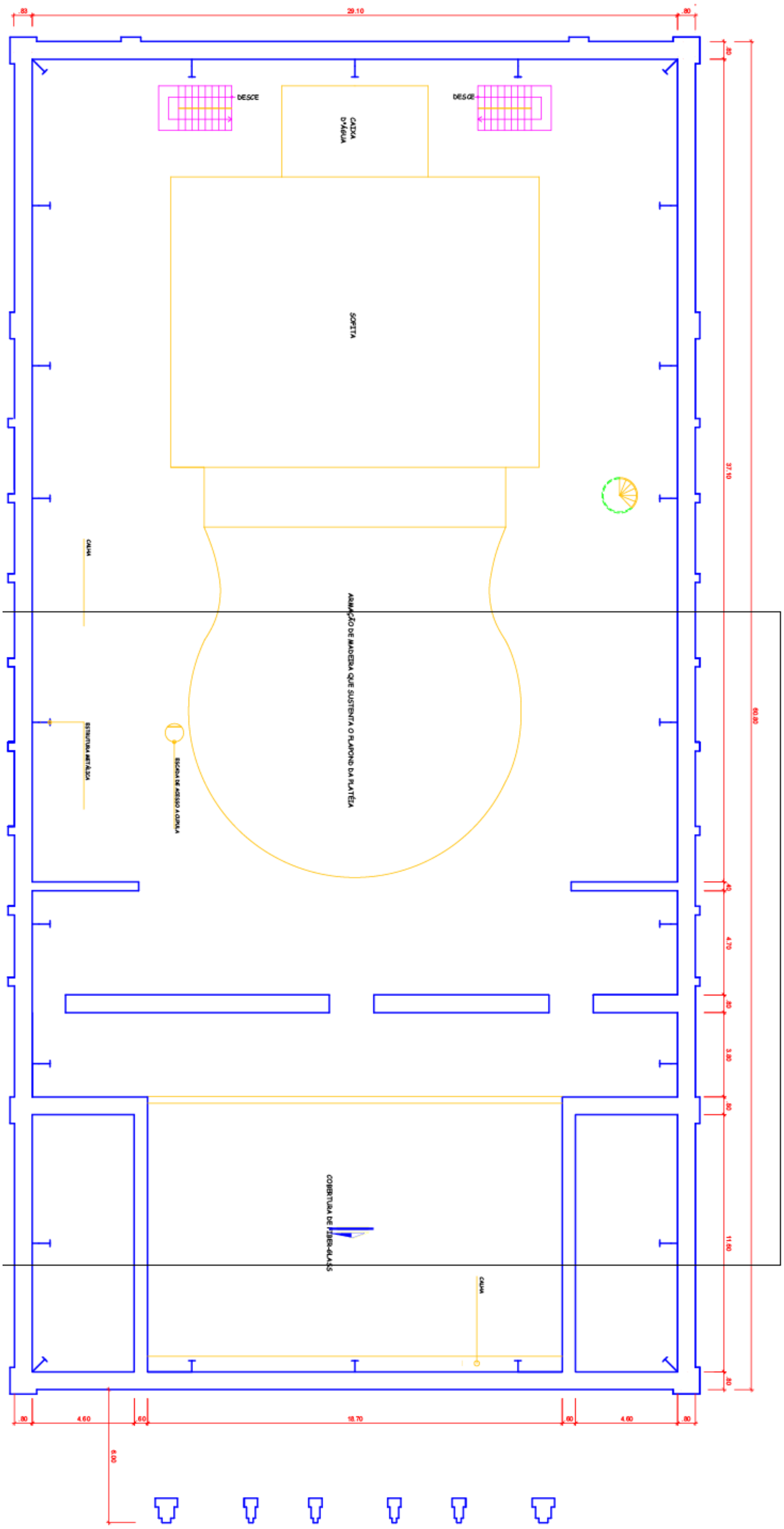

Figure 5.5: Plant of the warp.