DELIVERABLE 3.2.4.

Technical design for the outfitting of a room in Zadar Port Authority building for the implementation of virtual museum

European Regional Development Fund

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1. Introduction

Regarding Activity 3.2, Deliverable 3.2.4 “Technical design for the outfitting of a room in Port of Zadar Authority building for the implementation of virtual museum”, main purpose of this document is to provide review and technical specifications of state-of-the-art video wall display technologies in a simple and understandable way. Additionally, based on their characteristic’s comparison and micro-location placement characteristics of Port of Zadar Authority’s building this document presents proposal of optimal video wall technology along with detailed technical specifications, related to project REMEMBER.

Hence, document structure is divided into major three topics covering: General review of state-of-the-art video wall displays and their characteristics; Review of possible locations inside Port of Zadar Authority building suitable for setting up virtual museum – installation of video walls displays; Technical specifications – recommendation of optimal video wall display solutions suitable for installation regarding Port of Zadar Authority building specifics.

The information presented in this document has been collected from internal subject matter experts along with external sources, including industry research papers, dissertations, journals, and more. While every effort has been made to provide current, accurate, and useful information, it should be noted that individual products and user experiences might vary. In addition, video wall technology is advancing rapidly, and the characteristics of a particular display technology may shift over time. Ultimately, only the end user can determine optimal video wall technology depending on their specific application and environment. The information that follows is simply intended as a framework to provide state-of-the-art video wall technologies and present considerations that may be useful in the process of selecting the optimal solution.

Contents

2. Video walls display technology overview

A video wall is a large-scale visual display consisting of multiple monitors, projectors, or other display technologies that are tiled or overlapped to form a single, expansive display surface. Today, video walls are transforming the way people communicate, learn, and solve problems around the world. At their best, these large-scale visual displays are engaging and powerful tools that enhance users' ability to see, understand, and share information with others.

In many cases, video walls offer significant advantages over the use of a single, large display. Perhaps most importantly, video walls can provide much larger, higher-resolution images than single displays. A large, high-resolution central display enables all the users in a space to clearly view, interact with, and share information. Video walls can also offer far more flexibility of shape and dimension than single displays and oftentimes they are the only solution that can accommodate spatial constraints while delivering scale. Far more versatile than a single display, a video wall can function as an immersive research environment, a 3D simulation system, or even an element of architectural design. When integrated with effective processors and software, video walls can provide benefits for virtually any application and environment. In public spaces, video walls can create visually stunning platforms for promotional media or public information boards for critical messages.

Next section presents review of three most common technologies – LED-LCD (Led Emitting Diodes; Liquid Crystal Displays), Direct view LED and DLP (Digital Light Processing) used for video walls containing their specific characteristics. It is of uttermost importance in the context of this document to properly differentiate LED-LCD and Direct view LED technologies. They represent two very different technologies which often get confused because of the naming scheme where current generation of Liquid Crystal Displays (LCDs) use Light-Emitting Diode (LED) lighting to illuminate the thin liquid crystal display layer, from behind or around the edges. For the latter, that is why they are sometimes referred to as LED edge-lit LCD display but more often as D-LED displays, since nowadays almost all manufacturers of LCD displays use certain form of LED backlighting and declare their displays as D-LED displays. Therefore, to retain clarity in video wall setup context, nomenclature used in this document is referring to LED-LCDs as D-LEDs whilst Direct view LED displays will be referred to as such.

To make presented technologies comparable, each one is described using common and four most important criteria – Visual performance; Reliability; Design and installation; and Total cost of ownership.

2.1. D-LED video walls

D-LED video walls are the most widely adopted technology in the market. D-LEDs are flat panel displays composed of a layer of liquid crystals aligned between two polarizing filters and backlit by light emitting diodes. Application of the electric current reorients the liquid crystal molecules, blocking the light or allowing it to pass through to form an image. Modern high-performance video walls are built as an array of professional grade narrow bezel D-LED panels, with the size of each individual panel varying based on the project requirements in terms of space and resolution.

The frames around the edges of these displays, which hold them in place, are called bezels. Those bezels have grown steadily thinner through the years. Five to 10 years ago, a videowall had very noticeable gridlines because of thick bezels. For videowalls that ran content across all the conjoined panels, the aesthetics were not great. Text and images were interrupted and broken by large seams. These days, bezels are far thinner, and all but disappear when seen at a reasonable distance. There is a pricing premium on those D-LEDs with what are termed ultra-narrow bezels, and costs go down as the frames get thicker.

Figure 1: D-LED video wall illustration (Source: samsungdisplay.com)

2.1.1. Visual performance

D-LED video walls can provide high total resolution – 1,920 x 1,080 (full HD) or 3,840 x 2,160 (4K) pixels – due to their high pixel per inch (PPI) density. This makes D-LED video walls viewable from close distances without image quality loss and eye fatigue. D-LED video walls are most suitable when exhibiting images with lots of detail and text. D-LED video walls may be said to have a "stacked" resolution as each additional panel increases the total resolution of the video wall. This represents a significant advantage over projection-based systems, in which the projected image is simply stretched across a larger surface, diminishing the pixel density.

D-LED video wall solutions come in a variety of brightness options with quickly and easily adjustable settings (from 500 to 700 nit), making them a great contender for environments with changing lighting conditions or with substantial ambient light. Modern D-LED panels yield broad

color gamut and produce accurate, true colors for lifelike images. D-LED walls deliver wide viewing angles (up to 178 degrees).

While bezel width used to be a slight disadvantage of D-LED video walls, the technology is quickly moving towards nearly bezel-less solutions, with extreme narrow bezel models offering as little as 1.7mm width. This is crucial for providing disruption-free visual experiences, especially in contexts where highly detailed content needs to be presented.

2.1.2. Reliability

D-LED video walls are designed to deliver 24/7 performance over extended periods of time. Commercial grade panels are robust and resistant to environmental stressors, such as heat, moisture, and dust.

2.1.3. Design and installation

D-LED panels are lightweight and have a slim profile, resulting in spatial efficiencies and allowing flexibility in choosing mounting options. D-LED solutions offer increased design flexibility – they are scalable, allow for easy size adjustments, and can accommodate curved surfaces and most importantly – D-LED video walls easy to install.

2.1.4. Total cost of ownership (TCO)

Long lifespan – D-LED panels most commonly offer operational warranty of over 100,000 hours at 24/7 operations. Their initial costs are low to moderate and lowest of all described technologies in this document. Most importantly they imply minimal maintenance costs as the technology does not come with any consumable parts. They represent eco-friendly solution with low power consumption.

2.2. Direct view LED video walls

The new generation of indoor displays on the market are also called Direct view LEDs, because instead of LEDs just being the hidden lighting source for another technology, like D-LED, viewers are looking directly at the tiny LEDs that are creating the visuals.

Direct view LED displays are made by arranging hundreds of LEDs directly on the glass panel. Each pixel of a Direct view LED is comprised of 3 sub-pixel LEDs (red, green, and blue). By adjusting the voltage to each sub-pixel, the screen recreates the intended image on the screen. Since each pixel is made from the three diodes, reducing the size of individual diodes has been a focus of the LED technology players. While the original technology was only used for outdoor installations where displays were viewed from a distance, modern LED panels have shown promise with finer pixel pitches.

The biggest difference with D-LEDs, apart from viewing distance, is the lack of any seams on LED displays. The modules fit together like tiles, with no visible gaps. A high-quality LED display, expertly installed, looks like one continuous, unbroken image.

Figure 2: Direct view LED video wall illustration (Source: samsungdisplay.com)

2.2.1. Visual performance

Because of the nature of their design, even the latest Direct view LED video walls cannot provide as high of a resolution and pixel pitch as D-LEDs. Therefore, this technology can only be employed where content is viewed from the distance.

Intense brightness (from 800 nit for indoor to 4,000 nits for outdoor) is the main advantage of Direct view LED displays because of the direct light emission. The downside to the high brightness is that it is hard to reduce brightness below 500 nits, which makes it unsuitable for the dark room installations.

Direct view LEDs provide wider viewing angles than Digital Light Processing (DLP) video walls because of the direct light emission. Nevertheless, due to the round shape of individual diodes, they emit more light towards the front — hence when viewed from the side they may

produce subpar brightness and color variability compared to D-LEDs. Panels deliver seamless, bezel-free design.

2.2.2. Reliability

Direct view LEDs have a long useful life. Weather resistant to a range of temperatures and humidity levels.

2.2.3. Design and installation

Direct view LED panels are lighter than D-LEDs and provide design flexibility of shape – flat, curved, or cylindrical – for customized installations.

2.2.4. Total cost of ownership (TCO)

High resolution Direct view LEDs are substantially more expensive than D-LEDs and even DLPs and have low maintenance costs and are energy efficient. They are easy to access and service as panels are light.

2.3. Digital Light Processing (DLP) video walls

Digital Light Processing (DLP) technology uses the optical semi-conductor – digital micromirror device (DMD). This DMD chip is an extremely precise light switch that enables light to be modulated digitally. Under each DMD mirror, there is an electrode causing this mirror to tilt either toward or away from the light source, creating monochrome images with precise shades of gray. Next, the monochrome image is translated into color. A color filter – called the color wheel – is placed between the source of light and a DMD mirror panel. As the color wheel turns, it shines various colors on DMD mirrors, coordinating with each mirror position and producing the

color image. The latest iteration of the DLP technology as it pertains to video walls is the rear projection cube (RPC) solutions with LED light sources.

Figure 3: DLP video wall illustration (Source: samsungdisplay.com)

2.3.1. Visual performance

DLP video walls deliver relatively high total resolutions and a range of aspect ratios. DLP displays are not as bright as D-LEDs or Direct view LEDs and require control over the ambient lighting conditions. They are not suitable for high ambient light rooms or outdoors. DLP solutions provide broad color gamut and superior color fidelity. DLP viewing angles are narrower than those of D-LEDs or Direct view LED video walls. While not totally seamless, DLP video walls have bezels that are as narrow is 0-0.5 mm, providing nearly undisrupted viewing.

2.3.2. Reliability

DLP video walls can deliver 24/7 performance over extended periods of time. DPLs are vulnerable to vibration or instability, sensitive to humidity and heat. They require a temperature controlled stable indoor environment.

2.3.3. Design and installation

DLP panels are heavy and fragile, with large and deep footprint. Cubes need to be mounted to the floor. DLPs provide good design flexibility with a variety of options regarding the size and shape, allowing for even non-rectangular and curved installations. It is a stackable solution with an advantage of a built-in mounting system – D-LEDs require mounting frames or must be adjacent to a wall. Require significant efforts during installation and assembly.

2.3.4. Total cost of ownership (TCO)

Initial cost is significantly higher than that of the D-LEDs but lower than of Direct view LED technology. Power consumption is comparable to D-LEDs. Screens are prone to be damaged easily and might need replacement. They have a long lifespan (60,000 to 100,000 hours at 24/7 operations).

2.4. Distribution by the panel type and application in public spaces

Related to implementation of virtual museum in Port of Zadar Authority building this section provides insight of distribution by the panel type and application in public spaces of previously described video wall technologies. Provided information is presented in manner of providing additional value and is providing additional support to recommendations presented in this document.

As presented on Figure 4, D-LED technology dominates the video wall market because of the greater balance between its performance characteristics and total cost of ownership. D-LED

video wall market is expected to further expand, driven by the extreme narrow bezel segment. In the future, widespread adoption of the technology will be facilitated by nearly bezel-less designs.

Direct view LED market share size is quite small comparing to D-LEDs – but with the new generation of fine pitch products (1-5mm Direct view LEDs) and further cost reduction, this technology's share of the market is projected to grow at the expense of DLP.

Due to its high reliability and nearly seamless design, DLP still works for specific demands of certain control room applications or installations in large, dark spaces, but DLP video wall market share is expected to decrease in the future to the benefit of other technologies.

D-LED remains the prevalent technology across all sectors, Direct view LED walls are largely employed within retail and public space applications viewed from larger distance and not required highest resolution, whilst DLP is predominantly used in specialized control room settings.

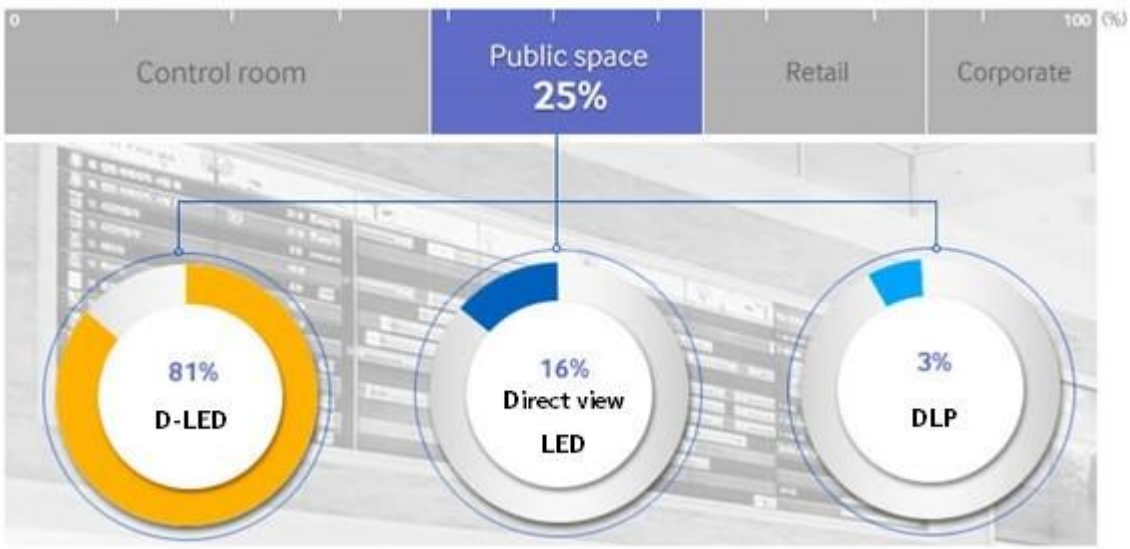

Figure 4: Distribution by the panel type and application in public spaces (Source: samsungdisplay.com)

Data presented on Figure 4 clearly supports adoption and implementation of D-LED based video walls displays as optimal one for implementing virtual museum in Port of Zadar Authority building.

2.5. Selecting optimal video wall technology based on application purpose

D-LED video walls are affordable, easy to install and maintain, deliver superior visual performance on all characteristics. They are thin and provide design aesthetics and flexibility and are highly reliable and resilient. Bezel is the main shortcoming of the technology if legacy solutions are employed.

Direct view LED video wall solutions' main advantage is their bezel-free design, extreme high brightness (suitable for outdoors), design flexibility and customization, as well as resilience. However, the cost of the modern, high resolution options may be prohibitive for most buyers.

DLP solutions deliver high visual performance and nearly bezel-less viewing experience with superior reliability for 24/7 environments. Nevertheless, these systems are bulky and require additional space for installation and maintenance.

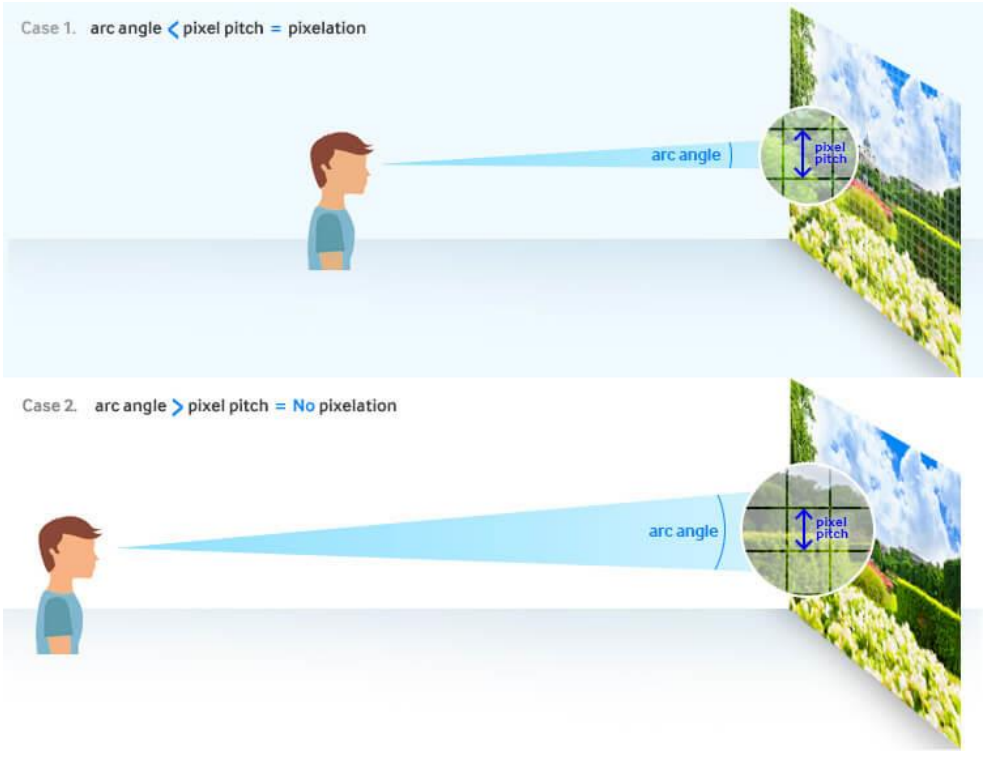

Figure 5: Infographic demonstrating pixelation effect (Source: samsungdisplay.com)

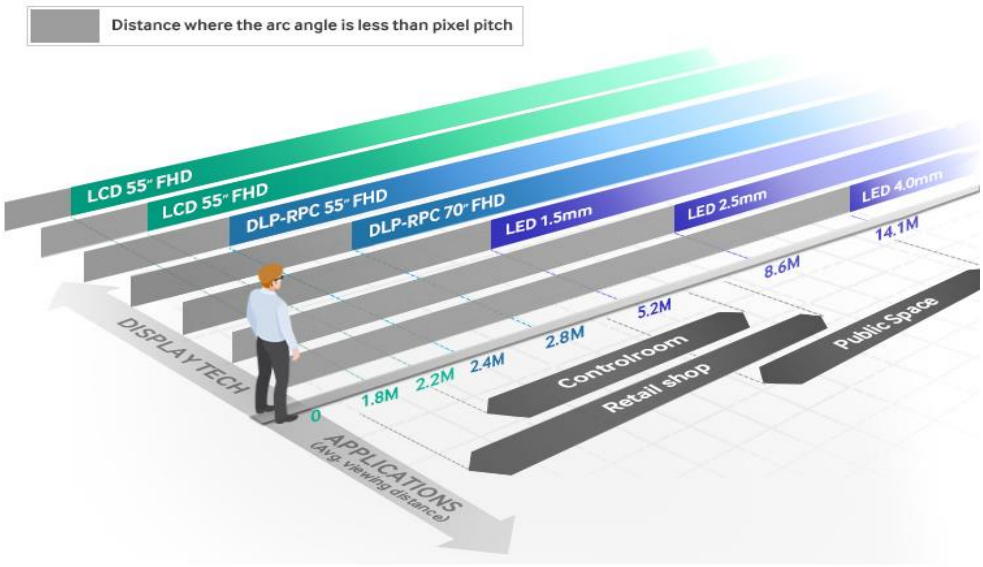

Figure 6: Infographic demonstrating minimum distance to avoid pixelation (Source: samsungdisplay.com)

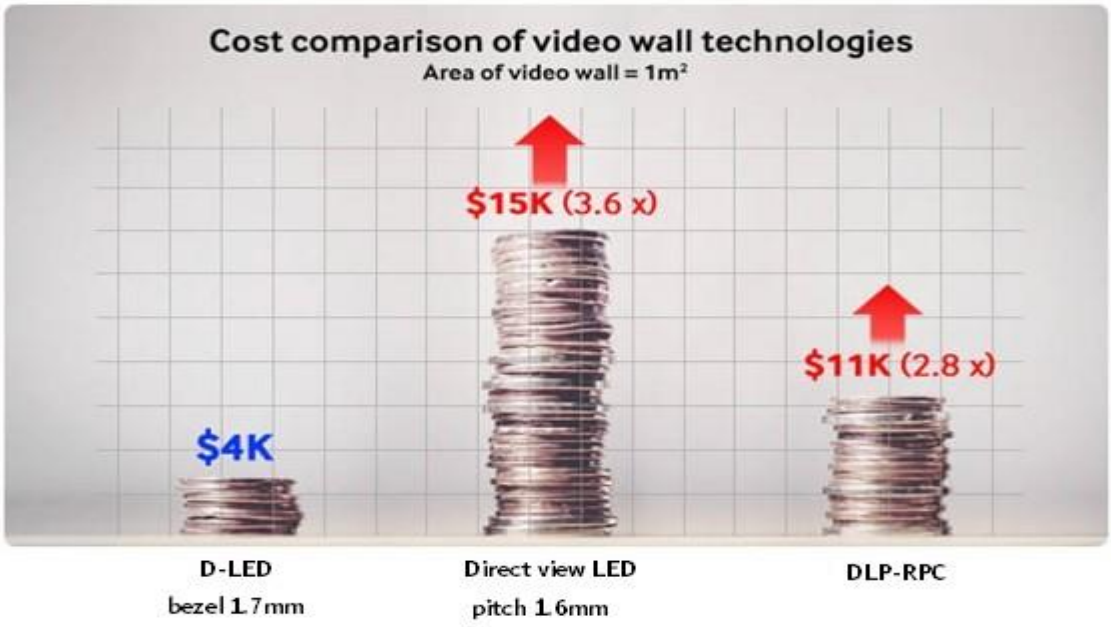

Figure 7: Cost comparison of video wall technologies (Source: All View Consulting – AVC)

Criteria / Technology	*D-LED*	*Direct view LED*	*DLP*
Visual performance	✓✓✓	✓✓	✓
Reliability	✓✓✓	✓✓✓	✓✓
Design and installation	✓✓	✓✓✓	✓
Initial costs	✓✓✓	✓✓	✓
Total cost of ownership (TCO)	✓✓✓	✓✓✓	✓✓
Maintenance	✓✓✓	✓✓✓	✓

Table 1: Criteria comparison of reviewed video wall display technologies

For public spaces visual performance, design, and low cost of ownership may take precedence over other considerations. Since main objective of outfitting of a room in Port of Zadar Authority building for the implementation of virtual museum will be displaying content with the high level of detail relatively near the viewers in high resolution with spatial restrictions and bright (sunny) environment, D-LED video wall is determined to be optimal solution.

2.6. Hardware and software requirements

Each video wall display setup along selecting proper display type and size require (depending on the number of displays at least) one central video wall controller (server), which process content sources and route them to be displayed on video walls player(s) attached to each individual video wall display setup. Selected controller will determine the type and number of sources that can be displayed on the video wall, the way that content can be displayed and manipulated, and the stability and reliability of the video wall display system. Video wall controllers (servers) are available as integrated (all-in-one) solutions or can be built upon regular personal computer (PC) hardware with installed video wall controller software.

In case of installing smaller number of displays (video walls) preferred solution would be video controller based on common PC hardware with companion controller software installed as it represents a lower initial cost, lower maintenance costs and easier hardware maintenance (requiring only common PC components to be potentially replaced whilst integrated video controllers require specialized maintenance) and is easier to operate. Moreover, software-based video controllers run under operating system graphical user interfaces (GUI) making them more easily operable than standalone video wall controllers. Therefore, it is critical to select hardware and software solution fully compatible with selected display type and size that enables users to perform the desired activities, is easy to learn and operate, and is compatible with user workflow.

Since video wall controller is an extremely important part of the system most common practice is it to be delivered by chosen display manufacturer along with chosen display technology for assuring maximum compatibility between controller and video wall displays.

3. Technical specification for virtual museum implementation in Port of Zadar Authority building

3.1. Location and placement of video walls

Prior to defining possible video wall display locations in Port of Zadar Authority building it is important to mention building itself consists of both national and international passenger terminals, whereas especially international terminal has strict security policies and restricted spaces, therefore limiting available locations for virtual museum setup. Furthermore, parts of building are under concession and therefore also represent certain limitations toward available space as they are reserved for exclusive use by concessionaire.

Considering mentioned space limitations, choosing a prominent locations whilst being aware of the fact sun or bright lights can darken the display and create glare ensuring visibility and legibility at various times of day and from all angles, four possible locations (Figures 8 to 11) within Port of Zadar Authority building have been defined as suitable for video wall display installations.

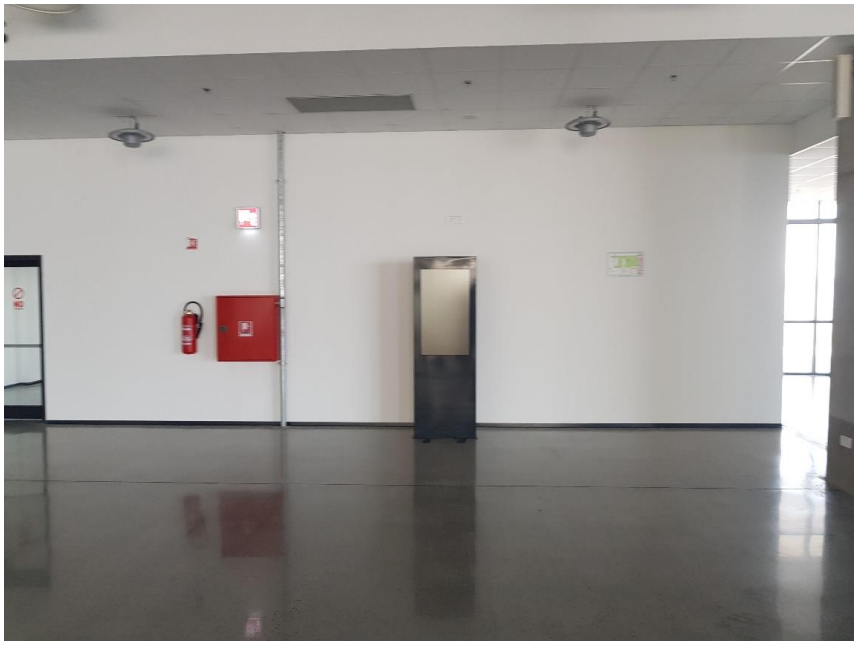

Figure 8: Location No. 1 – Video wall

Figure 9: Location No. 2 – Video wall

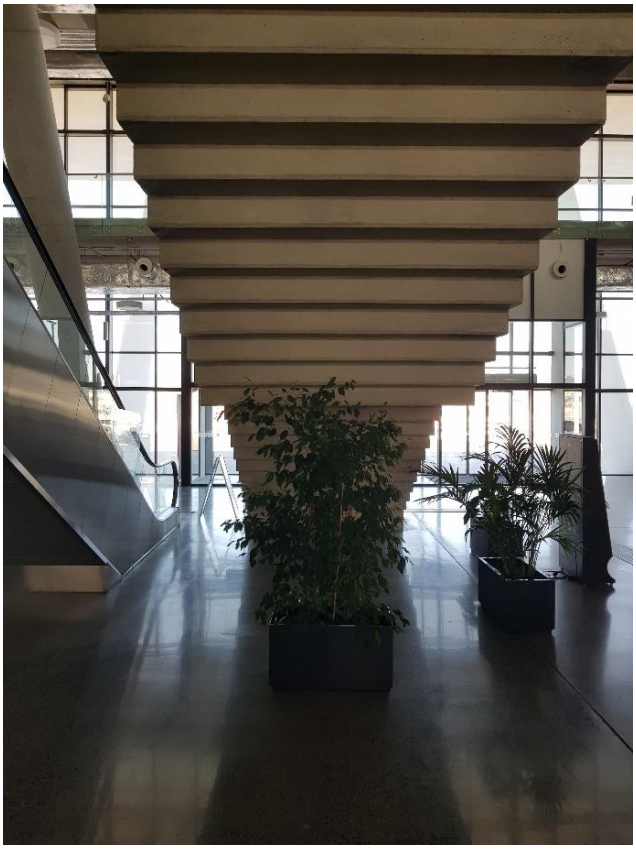

Figure 10: Location No. 3 – Video wall

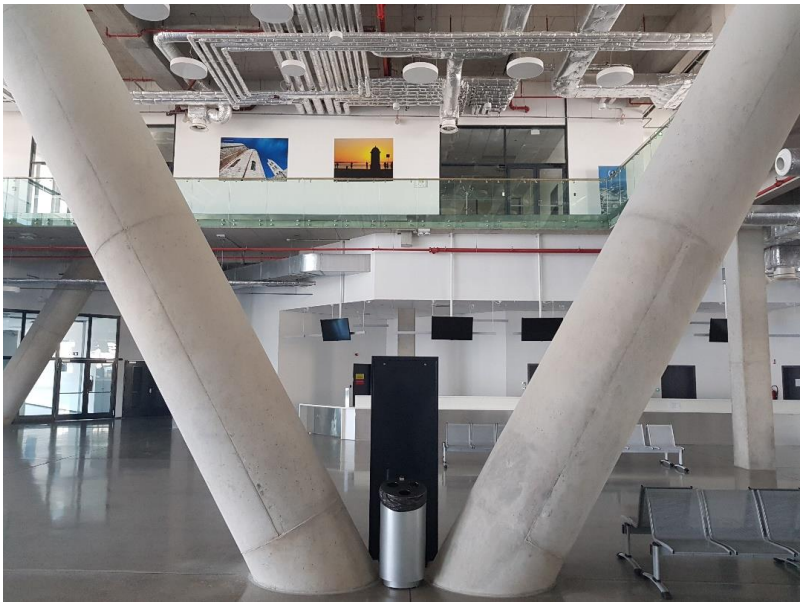

Figure 11: Location No. 4 – Video wall

3.2. Layout and sizing

Regarding previously defined video wall locations video wall specifications are as follows:

1. *Location 1 (Figure 8):*
    a. *Spatial dimensions:* *310cm x 172cm*
    b. *Recommended number of displays:* *9*
    c. *Recommended (single – diagonal) display size:* *46”*
2. *Location 2 (Figure 9):*
    a. *Spatial dimensions:* *310cm x 172cm*
    b. *Recommended number of displays:* *9*
    c. *Recommended (single – diagonal) display size:* *46”*

3. *Location 3 (Figure 10):*
    a. *Spatial dimensions:* *243cm x 137cm*
    b. *Recommended number of displays:* *4*
    c. *Recommended (single – diagonal) display size:* *55”*
4. *Location 4 (Figure 11):*
    a. *Spatial dimensions:* *410cm x 230cm*
    b. *Recommended number of displays:* *16*
    c. *Recommended (single – diagonal) display size:* *46”*

3.3. Wiring and connectivity

Video wall controller, if more than one video wall is installed are mostly located in video wall server room. It of course doesn't need to be exclusively used just for placing sole video wall controller (server) it rather implies a certain dedicated space in a room where in case of ethernet/wired installation/connection between video wall controller and player(s) cabling needs to be installed.

Wireless (Wi-Fi) connections are generally not recommended for connecting video walls as Wi-Fi bandwidth performance can drastically vary regarding their positioning and distance. In general terms, Wi-Fi is more prone to possible interferences.

3.4. Installation

Another important component needed for successful installation of video wall setup is wall mount which is usually delivered by chosen display manufacturer along with chosen video wall display technology and size.

Although dependent on various suppliers and/or installers of video wall equipment, some equipment parts like wall mounts are included into display price but special attention should be paid as installation costs are usually not included into equipment price, and should be added to initial equipment investment at a rate of at least 15% of initial video wall investment. Please keep in mind this value represents rough approximation as installation costs are very difficult to predict as they greatly depend on installation location specific conditions, cabling and special transportation and handling.

Since video walls require additional components needed for their installation (cabling, mounts, etc.), it is necessary to make sure all the needed components are delivered along video wall displays.

3.5. Total Cost of Ownership (TCO) and Warranty

Taking into account main purpose of Port of Zadar Authority's role in project REMEMBER is setting up virtual museum exhibition as non-commercial activity, rather than making huge initial investment on a video wall solution, optimal approach would be to actually minimize the initial expenses on the video wall providing maximum performance (ability to reproduce high quality content) in bright environment whilst requiring minimum maintenance costs.

Concludingly, to ensure minimum Total Costs of Ownership (TCO), manufacturer's warranty on all electronic components should be at least 36 months (3 years), and at least 6 months on all other equipment as well as provided installation services.

4. Technical specifications summary for chosen video wall technology

Considering previously mentioned technical specifications, requirements, financial aspects and environmental/spatial availability final recommendation and technical specification for outfitting Port of Zadar Authority building for the implementation of virtual museum is as follows:

- *Preferred display technology: D-LED (Figure 1)*
- *D-LED (individual) display specifications:*
    - *Type: D-LED DID*
    - *Resolution: 1920 x 1080 pixels (Full HD)*
    - *Bezel size (bezel-to-bezel; maximum): 3.5mm*
    - *Response Time (G-to-G; maximum): 8ms*
    - *Brightness (minimum): 500 nit*
    - *Viewing Angle (H/V; minimum): 178/178 degrees*
    - *Contrast Ratio (46”/55”; minimum): 3,500:1/4,000:1*
    - *Haze/Anti-Glare (46”/55”; maximum): 25%/44%*
    - *Display Colors: 8 bits (16.7M)*
    - *Connectivity (minimum): Display Port 1.2*
    - *Operation: Non-stop; 24 hours a day, 7 days a week (24/7)*

- *Video controller:*
    - *Server side:*
        - *Hardware: PC based – Intel i5, 8GB RAM, 500GB NVMe (SSD), Windows 10 Pro (eligible for up to 250 displays)*
        - *Software: Video controller software with lifetime license(s) according to number of video walls installed – one (1) per video wall client/player*
    - *Client/Player side: One (1) per each video wall installed*
    - *Software: One (1) lifetime license per each video wall – client/player installed*
- *Video wall interconnectivity (display to display): Display Port 1.2 video cable (1 per each display ie. 9 in case of 3x3 video wall display setup)*
- *Connectivity: Wired (Ethernet, LAN)*
- *Network equipment: Ethernet (LAN) cable (minimum CAT5e) and LAN switch (unmanaged/managed)*
- *Mounting: At least one (1) wall mount per video wall/display*
- *Warranty:*
    - *All electronic parts/devices/products (minimum): 36 months (3 years)*
    - *All other equipment as well as provided installation services (minimum): 6 months*

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