Mimaride Artırılmış Gerçeklik Uygulamaları: Alexandria Troas Podyumlu Tapınağın Kullanıcı Deneyimine Sunumu Örneği

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ETHICAL STATEMENT

I hereby declare that this thesis study titled "Augmented Reality Applications in Architecture: Presentation of Podium Temple at Alexandria Troas as a Case for the User Experience" has been prepared in accordance with the thesis writing rules of Eskişehir Osmangazi University Graduate School of Natural and Applied Sciences under academic consultancy of my supervisor Prof. Dr. Hakan Anay. I hereby declare that the work presented in this thesis is original. I also declare that, I have respected scientific ethical principles and rules in all stages of my thesis study, all information and data presented in this thesis have been obtained within the scope of scientific and academic ethical principles and rules, all materials used in this thesis which are not original to this work have been fully cited and referenced, and all knowledge, documents and results have been presented in accordance with scientific ethical principles and rules. 29/07/2021

Merve Ünal

Signature

ÖZET

Artırılmış gerçeklik, dijital ortamda üretilen ses, görüntü, grafik gibi sanal verilerin gerçek ortama eş zamanlı olarak aktarılmasıyla kullanıcılara artırılmış ortam deneyimi sağlayan bir teknolojidir. Mimarlık alanında eğitim, sunum, koruma, uygulama ve yönetim süreçlerinde kullanıldığı gözlemlenmektedir. Mimari kültür varlıklarının temsili noktasında da müze ve arkeolojik alanlarda bir araç olarak kullanılmaktadır. Mimarlık eserlerinin sunulması, diğer tarihi eserlere kıyasla daha zordur. Mimari yapılar, bağlam ve çevreleriyle güçlü ilişkiler kurduklarından, yerinde sunulmaları oldukça önemlidir. Bir kalıntının tarihsel önemi, yansıttığı kültür, geçirdiği süreçlerin öğrenilmesi yalnızca kalıntıya bakılarak anlaşılması oldukça güçtür. Bu noktada gerçek çevreyi ve verileri sanal verilerle birleştirerek sağladığı güçlü sunum tekniği ve interaktif deneyim olanağı ile artırılmış gerçeklik kültürel miras alanlarında oldukça ikna edici bir araç olarak karşımıza çıkmaktadır.

Tez kapsamında mimari kültür varlıklarının sunumuna odaklanılarak Çanakkale-Alexandria Troas antik kentinde bulunan podyumlu tapınağın ziyaretçilere sunulması için bir AR uygulaması geliştirilmiştir. Çalışmada AR kavramsal olarak incelenerek, geçmişten günümüze literatürdeki yeri anlatılmış, mimarlık disiplininde kullanım alanlarına değinilerek, mimari kültür varlıklarının sunumuna odaklanılmıştır. Alexandria Troas antik kentinin tarihi incelenerek kazı çalışmaları sonucunda ortaya çıkarılan tarihi eser ve yapılardan bahsedilmiş, podyumlu tapınak yapısı üzerinden mimari kültür varlıklarının sunumu hususuna bir alternatif olarak AR uygulaması geliştirilmiştir. Bu bağlamda tez, arkeolojik alanlarda bulunan mimari kültür varlıklarının temsilinin sağlanarak, kültürel miras bilinci oluşturulması açısından oldukça önem taşımaktadır.

Anahtar Kelimeler: Artırılmış Gerçeklik, Mimari Sunum, Arkeoloji, Alexandria Troas.

SUMMARY

Augmented reality is a technology that provides users with an augmented environment experience by simultaneously transferring virtual data such as sound, image, graphics produced in digital environment to the real environment. It is observed that it is used in education, presentation, protection, construction and management processes in the field of architecture. It is also used as a tool in museums and archaeological sites at the point of representation of architectural cultural assets. Representation of architectural works is more difficult compared to other historical works. It is matter that they are presented in place, as they establish strong relationships with architectural structures, their context and their environment. It is difficult to understand the historical significance of a relic, the culture it reflects, and the processes it has gone through, only by looking at the residue. At this point, augmented reality appears as a very convincing tool in the fields of cultural heritage, with the powerful presentation technique and interactive experience it provides by combining the real environment and data with virtual data.

Within the scope of the thesis, an AR application was developed to present the podium temple in the ancient city of Çanakkale-Alexandria Troas, focusing on the presentation of architectural cultural assets. In this study, AR is examined conceptually, its place in the literature from the past to the present is explained, and its usage areas in the discipline of architecture are mentioned, and the presentation of architectural cultural assets is focused. The history of Alexandria Troas was examined and the historical artifacts and structures unearthed as a result of the excavations were mentioned, and AR application was developed as an alternative to the representation of architectural cultural assets through the podium temple structure. In this context, the thesis is significant in terms of creating cultural heritage awareness by ensuring the representation of architectural cultural assets in archaeological sites.

Keywords: Augmented Reality, Architectural Representation, Archeology, Alexandria Troas.

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1. INTRODUCTION

With the rapid advancement of technology, several tools that were once only thought have become portable and even wearable by individuals today. In this respect, one of the technologies that have become easy to access and become a part of our lives is the Augmented Reality (AR) technology, where the real world combines with virtual world data in a new enriched layer. AR technology is a technology that is created by the simultaneous transfer of synthetic data such as voice, image and video produced in a virtual environment onto the real world, and it is a technology that encourages the user to participate with its interactive structure. When a technology layer created with AR is added to the real environment, some data that do not exist physically become perceptible in the real environment scene, allowing individuals to experience an increased perception level, making the individual able to touch different time and space dimensions. While this situation provides more information about the experienced environment or object, it also makes the experience more permanent in the mind. With these possibilities, AR applications, whose usage area is increasing day by day, are used for different purposes such as visualization, presentation and education in the field of architecture.

Architectural structures, which constitute an important part of our cultural heritage, are structures that take strong references from context and need to be addressed with context. When viewed from this point of view, the importance of a building or building remnant with cultural value, what it conveys to the context and what it means together with the context, is understood. Experiencing a historical place that has changed over time and has been subjected to various changes, visitors cannot get sufficient information about the state of the building at the time of its construction and the culture it reflects by looking only at the building remains. At this point, AR technology constitutes a bridge that enables visitors tourists to travel between the past and the present, to see different historical layers, to learn and even to have fun by re-experiencing architectural cultural assets at an increased environment and perception level. Visitors who participate in the experience emotionally as well as sensually feel themselves a part of the space, thus the experience becomes a conscious activity.

In this study, the usage examples of AR technology at the intersection of architecture and archeology are examined, focusing on the representation of the architectural heritage, revealing the current situation. The research, which is defined theoretically, aims to discuss the results by practically testing it with the AR application developed for the podium temple in the ancient city of Alexandria Troas, which was chosen as a case study.

Typically, an archaeological site consists of building remains that have been woven into different time layers. Sometimes completely destroyed and sometimes partially ruined, the ruins cannot provide us with sufficient information about their identity and the process they went through. Although the information in archaeological sites is tried to be enlightened by methods such as writing, painting and drawing, the experience remains two-dimensional away from bodily experiences.In this context, archaeological sites provide a very rich and demanding context in terms of representing architectural cultural assets with AR technology that combines the real and virtual environment. With this study, the two-dimensional representation of architectural works of cultural value, which are completely or partially destroyed in archaeological areas, is presented with a method that can be represented experience-oriented with the application developed with AR technology. At the same time, it is aimed to contribute to the literature in this field by aiming to base the developed application on other studies on the representation of cultural assets.

Within the scope of this study, AR technology is theoretically investigated, and its status from the past to the present, its technological components and areas of use have been examined in detail. An AR application is being developed for the representation of the temple structure in the ancient city of Alexandria Troas, which was chosen as a case to work with. The restitution drawings of the building to be presented within the thesis must be obtained, if not, these drawings must be provided, modeled in line with the data provided by the excavation area and calibrated to the application. At this point, the building to be used in order to provide an effective AR experience during the thesis period is limited to the temple with a podium.

Any structure or creation to be used in AR experience within the scope of the thesis must go through certain stages. First of all, restitution drawings should be obtained, if not, drawings should be made in line with the data, then modeling studies should be carried out in line with the drawings, AR application should be created while these operations continue, and finally the model created should be calibrated to the application. In other words, as mentioned above; drawing-modeling-application-AR experience stages must be completed and documented during the thesis period. In order to fulfill these stages in a qualified and effective way during the thesis process, it is limited to the representation of one of the historical artifacts and structures in the ancient city of Alexandria Troas – the podium temple - to the AR experience.

During the modeling process of the podium temple, the increase in the detailed ornaments and decorations of the elements such as friezes, capitals, doors cause the model size to increase and this causes technical errors during the application. In order to prevent this situation, modeling has been made at the level of detail where the model can work effectively in practice. This is particularly due to the limitations of the hardware and the software.

In this vein, as the visitors move away from the model during the experience, the number of surfaces perceived by the application increases, which causes the application to not work effectively. For this reason, the visitors are limited to a certain distance from which they can experience the model. This is also due to technical limitations same as above.

There is another, unexpected emergent limitation confronted as the study proceeds: Apart from timely and technical limitations, the duration of stay in the ancient city had to be kept short during the development and trial studies of the application due to some restrictions brought by the COVID-19 pandemic. At the same time, it caused the application, which was originally intended to be presented to the visitor experience, to be limited to field studies.

2. THE OVERALL METHODOLOGY OF THE STUDY

The methodology of this study consists of a literature review, problem definition, fieldwork and an application proposal for the problem identified. Based on these main topics, the potential use of augmented reality in the ancient city of Alexandria Troas can be divided into two categories as theoretical and practical.

The research is at the intersection of the disciplines of archeology and architecture, by context, as it aims to develop an AR application for the podium temple of the ancient city of Alexandria Troas by focusing on the representation of architectural cultural assets. For this reason, the methods and tools of different disciplines were brought together in the study, which is multi-disciplinary research both in terms of theory and application.

The theoretical part of the study consists of defining the necessary concepts, explaining the technological components and examining them through various examples. The methods and techniques from the archeology discipline were used to process the model to be used in AR application, which was developed by examining examples of different approaches to the representation of architectural cultural assets in archaeological sites. For this purpose, excavation studies were examined in detail and excavation reports and restitution drawings were obtained. At the same time, historical data on the ancient city of Alexandria Troas have been gathered and summarized.

In the application phase, 3D models were prepared with various visual and literary data by making field studies in the ancient city of Alexandria Troas. The ARCHICAD program was used to create the models, and the ARKit library was used for the application model that reflects the historical importance of the ancient city. At this point, technical assistance was received from software experts for the creation of the application and the integration of the created models into the AR application.

3. LITERATURE REVIEW

Studies concerning AR, scientific publications, articles, journals, books, websites, etc. are generally international studies. Studies carried out in Turkey mostly consist of master's and doctoral theses. The resources used within the scope of the thesis consist of studies on the concept of AR, cultural heritage areas and application examples used in these areas, and scientific studies covering Alexandria Troas. In the studies used, besides the explanation of the concept of AR, they are studies that contain data such as hardware and software components, development methods and techniques. In connection with the focus of the thesis, the use of AR applications in the intersection of architecture and archeology are studies that include motivations and different examples. The literature study and all these studies examined in the continuation of the thesis are scientific studies that contribute to the derivation of the purpose, scope and method of the application created within the scope of the thesis.

Augmented reality offers the user a new enriched environment with the virtual data it adds to the real world. Roland Azuma explained the basic structure of the Augmented Reality system as a technology that will strengthen the interaction of the AR user with the real world by combining real and virtual objects. Azuma (1997) has revealed that AR technology has 3 basic characteristics such as "combining real and virtual", "real-time interaction", "being registered in 3D". Azuma's work has been a literature on AR technology and for areas close to this field.

In 1994, Paul Milgram and Fumio Kishino explained the concept of mixed reality as an environment where virtual and real objects are presented as a single image and enriched this concept by schematizing (Milgram & Kishino, 1994). Oliver Bimber and Ramesh Raskar made the definition of "sending synthetic data to the real world" for the concept of Augmented Reality. With the "synthetic" expression in this definition, they stated that apart from 3D objects, data such as GPS, audio, video can be added (Bimber & Raskar, 2005).

The first appearance of augmented reality studies in history took place in 1965 by Ivan Sutherland. He published an article called Ultimate Display, which is a pioneer of AR work. Sutherland explained the ultimate display as "a room where the computer can control the existence of matter" and emphasized that computer technology can increase human perception through virtual experiences (Sutherland, 1965). Sutherland made the first prototype of the augmented reality system called Sword of Damocles three years later. He also created a three-dimensional display using one of the earliest examples of HMD glasses, the head-mounted display (Sutherland, 1968).

Sanni Siltanen examined the application development ways of AR technology in her study. In addition, she determined the areas where the application can be developed and made predictions about what innovations Augmented Reality could bring to our lives in the future (Siltanen, 2012).

Gartner, an IT research and consultancy company, conducts Hype Cycle graphics over current and different technologies (URL8). In these graphs, it predicts the interdependence of technologies, analytical advances and interface advances. Augmented Reality has been added to these studies since 2007, and current areas of AR technology have also begun to take place in the graphics.

AR technology has been used in different areas with different motivations after these studies. Various studies have also been carried out in the fields of cultural heritage for the purposes of presenting, preserving and documenting historical artifacts and structures. An application developed for cultural heritage sites is a MARCH application. It is developed for prehistoric cave drawings. With the users directing their mobile device cameras to the cave engravings, the images prepared by experts appear simultaneously on the captured image (Choudary, Charvillat, Grigoras, & Gurdjos, 2009).

Gunnar Liestøl developed an AR application for the display of the Athens Parthenon Temple (431 BC). The structures, whose virtual reconstructions were made in accordance with the original, were experienced by Norwegian institute students. In the AR application, which is experienced with a mobile device, a better look at the ornaments in the building is provided and detailed information is given about the building element selected by the user.

At the same time, the pillars of the temple are visible in low opacity. With this method, the entire temple becomes visible (Liestøl, 2011).

For the Gothic Silk Market Building in Valencia, which is on the UNESCO cultural heritage list, an AR application was developed and carried out on-site experiments. The aim of the project is to increase the accessibility of the users to the architectural elements of the monumental environment by using AR technology. A total of 145 visitors of different ages and backgrounds were able to experience the application. With this application, it was aimed to solve the situations such as perception problems caused by insufficient illumination, distance in multiple details (Cazorla, Calvet, Merino, & Contero, 2013).

Gunnar Liestøl conducted a study aiming to reveal the historical value of the "Via Appia" road, which connects Rome, one of the oldest and most important Roman roads of the Ancient Republic, to Brindisi in the southeast of Italy, using the AR system. In the project, three different periods of Via Appia were restructured with the AR system; These 3 time periods were visualized with different events of the period, using the method of storytelling, from 321 BC to 71 BC and from 49 BC to 49 BC (Liestøl, 2014). Also, an AR application called "Timetraveler" was designed in 2014, on the 25th anniversary of the fall of the Berlin Wall. With the help of mobile devices, photos and videos of years ago taken in different historical areas of the city have had the chance to experience. Through this application, the historical process of the city has been discovered (URL7).

AR application that provides virtual reconstruction of the middle portico column grit in an old market place in Athens city in 2015. With the application, users can experience the original state of the structure and observe the 3D model when they touch the tablet from their location (Verykokou, Ioannidis, & Kontogianni, 2014). Also in 2015, AR application was developed for the Czech Republic-Bylany city, which is one of the important Neolithic period excavation sites in Europe. With this application objects dating back to ancient times and found in the field were virtually reproduced (Květina & Unger., 2015).

A game called "Buildings talking about our city" has been developed that combines location-based and pointer-based AR systems. It is a game for primary school students to discover the culturally important structures in the west of Greece (Koutromanos & Styliaras, 2015).

A location-based AR game has been designed for an alternative experience of the area consisting of various royal tombs in Daereungwon, Korea's important cultural heritage. Three main goals were determined in the game with an integrated and immersive presentation technique. The user, who interacts with the augmented objects during the game, has been provided with information about the area (Shin, Kim, & Woo, 2017).

Mehmet Akif Günen and others conducted a study focusing on the use of AR for the documentation and presentation of historical artifacts. Modeling studies for the relief works of the Germir Panagia Greek Church were provided with Augment, an AR application. In this application, which is performed both with and without a pointer, the user can access the 3D images of the church when he points the relevant image to the camera. It has been suggested that this study will provide resources for future studies between architecture and geomatic engineering and will be a bridge between the two disciplines (Günen & Baydoğan, 2019).

Under the title "4.4. AR Applications in Architecture" it is possible to find applications on AR technology that constitute literature in many areas of the thesis, including software development.

4. THEORETICAL INFORMATION

4.1 What is AR?

Viewed from a certain perspective augmented reality is accepted as a special branch of virtual reality. And for another perspective augmented reality has a more general scope than virtual reality. Virtual reality puts the person in a fully synthetic world with the generated virtual data, but augmented reality overlaps the real world with virtual data produced in digital media such as sound, picture and video. Instead of creating a fully synthetic world or displaying the real world as it is, it creates a new environment by mixing these two environments. Therefore, it is certain that augmented reality does not detach the person from the real world like virtual reality (Azuma, 1997), (Bimber & Raskar, 2005).

Paul Milgram and Fumio Kishino described the relationship between augmented reality to virtual reality with concept of virtuality continuum. In this concept they described an axis with virtuality at one end and reality at the other. At the left side the environment consists of entirely real objects while at the right side the environment consists of entirely virtual objects. The virtual world with added real-world views is called augmented virtuality, and augmented reality is between the real world and augmented virtuality (Milgram & Kishino, 1994).

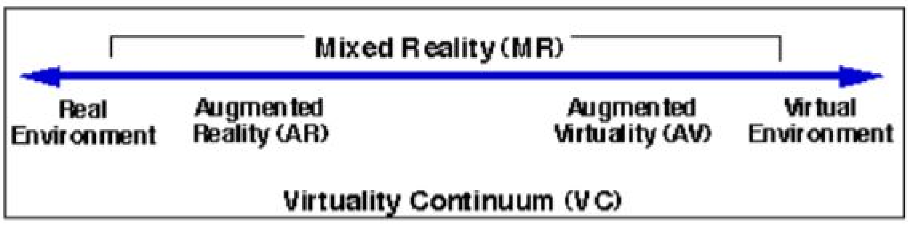

Figure 4.1. Concept of virtuality continuum (Milgram & Kishino, 1994).

4.2 History of Augmented Reality

The first appearance of augmented reality studies in history was occurred in 1965 by a computer scientist and professor of Electrical Engineering from Harvard University Ivan Sutherland. He published a paper named “The Ultimate Display” which was the forerunner of AR studies. Sutherland explained the ultimate display “as a room within which the computer can control the existence of matter” and emphasized that computer technology can increase human perception with virtual experiences (Sutherland, 1965). After 3 years Sutherland made first prototype of Augmented reality system named Sword of Damocles. He created a three-dimensional display by using an optical see-through head-mounted display which was also one of the earliest examples of HMD glasses (Sutherland, 1968).

The weight of prototype was so heavy, it was supported by mechanical ropes from the ceiling. And display was only able to show barely discoverable basic wireframe rooms (Sutherland, 1968). Despite all its limitations, the system was one the first AR step with the possibility of usability. After Sword of Damocles many people have tried to complete the vision of Sutherland. And today we no longer need headsets with mechanical ropes. Their weight is less and their strength is more than Sutherland’s did in 1968.

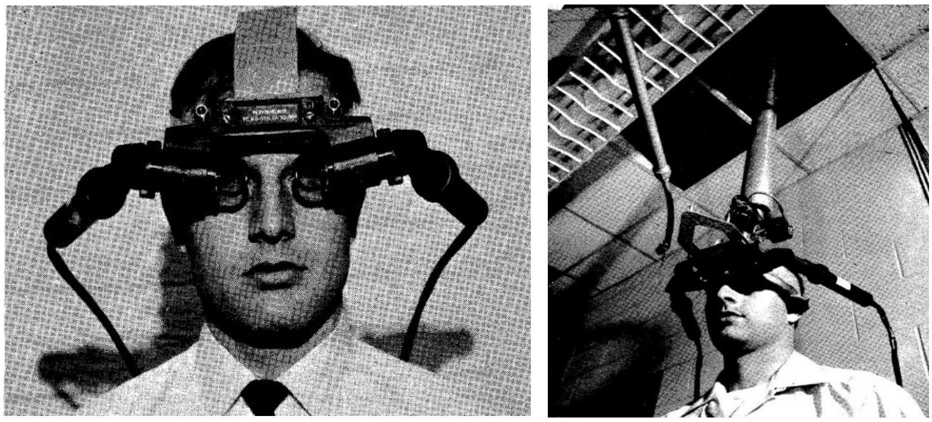

Figure 4.2. First headset mounted display the Sword of Damocles (Sutherland, 1968).

In 1975, the first AR system that allows users to interact with virtual objects was created by Myron Krueger. The lab called Videoplace is a technology that responds to the physical movements of the user without using any wearable technology. To do this, Videoplace contains hardware components such as projector, video camera (Krueger, 1977).

Figure 4.3. An image from the use of Videoplace (Krueger, 1977).

In 1992, Thomas Caudell and David Mizell, two Boeing engineers coined the term augmented reality for the first time. The point of their work was to discover simpler way to Boeing's manufacturing and building process (Caudell & Mizell, 1992).

Figure 4.4. AR system developed by Caudell and Mizell (Caudell & Mizell, 1992).

In 1995, a 2D visual recognition system was developed, which is now the predecessor of pointer-based AR systems. Navicam prototype was developed using 2D matrix marker by Jun Rekimoto (Rekimoto & Nagao, 1995). Thus, one-dimensional barcodes were switched to two-dimensional qr codes.

In 1997, Azuma defined AR as any system with three features to avoid limiting it with certain technologies:

1. "Combines real and virtual
2. Interactive in real time
3. It is registered in three dimensions" (Azuma, 1997).

The definition made by Azuma was used by many academics in their studies because it contains the first general definition of augmented reality and didn't restrain the study with a specific way.

In mid 1990s, with the development of computing and tracking devices becoming strong enough and portable at the same time, Columbia University produced the AR application prototype named Touring Machine that was able to navigate outdoors and provide information about the university (Höllerer, Feiner, MacIntyre, & Webster, 1997).

Figure 4.5. Images from the prototype campus information system (Höllerer, Feiner, MacIntyre, & Webster, 1997).

It can be said that AR applications accelerated by the publication of the open-source library named Artoolkit by Hirokazu Kato from Nara Science and Technology Institute. For the first time, Artoolkit enabled video tracking to interact with virtual objects and work on any operating system (Kipper & Rampolla, 2013). Since it can work easily in any browser over the internet with basic webcam and internet connection, it has enabled the diversification of AR applications.

AR technology has started to be used in game industry in 2000. ARQuake, the first game that can be used in the outdoor environment, was launched by the ID software company. The purpose of the game, which the user played using the head mounted display, was to build a game with a user-specific perspective (Piekarski & Thomas, 2002).

Figure 4.6. AR Quake as Seen by a Player (Piekarski & Thomas, 2002).

After the 2000s, AR started to be seen as a research area and various congresses were organized on it. The first congress of Ismar (International Symposium on Mixed and Augmented Reality held in 2001 brought AR technologies to the agenda in the academic field (ISMAR). This led to increase the importance of AR technologies (Kim, Billinghurst, Bruder, Duh, & Welch, 2018).

Augmented reality systems have expanded its application area in parallel with developing technology. AR applications that we encounter in every field of life are increasing day by day. New features are added in line with user demands and are becoming more and more interesting. Software and hardware developments have made the use of AR applications widespread. With the development of Wifi technology and the introduction of smartphones, AR systems have become more easily accessible. Technologies of basic computer and telecommunication were joined in these little gadgets. Many AR apps have been released on IOS and Android platforms, making users ' daily lives much easier. When we look at the changes in AR applications and their contribution to human life, it can be said that it will gradually increase its importance in the future.

4.3 The Components of Augmented Reality Technology

The AR application consists basically of 2 components; software components, and hardware components.

4.3.1 Hardware Components

Although the hardware changes according to the needs of the experienced Ar application, some basic hardware is similar. These can be examined in 4 ways: “Display”, “CPU”, “Input devices” and “Sensors” (Zlatanova, 2002).

R. Azuma wrote in his article in 1993 that AR systems must meet 3 criteria in order to function properly. The first is that the "tracker" device should give a clear result in positioning. Latter; The delay between “audience” and “graphics engine” should be kept low, and the third is that “audience” should have a large viewing area (Azuma, 1993).

4.3.1.1 Display

These are devices that combine information and visuals, where virtual items will be experienced by the user. Screens commonly used in AR systems; monitors (smartphone, tablet, computer), HMDs and Glasses (Zlatanova, 2002).

Monitors:

A monitor, or in other words, a display screen, is an electronic device used to display the desired image. It is the most important output device of many electronic devices such as televisions and computers. With the various signals sent to the screen component of the device used, a certain image is created on the screen and reflected to the user.

AR systems use monitors of devices such as computers, phones and tablets as display devices. The portability of devices such as phones and tablets and the ease of access nowadays make them frequently preferred in AR applications.


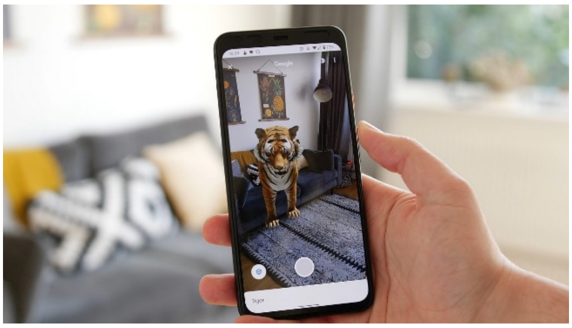

Figure 4.7. Monitors: a) tablet screen b) mobile phone screen (URL10)

HMD (Head Mounted Display):

They are head-worn wearable displays in the form of helmets. The user follows their movements with the direction receivers located on it. Displays real and virtual objects in the user's field of view simultaneously by projecting them onto the screen. Thus, AR experience is provided (Zlatanova, 2002).


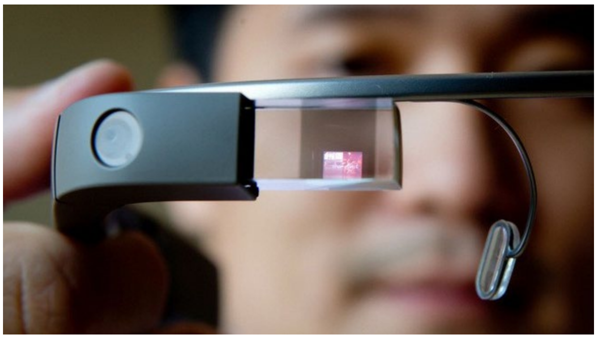

Figure 4.8. Examples of display types: a) HMD b) Google glass (URL11).

Glasses:

Digital glasses which are other wearable technology, are also used in AR applications. The best-known example is Google Glass. Made for direct AR applications. In addition to glasses, contact lenses are screens that have not become widespread yet.

Monitors are screens used on computers, tablets and smartphones. It is the most common display variety to use (Zlatanova, 2002).

4.3.1.2 <u>CPU</u>

It forms the main processing unit of devices such as computers, phones, tablets. It is the unit that interprets and executes data and performs certain operations electronically. It is the component that must be found for the AR system to work. The brain of the system is accepted. In AR systems, it processes environmental data such as image and sound and ensures the operation of the system. They are devices that combine the functions performed by other equipment such as virtual object production, image scanning (Zlatanova, 2002).

4.3.1.3 <u>Input Devices</u>

Because they are hardware used to capture the real environment and data, cameras come to mind first when they are called input devices. The set cameras also allow the virtual image to appear as desired. Webcam, digital or video cameras are used in AR systems. The mouse, keyboard, glove, and launch key on mobile devices are also input devices (Zlatanova, 2002).

Sensors

As Azuma mentioned, monitoring is very important for AR systems. User position and orientation must be calculated correctly. For this, sensors such as camera, optical sensor, GPS, gyroscope (provides direction measurement) compass, accelerometer are used. Today, a smartphone meets all of the necessary sensors for AR (Zlatanova, 2002).

4.3.2 Software components

Software is the infrastructure that allows all components in an AR system to do their job. Updating the position taken from the user, rendering of virtual data, elements needed for scene formation (light, texture, hardware, etc.) organization such as many operations are provided with software commands (Zlatanova, 2002). Today, projects can be easily created using AR software libraries such as ARkit, Vuforia, Wikitude Software Development Kit.

4.4 AR Applications in Architecture

Although AR technology is widely used in sectors such as education, entertainment and marketing, it has different applications in other fields such as architecture, medicine, tourism, design and military. Architecture is the art of designing and constructing various spaces and functional requirements with an aesthetic point of view, within technical possibilities, in order to facilitate human life, to ensure the realization of activities such as shelter, entertainment and rest. In other words, designing the buildings and the physical environment is the evolution of building production process into art (Hasol, 2019). In addition to architectural design and production, it is an important action at the point of repairing and functionalizing old buildings, streets and environments, making the necessary restoration processes and bringing them into urban life as a result of their renewal. Based on these definitions, it can be considered as 3 different practices in architecture; design, construction process and interventions in existing buildings. In this context, it is possible to examine the uses of AR technology in architectural practice in the design process of the building, construction processes and interventions.

4.4.1 AR in the design process

Design, in short, is the act of producing a structure, work of art or technical product in a way that meets functional and aesthetic criteria. By definition, it spreads from furniture to automobiles, from architecture to urban planning (Hasol, 2019). The Roman architectural theorist Vitrivius mentions that the components of "firmitas, utilitas, venustas" must be met in design for architecture (Vitrivius, 2005). Today, it is possible to talk about different criteria such as being economical, sustainable, and originality for architectural design (Hasol, 2016). Together with these requirements, the architect presents a project by examining and evaluating certain parameters. The first stage of the design development process is the analysis of the specified requirements together with schematic drawings, sketch drawings, 2D and 3D mock-ups and models. At this stage, AR technology is an important tool for the architect as an architectural drawing expression.

One of the AR applications produced as an alternative to traditional methods in the design process is the SketchAR application. SketchAR is an application that transforms architectural sketches into 3D models in real time at the architectural pre-design stage. The sketches drawn on the paper plane are converted to 3D objects in AR environment in line with the camera data. At the same time, furnishing elements such as doors, windows and chairs can be placed between the created objects. With the application, it was aimed to strengthen the 3D thinking perception of the students and to enrich the first idea that emerged during the preliminary design phase (Köymen, 2014).

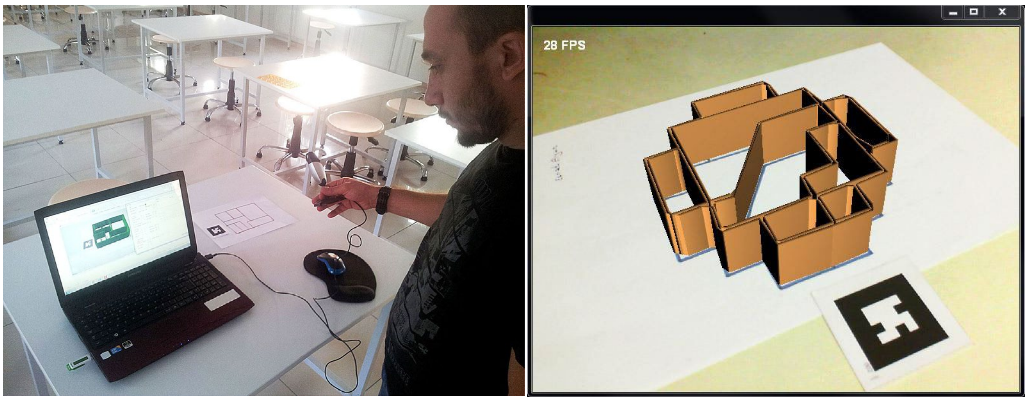

Figure 4.9. AR environment in SketchAR (Köymen, 2014).

Since it strengthens the perception of 3D, it helps architects at the design stage. Although the collaborative approach is limited to only sketches and computer drawings in the field of design and planning, AR offers several innovations. AR application named ARTHUR is an application produced to support the decisions made by architects during the design and planning stage. It enables different users to design together. In doing so, it supports the experience of CAD systems in the AR environment rather than completely isolating them from the design (Broll, Lindt, Ohlenburg, Wittkamper, & Yuan, 2004).

Figure 4.10. Designers working collaboratively with ARTHUR application (Broll, Lindt, Ohlenburg, Wittkamper, & Yuan, 2004).

The Fibrasa Connection project, carried out by Königsberger Vannucchi architecture in 2010, is an example of architectural visualization with AR systems. By visualizing virtual data in its actual location, it was able to be observed on-site before project construction. The QR code placed at the construction site was combined with AR technology by the camera attached to a helicopter and its presentation was carried out (URL1).

Figure 4.11. The Fibrasa Connection Project (URL1).

ARtect, developed with the Unity game engine, is an AR application developed for architects, designers and researchers. The application allows the 3D models and 2D drawings uploaded to the system to be visualized regardless of the interior and exterior. The prototype makes it easier for the designer to get in touch with real environment data and thus strengthen the 3D perception. It enables students of architecture to experience their projects interactively and in real place in the early stages of their designs. Students who have the chance to make changes on the scale can get feedback about the reliability of their designs. In this way, the application aims to develop creative thinking and expressiveness (Velaora, Roy, & Guéna, 2020).

With Artect, users can place 3D models and 2D drawings in the AR scene created indoors or outdoors. It provides manipulation of placed objects in x, y, z axes and scaling of objects. The application, which provides the user with an immersive environment in the AR scene, also offers a line tool that enables calculation on the stage. The created AR environment can be exported. The application can be used on mobile devices and thanks to its user-friendly interface, the user does not need to have extra knowledge (Velaora, Roy, & Guéna, 2020).

Figure 4.12. ARtect application augmented views: a) AR environment in Artect b) Experience on unstable surfaces with ARtect (Velaora, Roy, & Guéna, 2020).

4.4.2 AR in the Construction Process

AR applications can be used to eliminate the deficiencies in the process of data management and archiving, data deficiency or errors on paper, which occur when traditional methods are used during the construction phase of the building. Some changes and additions are made in the project during the construction processes. Reprocessing these changes causes the drawings to be reprinted and incur additional costs. At the same time, these drawings deteriorate over time and cannot be well preserved. AR applications to be used at this point can provide information transfer for architects and engineers at the construction site and facilitate the follow-up of the construction site process. It can provide support for architectural projects as well as systems such as electricity, natural gas and water installations.

One of the AR application called The Port Botany MAR Demonstrator, the user can view the electrical, hydraulic and sewage systems on the tablet screen. In addition, it can add its own settlement comments to the construction site on the system. This information uploaded to the system by the user can be added to the data archive and viewed by all team members (Abboud, 2014).

Figure 4.13. Use of The Port Botany MAR Demonstrator application in construction site (Abboud, 2014).

Another application that can be used in construction sites is programming the construction process and planning the construction site logistics using AR technology, as in the example of MAR to plan Virtual Construction Work Sites. This application, which defines the construction site process with the addition of virtual data on paper, enables the analysis of the different construction dynamics of the construction site and detects the cross points of the machines and vehicles used in the construction site. With this application, the construction process can be defined by the experts and planners through the machine movements that can take place on the construction site, and the production process can be observed in 3D before the building is built (Abboud, 2014).

Figure 4.14. Observation of the construction site process with the MAR to plan Virtual Construction Work Sites application (Abboud, 2014).

AR technology can also be used for reporting and supervision, depending on the progress of the construction site. Work progress report can be obtained by simultaneously integrating the work carried out in the field and the building construction schedule created in the AR application. An example of this is the D^4r application. In practice, a 3D model of a building under construction and a construction site photograph taken from a desired location are integrated onto the construction progress calendar (ultimately the 4D model). As a result of this registration, when the progress process is defined according to the calendar, the application displays the status of the building construction that will take place on the construction site for a certain date. With the comparison made in line with these data, it can be observed whether the building was built according to the schedule (Golparvar-Fard, Peña-Mora, Endowed, & Savarese, 2009).

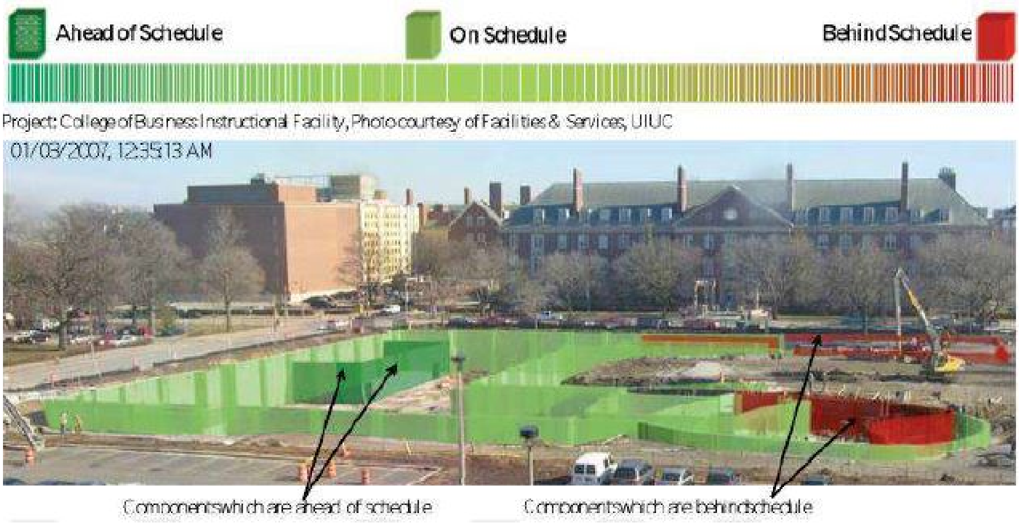

Figure 4.15. Example of construction site through D^4r application (Golparvar-Fard, Peña-Mora, Endowed, & Savarese, 2009).

According to Figure 4.15, the parts shown in dark green are built before the schedule, the parts shown in green are the parts built on the schedule, the parts shown in red show the parts that are behind the schedule.

4.4.3 AR in Post Completion Process

In time, buildings can become damaged due to natural disasters, various human activities, and some climatic effects. In such cases, interventions such as repair, maintenance, protection, renewal, improvement are made according to the damage size in order to ensure the continuity of the building. With applications created with AR technology, it can predict the damage that may occur in the structure in such studies and offer the opportunity to experience the intervention studies to be carried out (Abboud, 2014). One of the AR application examples that can be used in existing structures is the Magic Plan application. With the application, interior measurement can be obtained without the need for any vehicle. The plan of the building can be created in line with the measurements taken. When the user opens the application, any desired corner is selected in the coordinate system that appears on the screen and the plan is started. The distance between the corner points can be perceived by the application and the plan is created by creating wall points (URL2).

Figure 4.16. Magic Plan application (URL2).

4.4.4 AR in Cultural Heritage Sites

Undoubtedly, the protection and sustainability of natural and historical heritage is an important issue for all humanity. All experiences from past civilizations to the present constitute the historical and cultural heritage of humanity today. The areas that bear these traces of the past and where historical and cultural values are intensely felt are historical environments. Historical environments are settlements and ruins from past civilizations. These areas contain many valuable information of civilizations such as social life, economic situation, and aesthetic perception in their structure (Ahunbay, 1996). Therefore, it is important to protect these environments in the best possible way and to transfer them to future generations to ensure the sustainability of cultural heritage. The desire to protect historical buildings and environments also stems from the fact that humanity and society will become meaningful with their past (Kuban, 2004). The buildings in historical environments are an indicator of the culture of past civilizations with their architectural styles, spatial formations and construction techniques. Examining the ancient city and its surroundings helps us to know ourselves in a sense and make sense of today (Ahunbay, 1996).

With this understanding archaeological sites are of great importance as they have witnessed history and contain a certain cultural heritage. Typically, an archaeological site consists of building remains belonging to different time periods, which have been weathered and even destroyed over time due to various reasons such as natural disasters, human activities. The inability of physical intervention in such cultural heritage areas causes different solutions to keep the history alive and to pass it on to the masses. In such a situation, it is possible to provide virtual reconstructions of historical buildings and environments whose destruction cannot be prevented with AR technology. In this way, cultural assets that cannot survive physically can at least be stored and exhibited digitally. The fact that the structures with virtual reconstruction are provided for remote access by researchers, students, etc. is an important tool for learning about cultural assets. With AR applications used in archaeological fields, not only tourists, but also art historians, archaeologists and architects can have the opportunity to experience and interpret cultural assets in 3D.

At the same time, architectural structures, which constitute an important part of our cultural heritage, are products that take strong references from context and need to be addressed with context. From this point of view, the importance of a building or building remnant with cultural value, what it conveys to the context and what it means together with the context, is understood. Experiencing a historical place that has differentiated over time and has been subjected to various changes, visitors can only look at the ruins of the building to see the state of the building at the time it was built, the culture it reflects etc. cannot get enough information about the situations.

AR enables the redefinition of these environments with virtual data without any intervention in the historical environment. It makes it easier for users to access more information about the historical environment by not only seeing the ruins, but also allowing them to experience the original state of the structures. In addition to the physical environment, the user interactively experiences virtual data such as 3D animations, sound and video during the tour, increasing the interest in the field and gaining the awareness of historical heritage, thus transferring that culture to other generations. At this point, AR technology has an important potential in terms of maintaining and understanding architectural cultural assets and historical environments better.

As in many areas, AR technology has a number of application issues in the areas in cultural heritage areas. These topics can be divided and titled as follows: documentation for restoration and reconstruction of historic buildings, virtual reconstruction for historical buildings that no longer exist, interacting with structures and objects without the risk of damage, creating educational resources, visualizing scenes.

4.4.4.1 Documentation for restoration and reconstruction of historic buildings

Historical buildings that are in danger of extinction as a result of natural disasters such as earthquakes, floods or various human activities need to be documented in order to ensure restoration or reconstruction in the ongoing process. At this point, AR technologies are an aid to architects, archaeologists and art historians. With the help of the data transferred from the paper plane to the virtual database, documentation of the historical structures can be provided and it can make it easier for the experts to continue their work (El-Hakim, Beraldin, Picard, & Godin, 2004).

4.4.4.2 Virtual reconstruction for historical buildings that no longer exist

For historical structures that cannot be physically sustained or partially sustained for various reasons, even if AR cannot eliminate these factors, AR can ensure that it is kept alive with virtual reconstructions and passed on to future generations (El-Hakim, Beraldin, Picard, & Godin, 2004).

4.4.4.3 Interacting with structures and objects without the risk of damage

In places that are cultural heritage sites, users cannot physically connect because there is a danger of damaging historical buildings and objects. However, due to the interactive environment that AR systems offer to the user by combining real environment and virtual data, it can connect with the historical environment without any risk factor and the user who is dominating the field has a sense of belonging. As a result, the user gets more information about the field (El-Hakim, Beraldin, Picard, & Godin, 2004).

4.4.4.4 Creating educational resources

AR technology, which creates a strengthened perception level with the overlapping of the virtual environment and the real world, makes the learning activity easy and permanent. AR applications, which transform information into practice with its interactive structure, are also educational resources (El-Hakim, Beraldin, Picard, & Godin, 2004).

4.4.4.5 Visualizing scenes

AR technologies are an important tool for archaeological sites, in terms of inaccessible locations or the reconstruction of virtual assets of historical environments for users with physical disabilities. AR technologies are an important tool for archaeological sites, in terms of inaccessible locations or the reconstruction of virtual assets of historical environments for users with physical disabilities (El-Hakim, Beraldin, Picard, & Godin, 2004).

In the light of the advantages it provides, AR technologies are used in many different ways such as presentation technique, documentation method, and educational purposes in archaeological areas that have important cultural heritage. AR expands its usage area with the development of technology day by day.

4.4.5 Related Works

AR technology, which has different usage examples in the field of architecture with the new environment created by blending the virtual and real environment, is also used as a representation tool with its effective visualization opportunity. It enables virtual reconstructions of architectural works in museums and archaeological sites with audio, video and 3D visual support, enabling these works to be exhibited effectively. In this part of the study, various case studies have been made on how AR technology can be used to represent architectural cultural assets. The problem definitions stated by the projects examined, the approaches and methods for solving this problem have been examined in detail. In the light of these examinations, the structure of the application to be developed within the scope of the study was established.

4.4.5.1 The Ancient Pompeii

Pompeii, which is located at the foot of the Vesuvius volcano, became a part of history with the eruption of the volcano on August 24, 79. During canal work between 1594 and 1600, the remains of the city were noticed and archaeological excavations commenced.

Many archaeological and research studies have been done to show the history of Pompeii and the effects of the disaster it experienced, and much work is still being done today. Technology is also used to protect the cultural heritage and display it to the masses. One of these is the LIFEPLUS project, which adds virtual data to real scenes in the cultural heritage site, completed in the year 2000. It is an electronic tour guide for tourists coming to the site (Papagiannakis, et al., 2002).

In the ancient Pompeii project, visitors were experienced the area by using realistic scenes with AR technology and virtual storytelling techniques. Based on the fresco paintings in the area, plant and animal models were made and an artificial life was designed with human simulations reflecting the lifestyle of the period. Face and speech simulations, voice data, and clothing simulations were made to the characters according to the stories (Papagiannakis, et al., 2005).

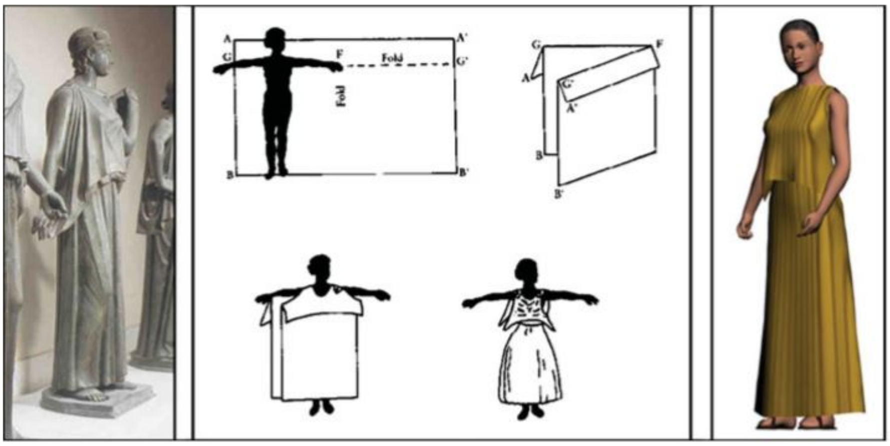

Figure 4.17. Virtual garment based on a real ancient dress (Papagiannakis, et al., 2005).

In the Pompeii project, users get the chance to experience an interactive environment with animations acting according to fictional stories, enriched with virtual data during their visits. As Pappagiannakis and others explain, the opportunity to experience with storytelling broadens the visitor's perspective. With AR technology and virtual storytelling technique, which is the main purpose of the study, visitors have stepped into the past and went on an interactive and immersive trip (Papagiannakis, et al., 2005).

Figure 4.18. AR demonstration results (Papagiannakis, et al., 2002).

4.4.5.2 <u>Archeoguide</u>

Archeoguide is also an application that offers guidance to the user using augmented reality technology. By using the user's location, it enables the historical buildings to be displayed without any intervention by providing augmented reality reconstructions. It presents the reconstruction of the historical buildings in the area with AR technology, on-site and full-time to the user. This project, which has been tried in the ancient city of Olympia in Greece, also offers access to virtual tours and database thanks to internet access (Vlahakis, Karigiannis, Tsotros, Gounaris, & Almeida, 2002).

Three different mobile units were implemented in Archeoguide Project; laptop, pen-tablet and palmtop. With this hardware, many 2D pictures, 3D models, audio, video and information content articles were provided to the users. Thanks to its GPS support, the system can overlap the actual data and virtual ones provide the user with increased views (Vlahakis, Karigiannis, Tsotros, Gounaris, & Almeida, 2002).

Figure 4.19. Archeoguide application: a) Real Environment b) Virtual Environment (Vlahakis, Karigiannis, Tsotros, Gounaris, & Almeida, 2002).

In addition to tangible heritage objects, abstract cultural actions are also included. As an example, for users in the stadium area, the Ancient Olympic Games reconstruction was exhibited to the user with athletes competing in the stadium. In order to do this, people who are experts in Greek civilization were informed about the former Olympic athletes and virtual human models were created. It is animated by adding the necessary movements related to the sports on the created models (Vlahakis, Karigiannis, Tsotros, Gounaris, & Almeida, 2002).

Figure 4.20. Ancient Olympic Games reconstruction (Vlahakis, Karigiannis, Tsotros, Gounaris, & Almeida, 2002).

4.4.5.3 Yenikapı Explorer

Recent studies have shown that mobile games made with AR applications are also educational. Towards to these games, it has been observed that the users interact more strongly with the space they are in. Yenikapı Explorer is also an AR supported mobile gaming platform created in 2012. The purpose of the study is to show the historical richness of Yenikapı to the users with the game designed.

In order to solve the transportation problem of Istanbul, a transportation network project was wanted in Yenikapı, but archaeological excavations were carried out due to the historical importance of the area (Kocabaş, 2012). In these excavations, a lot of historical elements emerged. Necessary symposiums and competitions were organized in order to find a solution because it is impossible for the works to remain in place.

Sibel Özgan, who emphasizes the potentials of augmented reality in cultural heritage areas, proposed an AR game in order to display the history of Yenikapı. In order to achieve this, 3D reconstruction of historical objects in the area has been carried out and characters belonging to different time periods have been created. Users participating in the application have experienced these historical objects virtually in their original places (Özgan, 2012).

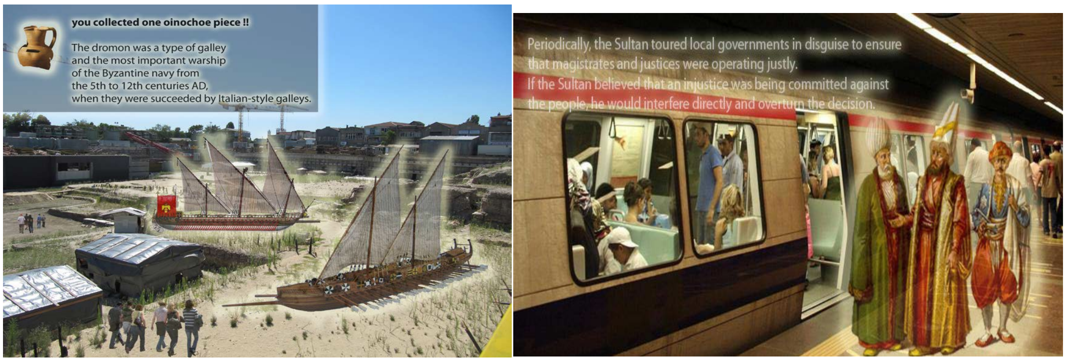

Figure 4.21. AR environments in Yenikapı Explorer application (Özgan, 2012).

Yenikapı Explorer is a location-based AR game where the user has the chance to watch virtual scenes by collecting all virtual objects. The user must answer the questions asked about the object correctly in order to collect the objects. All objects belong to a certain collection. When all the pieces are collected and the collection is completed, the user gets the chance to observe scenes with more detailed information and data about the area (Özgan, 2012).

4.4.5.4 JejuView App

Jeju Island, one of the most important touristic places of Korea, is a location where visitors can visit for a short time without experiencing its cultural and historical value due to its isolated location. In this context, Jung and his team produced the JeuView application in order to present the cultural value of Jeju Island to visitors, even if they are not physically present in the area (Jung, Nguyen, Piscarac, & Yoo, 2020).

The application offers its users the opportunity to explore Jeju island using Augmented reality and virtual reality technologies. Users can access the Jeju island map and experience the area without being in the area by scanning a QR code on their devices. Users who can access 3D content with their WebGL-supported devices can access an AR library that enables similar content to be produced if they wish (Jung, Nguyen, Piscarac, & Yoo, 2020).

The JejuView app offers a VR experience with a smartphone or a low-cost headset such as Google Cardboard. Users can access any location they want within the island with the virtual assistant support available in the application. Distant users who are not in the area can experience various venues with the virtual guidance of Jeju's stone guardian, Dol Harubang, prepared with AR support.

Figure 4.22. Experience map in Jejuview app (Jung, Nguyen, Piscarac, & Yoo, 2020).

The application offers 4 options that users can experience on the map.

1- Jeju's iconic symbol Dol Harubang

2- Gwandeokjeong Pavilion built under King Sejong to empower soldiers' spirits and minds

3- Bijarim forest, nicknamed "Forest of a Thousand Years", which is the largest forest in the world consisting of a single type of plant species

4- Jeju Folk Village, the highlight of the island's cultural heritage, where the true shaman ritual is performed.

When the user clicks on one of the options, they can experience the work in VR or AR environment, or get information by watching various videos.

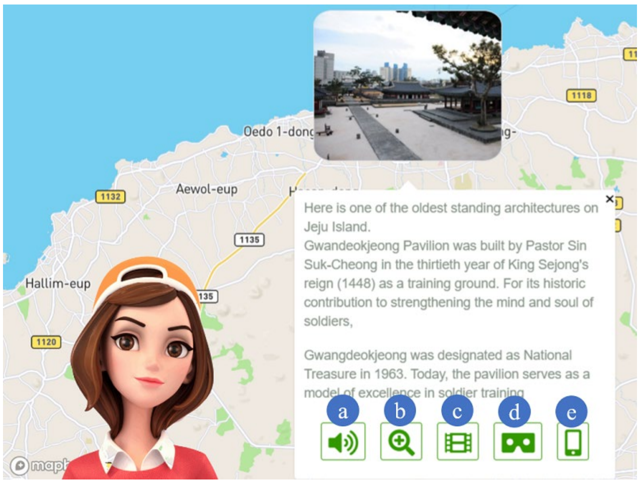

Figure 4.23. Different options of information that users can choose in the application (Jung, Nguyen, Piscarac, & Yoo, 2020).

When the user clicks on the symbol indicated by “a” in the figure 4.23, they can listen to the information about the work with sound. When they click on the icon indicated by “b”, they can access the area where the work is located and watch the video associated with the “c” symbol. While the “d” icon enables viewing the artifact in VR environment, the “e” icon provides the opportunity to experience in AR environment (Jung, Nguyen, Piscarac, & Yoo, 2020).

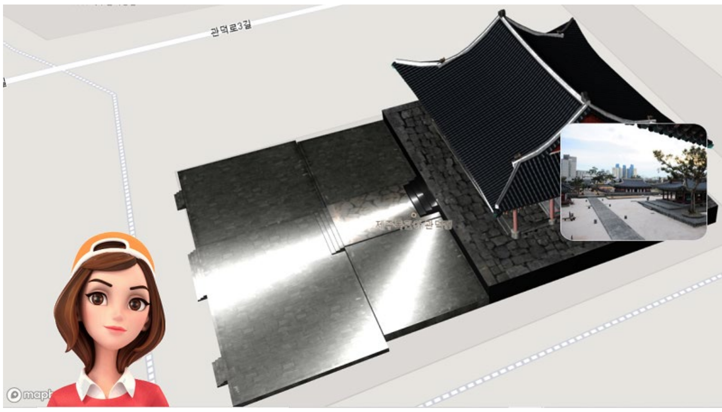

Figure 4.24. Experiencing the structure in the actual location of the map with the zoom icon (Jung, Nguyen, Piscarac, & Yoo, 2020).

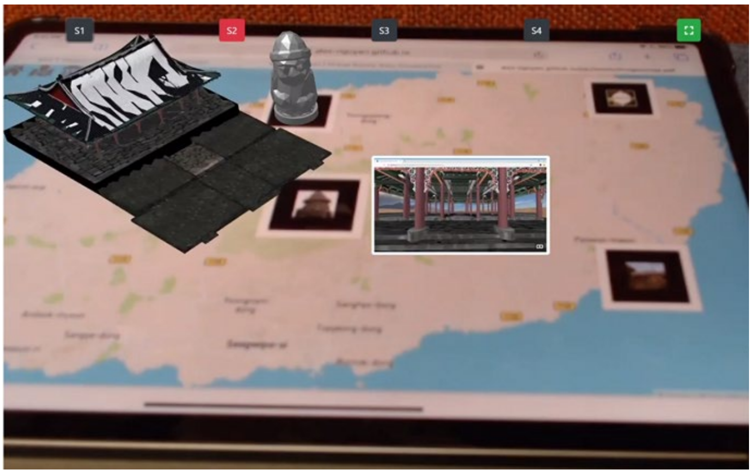

Figure 4.25. AR components in JejuView app (Jung, Nguyen, Piscarac, & Yoo, 2020).

The works with AR content integrated into the application provide the user with various information about Jeju island via storytelling. For example, when the user selects the Dol Hareubang option, the story he/she will listen to is as follows:

> *Dol Hareubang (S1): "Hello! My name is Dol Hareubang. I am also called Tol Harubang,or Harubang. I am a large rock statue found on Jeju Island, off the southern tip of South Korea.I am usually considered to be a god granting both protection and fertility, and placed outside of gates for protection against demons travelling between worlds. I have become the symbol of Jeju Island, and replicas of various sizes are sold as tourist souvenirs. Now let me take you to the great tourist spots of Jeju Island!"*

The effectiveness of the application was tested with the participation of 251 people. As a result, Jung and his team stated that the users focused on the hedonic value they obtained rather than the information they obtained while using the VR-AR application. As stated by Jung and his team, the application is the first multi-modal and web-supported VR-AR application created to promote national values. In this context, the application is important with the hypothesis that it encourages the Jeju Island culture by offering various experiences to the users (Jung, Nguyen, Piscarac, & Yoo, 2020).

In the past years, when the world faced disasters such as earthquakes, tsunamis and Covid-19, it was almost impossible to travel and different solutions were sought (Gössling, Scott, & Hall, 2021). JejuView app, which provides users with remote experience with the AR environments it offers, can be shown as an example of these solutions.

4.4.5.5 Virtual Restoration of The Cinema "Sever"

The project was developed for Sever cinema, which is located in Arkhangelsk, Russia, and has regional cultural importance. It aims to provide the virtual restoration of the Server cinema, which reflects the culture and history of the 19-20 centuries, as well as the existing restoration works (Tomilina, Gontar, & Frolova, 2020).

Figure 4.26. Current status of the structure (Tomilina, Gontar, & Frolova, 2020).

Considering that AR technology can be a tool for reviving lost cultural heritage items, the Sever project aimed to preserve the image of the city, which lost its physical existence, by creating models from different periods of cinema. For this, firstly, the archive research of the building was made and 6 different period- I. period 1895-1908, II. period 1908-1915, III period 1915-1929, IV. period 1929-1950, V. period 1950-1991, VI. period 1996 - to the present time- models of the building were created.

Figure 4.27. Models of the Sever cinema in different time periods: a) Model of the building, 1903-1908, b) Facade of the yard, 1903-1909, c) Model of the building, 1916 d) Courtyard and main façade of the building, 1950 (Tomilina, Gontar, & Frolova, 2020).

In order to create a hyper-realistic image, the required texture assignment has been made and the resulting models are rendered. Finally, the AR environment was prepared and the project was finalized. Various animations of the structure are presented to users on a digital platform (Instagram) to increase the use of the application (Tomilina, Gontar, & Frolova, 2020).

Figure 4.28. Augmented views of cinema: a) The backyard of building, 1908-1913, b) Cinema “Sever”, 1951 (Tomilina, Gontar, & Frolova, 2020).

4.4.5.6 <u>Parion Theatre Project</u>

It was prepared in 2015 to represent the cultural value of the Parion Theater in Izmir Biga. In the ancient city of Parion one of the most important archaeological sites in Turkey, there are up to 1-2 century AD structure and dating finds. The ancient city in the Troas region has an important position due to its natural harbor. Excavation work in the area started in 2005 and continues today. Located in the center of the city, Parion theater is positioned by taking advantage of the slope of the land like most theater structures in Anatolia (Özer, Nagakura, & Vlavianos, 2016).

Figure 4.29. Physical model (Özer, Nagakura, & Vlavianos, 2016).

With the data obtained from the excavations, the required drawings of the theater were made and documented by photogrammetry method. In the last stage, 3D reconstructions of the area were presented to the users using the Multirama AR application. In this context, the physical model created and the virtual drawings integrated into it are presented to the users' experience via a tablet. Users holding the smart device to the object offer 4 different options as the model of the area, 2 different sections, and structure of the theatre, by the application reading the pointer (Özer, Nagakura, & Vlavianos, 2016).

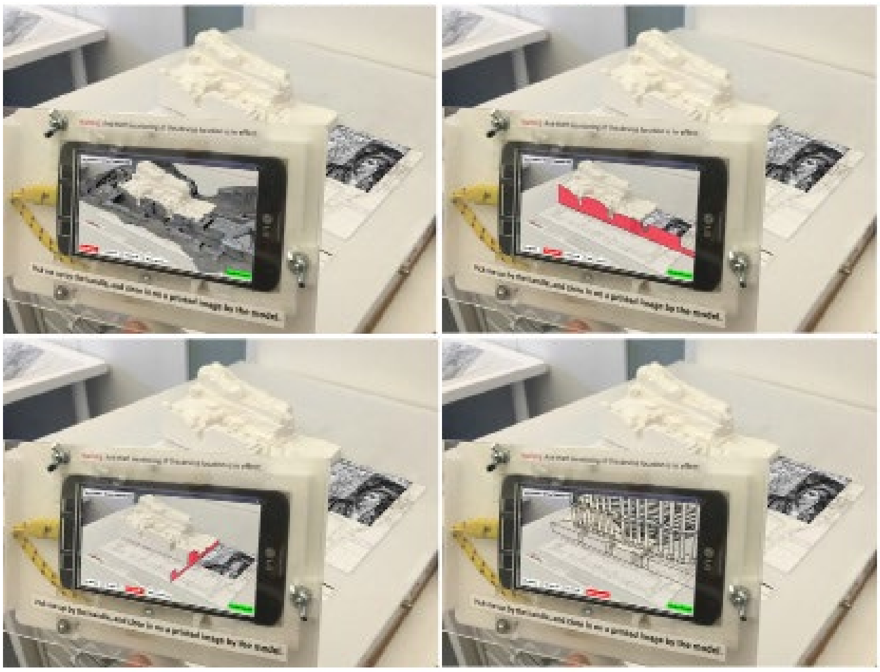

Figure 4.30. Experience of 4 options offered through Multirama AR app to the user: a) model of the area b) section of the theatre c) section of the theatre d) structure of the theatre (Özer, Nagakura, & Vlavianos, 2016).

Using the Multirama AR application in the project, it was aimed to provide documentation, calculation and representation of the cultural heritage of the ancient city of Parion. The project is important in terms of providing the representation of the Parion Theater with its low cost and holistic approach. The technical drawings created provide integrity with the 3D model thanks to the AR environment. In this context, art historians, archaeologists and architects can carry out their work more easily with drawings integrated with the 3D model. It also provides 3D documentation and promotion of cultural heritage (Özer, Nagakura, & Vlavianos, 2016).

With the Parion Theatre Project, which offers an alternative proposal for the reconstruction of cultural heritage elements, it has been revealed that cultural, architectural, archaeological, etc. studies can be carried out without using any special equipment or expensive methods (Başaran & Ergürer, 2016).

5 CASE STUDY: ALEXANDRIA TROAS ANCIENT CITY

Based on the AR applications, the usage examples of which were examined in the previous section, within the scope of the thesis, it was aimed to develop an AR application in order to present the podium temple in the ancient city of Çanakkale-Alexandria Troas. In this direction, detailed research of the ancient city of Alexandria Troas is included in this section, the history of the ancient city, its importance and the historical artifacts and structures that have been unearthed as a result of the excavations and researches carried out in the area are revealed. Studies have been carried out to present the Podium Temple structure, one of the historical artifacts and structures unearthed, to the AR experience. For this, literature research was carried out in the process of creating the models, the desired models were completed, the AR application was developed and field studies were carried out. In this direction, first of all, literature studies of the ancient city of Alexandria Troas and the podium temple were carried out. In line with the literature studies, the history of Alexandria Troas was examined in detail, and restitution drawings, excavation reports and visuals were obtained from the excavation archive of the podium temple. Interviews were held with the excavation director, Prof. Dr. Erhan Öztepe, to investigate the period structures and temple architecture thought to belong to the temple structure. Finally, by evaluating all these data obtained, 3 different states of the temple were modeled. For the modeling process, the restitution drawings were transferred to the AUTOCAD environment and 2D drawings were made. 3D models were made in ARCHICAD environment. In this direction, the temple architecture characteristics and typologies of the temple architecture of the geography and period were examined in order to understand the podium temple and to carry out modeling studies, and the modeling process was included with the field data obtained from the excavations. The development stages of the AR application, which was created to provide the augmented experience of Alexandria Troas city, are included. In the continuation of the process, field studies were carried out and augmented experiences in the field were revealed with the application.

Studies in the ancient city of Alexandria Troas, which dates back to the end of the 4th century BC and harbors an important cultural heritage, were first initiated by Prof. Dr.

Coşkun Özgünel between 1993-1995 as systematic survey studies. In 1997, surface studies continued in the area with the cooperation of Çanakkale Archeology Museum and Münster Asia Minor Institute. The first archaeological excavations were started in the area between 2000-2007. Studies in the area were transformed into systematic excavations by Prof. Dr. Elmar Schwertheim and his team. As of 2011, Alexandria Troas excavation and research studies are carried out by Prof. Dr. Erhan Öztepe and his team from Ankara University Archeology Department. Since 2018, excavation and research studies have been continuing under the main sponsorship of the Ministry of Culture and Tourism and İÇDAŞ AŞ. Apart from these institutions, studies are carried out with an academic team from different universities. For the last 6 years, a team under the leadership of Prof. Dr. Hakan Anay of Eskişehir Osmangazi University has been involved in the excavations in order to carry out architectural documentation, conservation and restoration works. Interns of 5-6 people are recruited for systematic excavations carried out every year. At the same time, the thesis work was derived as a part of this association, and it is the first architectural work carried out at the graduate level.

5.1 Alexandria Troas Ancient City Location and History

The region located in the northwest of Çanakkale, which covered a large part of Çanakkale in 1000 BC, was called Troas. It has been the most important region of Anatolia due to being a connection point between Anatolia and Thrace in the Ancient Age and being located on the trade routes. There were 18 cities in the region. One of these cities was the city of Alexandria Troas, famous for its trade and maritime activities.

Figure 5.1. Troas region.

The ancient city of Alexandria Troas is located within the borders of Dalyan village of ezine District of Çanakkale province. The city is in the region where the name is still used in the region and Pir-i Reisi is known as “old Istanbul " (Cook, 1973).

The city is a port city founded in 310 BC by Antigonos Monophtalmos, the commander of Alexander the Great (Alexandros), with the name Antigoia. The city, famous for its port, could be connected with coastal cities in ancient times by sea,while it could also be connected with surrounding cities by road traveling through the region from land (Taşçı, 1998). After the death of Alexander the Great, the city received its present name as Alexandria Troas, which means the city of Alexander (Alexandros)by Lysmimakhos (Başgelen, 2000). Lyksimakhos settled the peoples of Colonia-larissa-Hamaksitos, one of the coastal cities in the south of the Menderes Valley, in the region in order to ensure the development of the city. Alexandria Troas has become an important Trade Center in time with this strategy of Lyksimakhos (Taşçı, 1998). In 133 BC, the city was left to the Roman Empire and included in the Roman provincial system. The Roman-dominated city received the title of “colony” during the reign of Augustus and increased its importance among the surrounding cities (Şimşek, 2010).

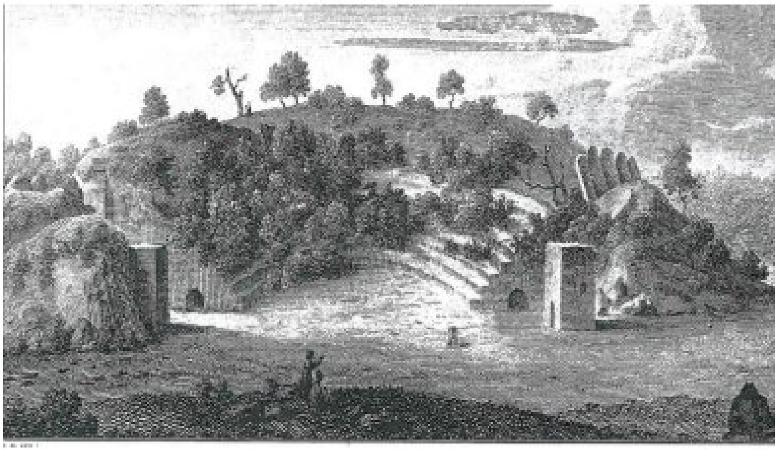

Figure 5.2. Alexandria Troas. (Sevim, 2002)

During the reign of Emperor Hadrian, construction activities accelerated with the financial aid made to the city. During this period, when Herodes Atticus was the governor of the region, many baths and cisterns were built in the city. With the increased importance given to the city, Hadrian was honored by the public as the second founder of Alexandria Troas. The city became an important episcopal center with the visits of St. Paul in the Early Christian period. The city lived its brightest period in the 2nd century AD and preserved its importance until the 4th century AD. One of Constantine's biographers wrote that the city, which has an important location between Asia and Europe, is also considering making it a capital due to its close connection with Rome. Constantinus' desire to establish Constantinople here reveals the importance of the city. The city lost its value as the port of Alexandria Troas lost its functionality. The exact reason and date of the abandonment of the city is unknown (Schwertheim, 2008).

Demolitions started in Alexandria Troas in the 17th century and many marble materials were brought to Istanbul to be used in the construction of new buildings. In this period, the city became the quarry of the Ottoman Empire. The Ottoman sultan, Mehmed V, bought many columns from the city to be used in the Sultan Mosque (Texier, 2002). In his speech at the Çanakkale Troas Archeology Meeting, Schwertheim emphasized that the name Kestanbol transformed into Istanbul over time when Istanbul was established with the materials removed from Alexandria Troas (Çavga, 2002). The fact that Alexandria Troas is a coastal city enabled materials to be easily transported to different places and accelerated the destruction of the city (Taşçı, 1998).

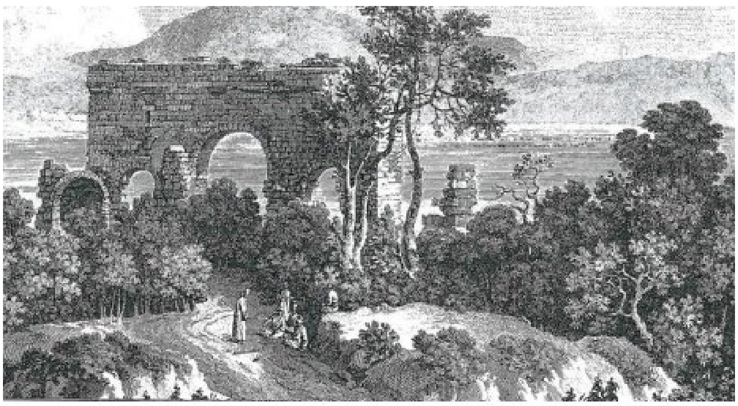

Figure 5.3. Alexandria Troas. (Sevim, 2002)

5.2 Alexandria Troas Excavations and Ruins

The city has been one of the most important cities with a theater, Stadium, baths, temples, fountain, waterways and walls surrounding the city. Because it is home to many civilizations, it has attracted the attention of many researchers and archaeologists. 16. the city, which attracted the attention of travelers from the 20th century, was named after him. it has hosted research and excavations since the century. In 1994, the first surface surveys were carried out in the region by the German Anatolian Research Institute and a map was prepared revealing the city boundaries. Excavations in the area began in 1997 under the leadership of the Çanakkale Archaeological Museum. In 2002, excavations were carried out by Elmar Schwertheim. Since 2011, archaeological are continued under the leadership of Erhan Öztepe.

Figure 5.4. Alexandria Troas forum area aerial photo (Alexandria Troas excavation archive).

Many structures and ruins such as baths, odeion, temple, city wall was unearthed during the excavations. According to Schwertheim, the city walls in the area are the longest city walls in Asia Minor and cover an area of approximately 400 hectares. Schwertheim was able to detect 4 gates, one on the south, one in the direction of the ancient harbor, one on the road to the Apollon Smintheios sanctuary, and the other on the road to Troy. Among these gates, the "East Gate or Neandria Gate" located in the east of the area differs from other gates. There are defensive towers on both sides of the door with a circular inner courtyard. During the excavations, it was found that the door had a diameter of 20 m. The monumentality of the gate built by Lysimachus makes it the most important gate of the city. Schwertheim stated that St. Paul passed through this gate twice when he came to the city (Schwertheim, 2005). He stated that another door in Messene, Greece, is the only door similar to the structure (Schwertheim, 2008).

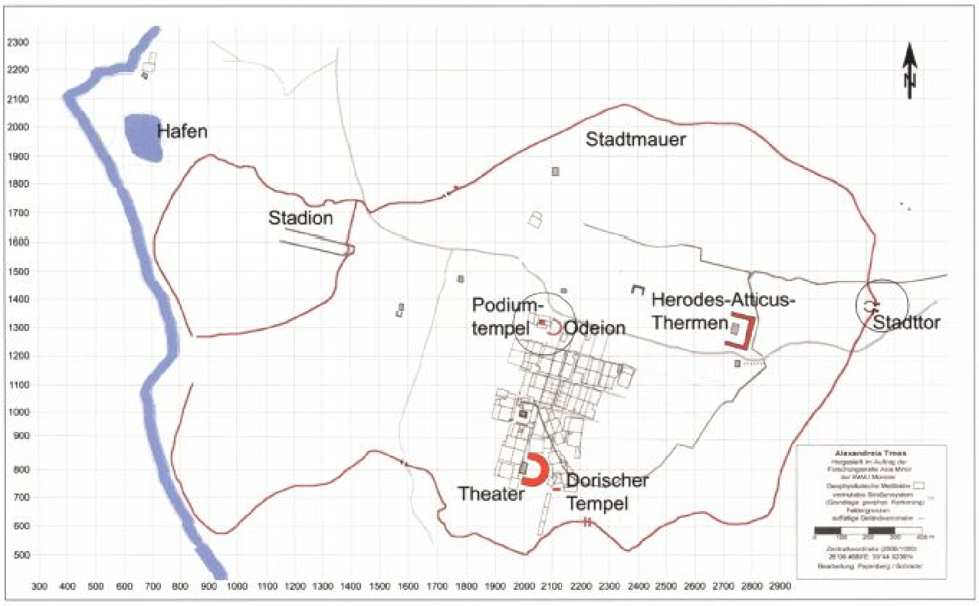

Figure 5.5. City plan of Alexandria Troas (Öztepe, 2017).

Herodes Atticus Bath in the area is the biggest structure of the city that has survived to the present day. A large part of the building, which was built in 135 AD, was destroyed by an earthquake. During the studies, it was determined that the bath, which has a façade of 100 meters, surrounds a square-shaped space (Schwertheim, 2002). The place is surrounded by 3 arches and pedestals. It is thought that there were other arches on these arches in the past. In the estimation made based on the positioning of the arches, it is possible that the structure has a dome-shaped top cover (Tutkun, 2016). Today, the western arch of the building has collapsed, and the east, north and south arches are still standing. Efforts were made to protect the building, which is the largest bathhouse in Anatolia, by preparing its relief drawings in 2013 (Öztepe, 2013). In order to protect the arched structure, which is in danger of collapse, a structural strengthening project was prepared and the project was implemented in 2018.

Built by Herodes Atticus during the reign of Emperor Hadrian, the theatre structure is located at the highest point of the city. At the highest point of the city is the theater structure built by Herodes Atticus during the reign of Emperor Hadrian. It is a classical Roman theater with its structural features. During the excavations, it was found that the stage facade of the building was in Corinthian order (Taşçı, 1998). Another building located in the northwest of the theater and at the third highest point of the city is the building complex with a square plan of 30 * 30. The building, which has a vault arch on its front facade, was built with cut stone material and 2 floors. This structure, which is dated to the Roman period, is referred to as "Maldelik" in the region (Schwertheim, 2008). The drawings of the building were completed during the excavations carried out in 2005.

Figure 5.6. Ruins of Herodes Atticus Bath (URL9).

There is an odeion structure near the agora area, which is considered to be the center of the city, and to the north of the east-west axis, one of the main streets of the city. The building, which has a semicircular seating arrangement, is thought to be a Roman period building (Taşçı, 1998). During the studies carried out in Alexandria Troas, a building with a rectangular podium was found in the north of Odeion and approximately in the middle of the city. In the beginning, the building was named as "Agora temple" because of its rectangular area. In the ongoing studies, it is stated that the building is a temple built with opus-caementicium technique. It is known that the podium, which consists of cut stone and lime mortar filling is supported by block stones on the corners of the building. It is known that the building, whose foundation walls are 8 meters deep, has a width of 16 meters and a length of 23 meters (Görkay, 2002). Although it is thought that the temple may have been dedicated to Emperor Augustus, there is no exact information. Two wells were found on the foundation of the temple and it is known that these wells are connected to the underground water system. The existence of different wells within the boundaries of the city shows that the sewerage network is not limited to the temple area. During the ongoing studies in this area, a treasure belonging to the Roman period was found with many silver coins (Schwertheim, 2002). There are different suggestions regarding the plan of the temple. In the continuation of the study, possible plan types of the temple were examined and modeling studies were made. Near the temple, there is the remains of a building that was unearthed in 2003 and thought to be a fountain structure. Considering the location and structure of the fountain, it is thought that it is not a drinking well, but an ornamental well (Schwertheim, 2006).

Figure 5.7. Ruins of the podium temple, present day (Author archive).

During the excavations carried out in 2008, the remains of a building with a podium made of opus caementitium were found in the northeast of the forum. Considering the traces found on the side walls of the building, it is thought that it was covered with marble, and the north facade has an opus reticulate façade. Its construction date is thought to be 1 century

AD. Adjacent to the building are ruins called the "eastern portico of the forum" (Schwertheim & Tanrıöver, 2011). During the ongoing studies, the remains of a 12-sided polygonal building were found in the south of the podium hall. It is thought that the transition to the odeion or a window opening may exist over the opus caementicium wall located between the southeast outer wall of this building and the curved wall of the odeion (Öztepe, 2016).

In 2006, a semicircular structure was unearthed in the east of the area called the lower agora. In ongoing studies, the building is named "exedra". It was revealed that the building, which has a width of 11.40, is not a single building, but a large apse in the east-west direction. The outer shell of the building consists of limestone blocks, the inner part is opus reticulatum and the shell construction is opus caementicium technique. With these features, the building is thought to be a 2nd century AD Roman period structure. Schwertheim and Tanrıöver stated that, considering the plan, the building could have been a meeting hall during the Roman period and that it was converted into a Christian church in the following years (Schwertheim & Tanrıöver, 2010). A bronze hand sculpture was also found in this area during the studies (Schwertheim, 2006).

Figure 5.8. Alexandria Troas aerial photo of part of forum area (Alexandria Troas excavation archive).

To the south of the forum area, there is a kryptoportico structure on the north-south axis. On the south end of Kryptoportikon is the Hellenistic stoa structure. Öztepe stated that there are 4 column drums with different heights in doric order inside the stoa and these columns were probably used for wooden posts supporting beams passing through (Öztepe, 2016). During the studies carried out in this area, fragments belonging to a lagynos, one of the characteristic tools of the Hellenistic period and pointing to 150-50 BC, were found. In the ongoing studies in the interior of the stoa, finds such as bowls, oinochoes, pans, and terracotta stoves were found. (Öztepe, 2017). Excavations in the ancient city of Alexandria Troas have focused on the forum and the stoa since 2013. While the works in the field of the forum are moving towards conservation and regulation, the stoa works progress in the form of excavation and arrangement. In these areas, important finds have been reached from the 2nd century BC to the 6th century AD (Öztepe, Kaşka, & Fırat, 2018).

Figure 5.9. Hellenistic Stoa aerial photo. (Öztepe, 2017)

Carpentry and agricultural tools were found in a pithos in the city wall during excavations in 2018. The found tools such as iron sickles, soil scraper, hoe, plow blades show agricultural activities that can be associated with viticulture. This situation is important for the agricultural activities of the ancient city of Alexandria Troas in the Late Roman-Early Byzantine period (Öztepe, 2018).

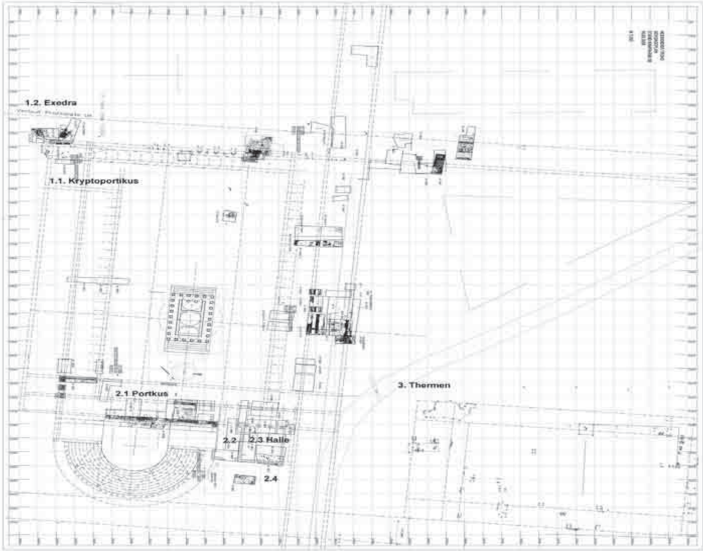

Figure 5.10. Alexandria Troas plan 2008. (Schwertheim, 2008).

In the excavations carried out in the area, a large number of filling materials of different origins, colors, shapes and functions from the early empire period to the late antiquity, ceramics, sculptures, terracotta pieces and coins of different periods were also found (Öztepe, 2018).

Figure 5.11. Historical findings (Öztepe, 2018).

5.3 Understanding the Podium Temple

In this section, the temple architecture has been studied in order to understand the podium temple structure, which is the focal point of the research, and to make models by evaluating it correctly. In this direction, temple space organizations and architectural layouts were investigated in order to understand and evaluate the data obtained from the results of restitution and interviews. At the end of the chapter, it was studied in parallel with the restitution data and modeling studies were carried out.

Temples are architectural structures specially built for the gods. The structures, which were first built using wooden materials, started to be built using stone and marble after the 7th century BC. In the Archaic period (700 BC - 480 BC), the act of worship around the god or goddess statue in high places continued with the formation of specialized spaces around the statue in later periods. The part of the altar placed to make a dedication to the god / goddess statue is called the cella or naos. The cella-naos, which is a sacred area, was covered in order to prevent the statue from being negatively affected by natural events (Büyükkolancı, 1996). In the following periods, the temples were surrounded by rows of columns in order to carry the upper cover. In this way, temple architecture began to take shape and different temple spaces were formed.

Greek temples used to be located in the acropolis, the city center situated on a high hill. The area reserved as temenos in the acropolis were sacred areas and temples were built in these areas. Temenos was an area belonging to the gods and people were forbidden to use this area. For this reason, religious ceremonies were held around the altars set up in front of the temple (Er, 2017). Temples generally started with a floor without molding called stereobate. There is a crepidoma consisting of 2 or 3 steps depending on the architectural order on which it was built. The room where the statue of the god or goddess is thought to live is called the naos and is the most important area in the temple spaces. It is called the pronaos located in front of this area and between the temple walls-anta- and constitutes the entrance to the sanctuary. Behind the naos area is an area similar to the pronaos. This area, called opisthodomos, is separated from the naos by walls and is the area where gifts brought to the god or goddess are located (Tekçam, 2011). The cella area, which is the sanctuary, is surrounded by rows of columns and the column sequences follow a certain ratio, not random.

In general, the number of columns on the long side of the temple is either one less or one more than the two times more columns on the short side. Different plan types were formed with the number and arrangement of the columns surrounding the cella (Büktel, 1998).

Roman temples are also structures designed with the belief of the house of gods, and like the Greek temples, Roman temples are also located in the temenos. The main function in these structures was to influence the people gathered in front of the temple. To achieve this, the temples were raised on a podium and access to the temple was provided by a staircase (Wheeler, 2004). This is one of the differences between Greek and Roman temples. While Greek temples could be approached from all facades, Roman temples could only be approached from the entrance facade, with stairs providing access to the podium. Roman temples were also surrounded by rows of columns. A typical Roman temple is in the form of a podium accessed by stairs, a portico with columns and a cella that continues to the end of the platform (Büktel, 1998).

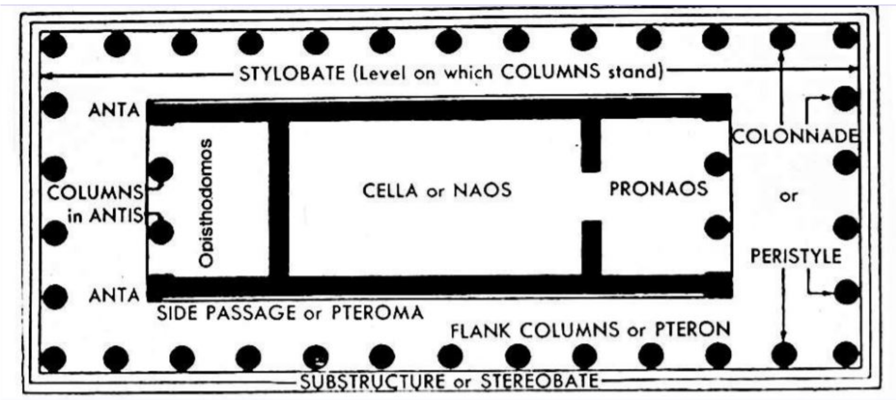

Figure 5.12. Parts of the ancient temple. (URL4)

Accordingly, a temple consists of elements such as naos, pronaos, opisthodomos, anta, stylobate, and peristyle. The main place where the god-goddess statue is located, the sanctuary naos and the entrance to the naos are called pronaos. Opisthodomos is the place where gifts given to the Gods are placed. It is seen in Greek temples. The side walls of the naos are anta and the floor on which the temple sits are a stylobate. Peristyle describes the continuous column series surrounding the temple.

The temples built with the belief of the house of God, were structures containing the statue of the god and his sacred items. In the 6th century BC, it began to take its main forms. Temple architecture has been built in various compositions over time, differentiating in terms of space organization, construction techniques, and architectural formation in line with many physical and cultural factors.

Temple architecture has been built in various compositions over time, differentiating in terms of space organization, construction techniques, and architectural formation with many physical and cultural factors.

5.3.1 Plan layouts

The temples are shaped as rectangular, square or round. While access to Greek temples was provided from all facades, Roman temples were elevated on a podium and access to the temple was provided only from the entrance facade. Square planned temples built in the Roman period are on a podium with stairs and the temple facade consists of several rows of columns. In the rectangular temples, the number of columns has increased and the facade has gained importance by widening. The side facades are narrower compared to the front. Circular planned temples, on the other hand, are structures surrounded by columns that are sometimes built without a cella. The temple typologies differ according to the placement of the columns surrounding the cella in the plan plane, and the plan types have developed. These plan types can be explained as follows;

Tholos: These are temples with a round plan.
Prostyle: These are the temples with a row of columns on the entrance facade.
Amphiprostyle: Describes temples with a row of columns on both front and back sides.
Peripteral: It is a plan type in which the temple is completely surrounded by a single row of columns. The distance between the pillars is equal to the distance between the temple side walls and the temple.
Dipteral: It is a plan type in which the temple is surrounded by 2 rows of columns.
Pseudoperipteral: It is the plan type with single row columns in front of the temple and columns embedded in the outer walls.

Pseudodipteral: These are the temples with double columns in the dipteral plan, where the inner columns are embedded in the outer walls (Atalay, 2010), (As, 2014).

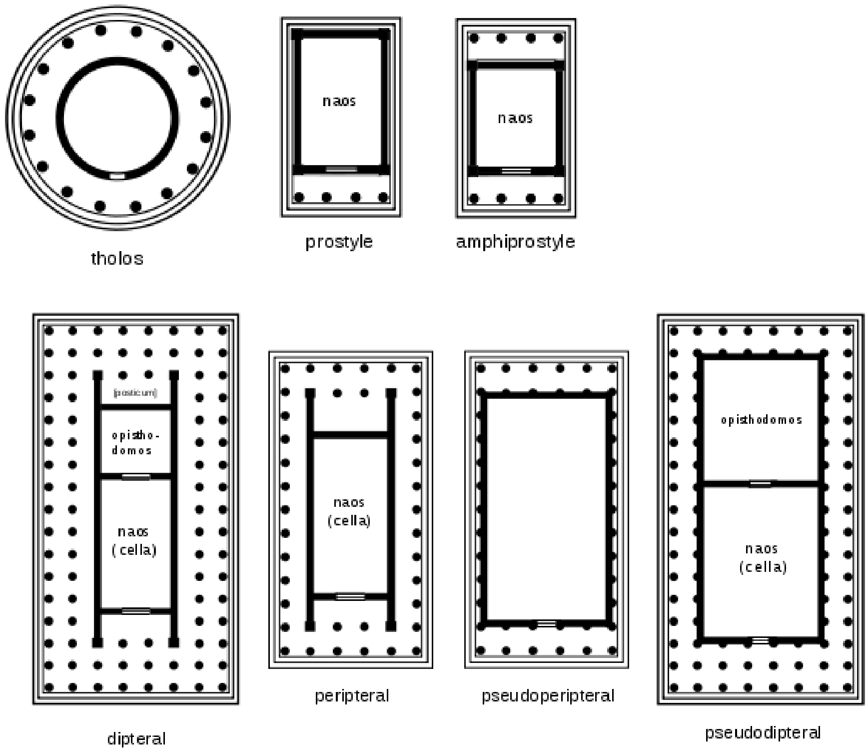

Figure 5.13. Different temple plan layouts: a) tholos, b) prostyle, c) amphiprostyle, d) dipteral, e) peripteral, f) pseudoperipteral, g) pseudodipteral. (URL3).

5.3.2 Architectural Order

Temple architecture is an architecture formed with various emphasis on the structural elements of the building. This system, which affects the external appearance of the buildings, is called the architectural order (Atalay, 2010). While Greek architecture consists of 3 main orders, dor, ion and corinthian, Roman architecture has developed two more distinctive styles called composite and tuscany (As, 2014).

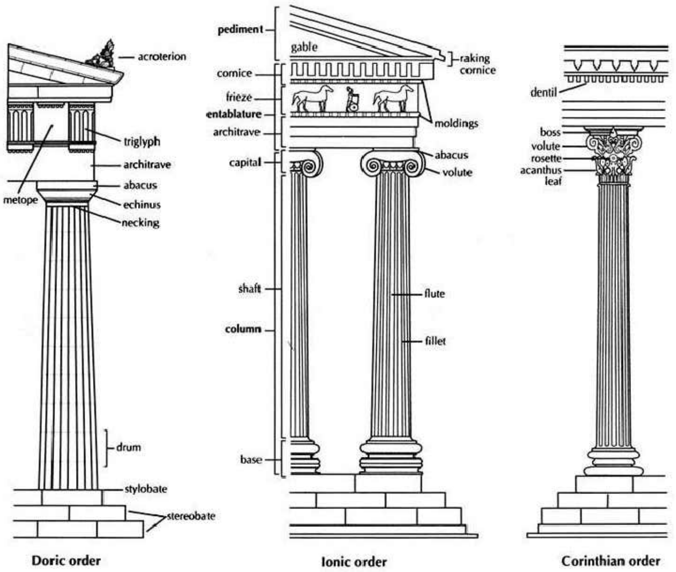

Figure 5.14. Architectural orders: a) doric order, b) ionic order, c) corinthian order. (URL3).

Doric columns do not have pedestals and the columns sit directly on the temple floor, namely the stylobate. The columns become thinner from the bottom to the top and there are vertical grooves on the trunks (Atalay, 2010). The Doric column capital consist of three different parts; a small ring separated from the grooved column body by an the equinus (round mold) and abacus on this ring. Abacus provides a connection between the column and the roof (As, 2014). The columns are connected to each other by means of an architrave, which is a stone beam. There are pediments on the short side of the temple and these pediments are decorated with various reliefs. One of the Doric temple examples is the Athens Parthenon Temple.

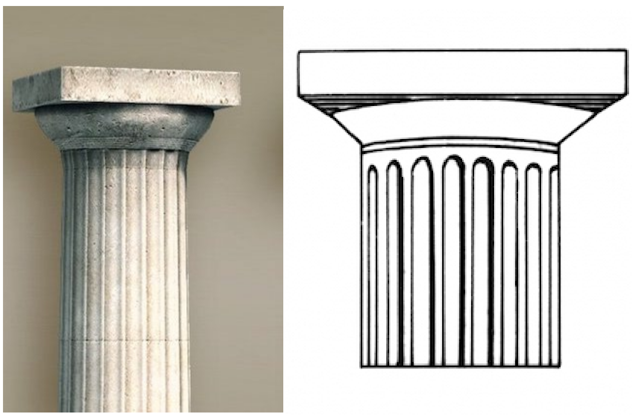

Figure 5.15. Doric order drawings: a) 3D model, b) 2D drawing (URL4).

Ionic columns are located on a base. The number of crepis in the crepidoma part is between 5-7. The rise of the crepidoma supports the monumental appearance. Column capitals consist of a curved shape in the form of ram's horn called volute. Column bodies are thin and tall. Columns sit on a pedestal called plinthos with a convex torus and a concave bracelet called trochilos. The architrave is outstretched and arranged in 2 or 3 bands (fascia). There is an embossed frieze block on the architrave that connects to the roof (Atalay, 2010). An example of an Ionic temple is the Athens Nike temple.

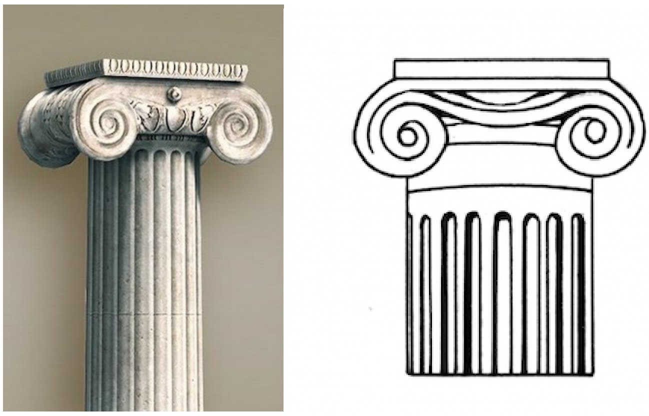

Figure 5.16. Ionic order drawings: a) 3D model, b) 2D drawing (URL4, arkeofili).

The corinthian order, on the other hand, is the Ionic order that has undergone some changes. Basically, the part that differs is the column heading. The volutes seen on the ion column capitals are decorated with acanthus leaves in corinthian order. The column is again on a base and consists of plinthos, torus and trochilos sections. The architrave is arranged with 3 fascia and there is a frieze consisting of reliefs in various patterns. Then there are sections called geisopodes, geison and sima. The number of crepis is more than in the ionic pattern. For this reason, the temples look higher. Athens Zeus Olympios Temple is a temple with Corinthian order (Büktel, 1998).

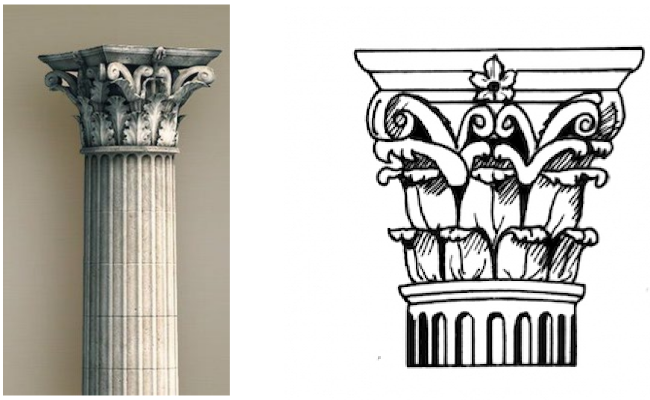

Figure 5.17. Corinthian order drawings: a) 3D model, b) 2D drawing (URL4, arkeofili).

Composite order, formed by the combination of volutes found in ion column capitals and acanthus leaves found in corinthian column capitals. It was developed by the Romans. Column capitals are arranged sometimes with grooves and sometimes without grooves. The Tuscan order, on the other hand, is the Doric order used by the Romans after being differentiated. Doric order is formed by adding pedestals to the columns and leaving the columns without grooves (Karatağ, 2013).

6 GENERATION PROCESS OF THE PODIUM TEMPLE

Any residential area such as a village-city, a temple or a sanctuary is abandoned for various reasons. Sometimes a war-looting situation, sometimes a natural disaster can cause this situation. Abandoned buildings or cities go into a process of extinction over time. Factors such as climatic conditions, human activities, erosion and decay are the main factors that cause architectural structures to become soil again. In this respect, archaeological sites are settlements that have turned into rubble. Such settlement areas can be discovered by chance after a construction activity, or they can be determined as a result of systematic studies. The work carried out by archaeologists to identify such areas is called "surface survey". Observation of traces of ruined, abandoned city and building debris on the surface indicates underground remains. Ultimately, with the survey method, archaeologists can identify archaeological sites by collecting underground remains from the lower layers to the surface. The method of surface research is an archaeological method that requires a systematic study. A part of the historical artifacts and structures are more than systematic researches; It can also be detected by chance, such as roads, bridges, new building constructions, agricultural activities. Studies called "rescue excavation" are carried out in order to reveal and document the immovable cultural assets discovered during these activities, and to document and remove the movable cultural assets to museums.

After the archaeological sites are identified, pre-planned excavations with established conditions, called "scientific excavations", are carried out. Scientific excavations are carried out by the head of the excavation, who is allowed to excavate by the decision of the council of ministers, and the excavation team, which consists of archaeologists, art historians, architects and necessary experts. Excavations are works that take many years and require great care and attention.

As a matter of fact, the ancient city of Alexandria Troas spreads over an area of approximately 400 hectares within the 8 km long city wall. Surveys of the area were first carried out in 1993 and the first excavations in the area were started in 2000. Excavations are still continuing in the area today. It is very difficult to perceive a whole city image as an ancient city of such a size turns into a pile of rubble under the influence of wars, looting, earthquakes, etc. At this point, it is thought that the AR application developed within the scope of the thesis will be the first steps of a great project in terms of perceiving the original state of the city with the increased experience of the ancient city. In order to create a holistic perception of the city, it was first decided to present the podium temple structure in the middle of the forum area to an enhanced experience. In this section, different temple layout models of the mentioned temple, which were obtained in line with literature studies, restitution drawings and interviews, were mentioned, and the production processes of these models were given.

This phase was done by examining the architectural elements that make up the temple and the ways in which these elements come together. In this direction, the stage of creating temple models is divided into specific sections. For this, first the drawings of the elements that make up the temple were made. Subsequently, different settlements formed by the combination of these elements were formed.

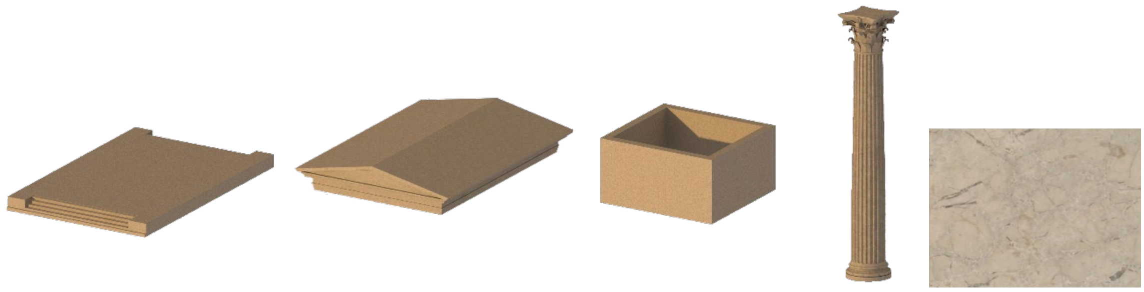

Figure 6.1. Elements and materials: a) podium, b) roof, c) walls, d) column, e) material (Author archive).

In line with the findings, it was revealed that the Alexandria Troas podium temple has column heads in corinthian order. For this reason, the column base, column body and column capital are modeled in accordance with the corinthian order. For the column head, acanthus leaves opening in all directions were drawn and modeled by arranging the volutes to open in the corners. There are grooves in the column body and the plinthos, torus and trochilos parts that must be found on the column base are modeled.

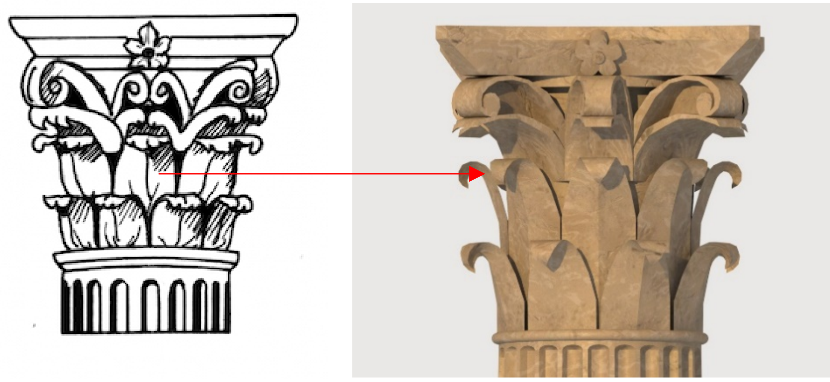

Figure 6.2. Model created from 2D drawing (Author archive).

After the modeling of the architectural materials in the temple structure was completed, the possible plan layouts of the temple were created through the excavation reports, restitution drawings and interviews. This stage was carried out based on the rules and period structures previously mentioned in the temple architecture. Accordingly, 3 different model of order for temple were produced, namely prostyle, peripteros and pseudo-peripteros.

6.1.1 Prostylos

Early excavations suggest that the temple with a podium was in prostyle order. As described earlier, the prostylos plan is the temples with a row of columns on the entrance façade. Accordingly, the modeling process of the prostyle plan layout of the temple with podium was defined in the figure 6.23. Modeling studies were carried out with reference to the data obtained from the excavations and period structures.

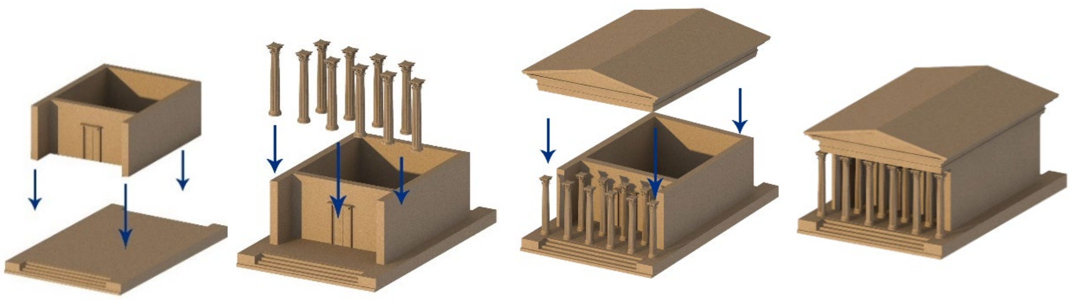

Figure 6.3. The process of creating the prostyle model (Author archive).

6.1.2 Peripteros

Görkay suggested in his article that the temple may have a peripteral plan. It is a plan type in which the temple is completely surrounded by a single row of columns. The distance between the pillars is equal to the distance between the temple side walls and the temple. In this direction, the model of the peripteral order of the temple was realized and shown in figure 6.4.

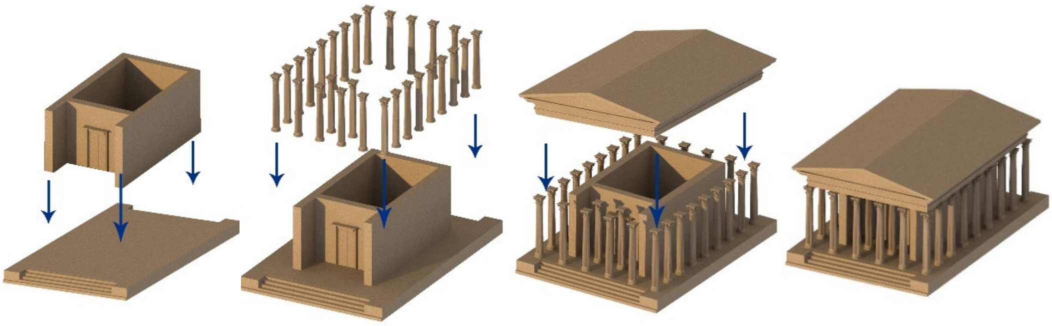

Figure 6.4. The process of creating the peripteros model (Author archive).

6.1.3 Pseudo-peripteros

During the field studies, during the interview with the excavation chief Erhan Öztepe, it was mentioned that the temple might belong to the pseudo-peripteros plan. Öztepe Nimes Maison Caree mentioned that similar finds were found during excavations, referring to it. In this direction, the temple model with podium belonging to the pseudo-peripteros plan was realized. Figure 6.5 shows the creation process of the model.

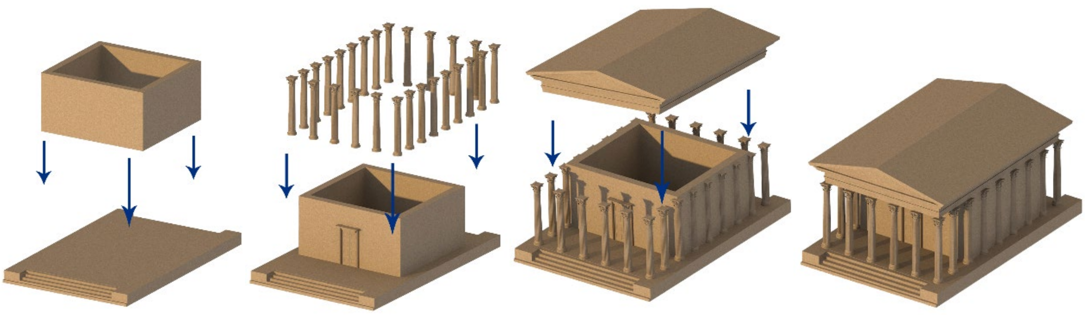

Figure 6.5. The process of creating the pseudo-peripteros model (Author archive).

In order to make a model of the podium temple, which is one of the buildings in the forum area of the city of Alexandria Troas, the excavation report data were examined and the archaeologists who involved in the excavations were interviewed. When the ruins and architectural details of the temple structure are examined, it is thought to be an early period empire structure belonging to the 1st century. The foundation walls of the temple have reached the present day after the building materials were ripped off and removed in order to carry out different construction works of the buildings in the area. It is known that the building, whose foundation walls go 8 meters deep, has a width of 16.60 meters and a length of 23.65 meters. It is thought that the column capitals are in the corinthian order in line with the findings unearthed during the excavations. The building was built with the Opus Caementicum technique and limestone blocks with mussel shells were used in its construction.

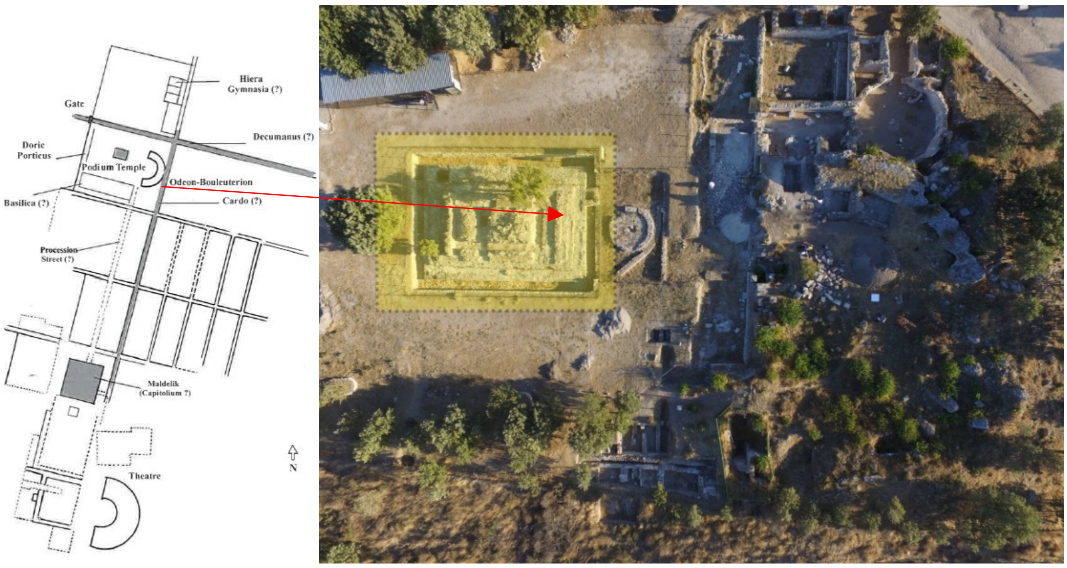

Figure 6.6. Partial settlement plan with an image of Alexandria Troas (Görkay, 2002)(Alexandria Troas excavation archive).

Looking at the early excavations, the temple is believed to have a prostylos plan layout. As stated by Görkay, the temple is an early imperial structure, which consists of 4-6 columns with the first column series with a peripteral plan.

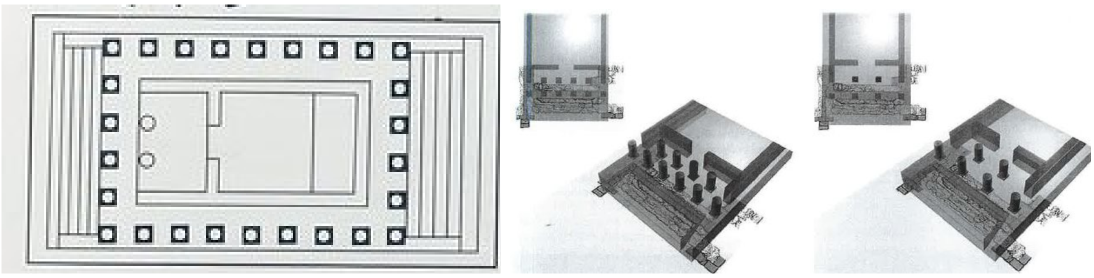

Figure 6.7. Drawings of the podium temple: a) existing restitution drawing, b) existing models (Alexandria Troas excavation archive).

During the field studies, it was discussed that the temple might have a pseudo-peripteral plan during the meetings with the head of the excavation at Alexandria Troas ancient city, Erhan Öztepe. Referring to the Maison Carrée temple in the Nimes region of France, Öztepe stated that similar architectural features of the Maison Carrée temple were also found in the temple excavation. While modeling the temple in this direction, 3 different models were made. In this way, it has been shown that AR technology allows flexible working and virtual reconstructions can be achieved without damaging the structure.

In the light of the existing restitution study obtained as a result of the studies, a 3D model was made using the ARCHICAD program. Firstly, the temple plan was drawn and then the column capitals were modeled. In order to model the column capitals, friezes, etc., the structures of the same period were examined and the comparison method with the findings obtained in the excavations was used. While the peripteral plan proposal was modeled with Görkay's article, the pseudo-peripteral plan proposal was modeled with reference to the Maison Carrée temple. In line with these references, the acanthus decorations on the column base, column body and column headers were modeled with the morph tool in the ARCHICAD program.

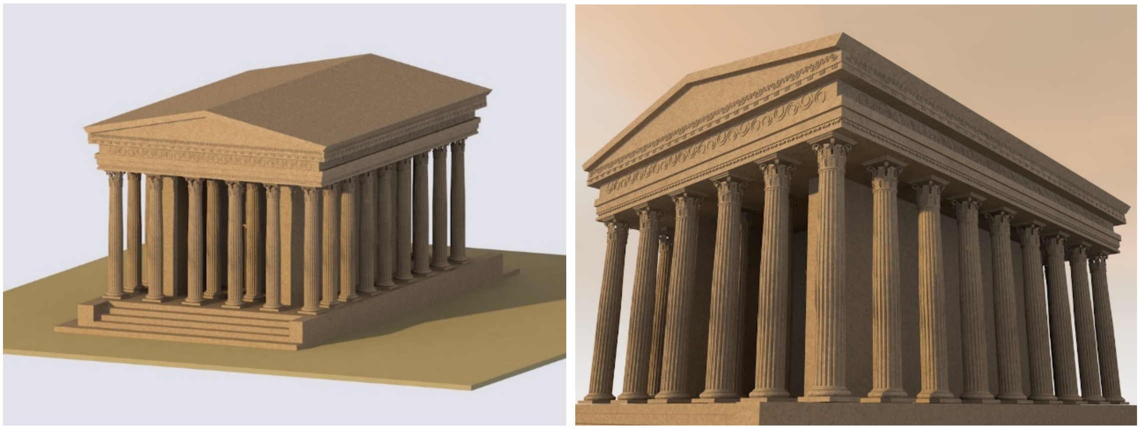

Figure 6.8. Peripteros model of the temple structure (Author archive).

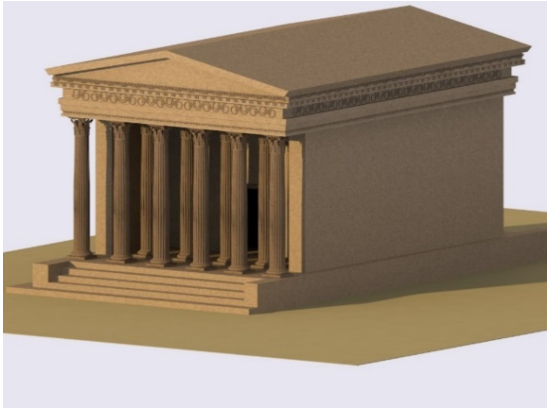

Figure 6.9. Prostylos model of the temple structure (Author archive).

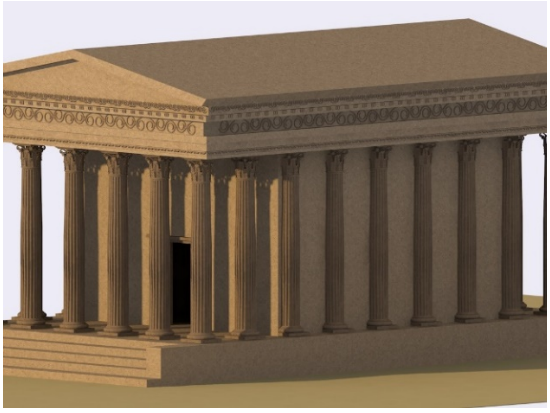

Figure 6.10. Pseudo-peripteros model of the temple structure (Author archive).

The architrave, frieze, cornice and pediment parts were modeled and integrated with the column capitals, creating a holistic model of the temple. Limestone, which is the main material of the building, was added to the model in order to provide a realistic appearance during the modeling phase. The final model has been saved in .dae format so that it can be run in the ARkit program when completed.

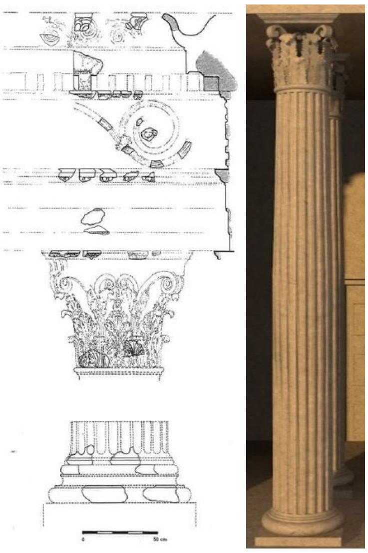

Figure 6.11. Column modeled with reference to Görkay's drawing (Görkay, 2002),(Author archive).

6.2 An AR Application for Alexandria Troas Podium Temple

As described in previous chapters, AR is the process of superimposing real environment and virtual layers creating an increased level of perception. When presented to the user simultaneously, this process has the potential to create various educational and entertaining content. It is possible to create these contents with different AR methods such as location based, marker based, user defined. In this section, the generation stages of the AR application, which was developed to represent the podium temple in the ancient city of Alexandria Troas, which constitutes the case of the research and whose historical and cultural importance has been shown before, will be explained. Since the research focuses on the virtual reconstruction of the temple structure, it has been studied primarily on a location-based AR application. The application, which works over the user and the temple location, could not achieve the desired result because the location services did not work clearly. In order to solve this problem, the application has been changed so that it can run in a location determined by the user. In this way, the user can experience the virtual reconstruction of the building in the ancient city, at the exact location of the temple. In order to achieve this situation, after the software processes of the application were completed, the data of the temple, whose drawing and modeling studies were done before, were transferred to the application and trial studies were carried out. Field studies of the application, whose test phase was completed, was experienced in the ancient city of Alexandria Troas.

6.2.1 Motivations For Software Selection

Within the scope of the thesis, the users of the cultural heritage area are asked to access more information about the historical environment by not only seeing the ruins in the area but also experiencing the original forms of the buildings. At the same time, it is aimed to discuss the hypothesis that "users who experience the structure in place and in a holistic way with its real dimensions have more information about the area" in line with user experiences.

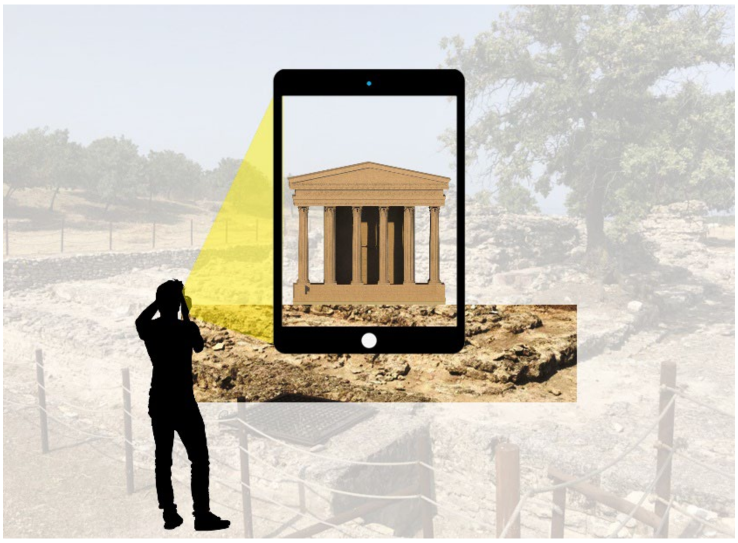

Figure 6.12. The concept of the AR application (Author archive).

In line with the goals determined above, it was decided to create a location-based AR application for the ancient city of Alexandria Troas. Accordingly, users in the ancient city now have the opportunity to experience the application developed for the podium temple with their IOS-based devices. With the users pointing their mobile devices at the temple, the holistic virtual reconstruction of the temple, which has reached today's foundation walls, appears on the device screen in 3D. They get the opportunity to get closer to the temple and walk around and within the area as much as allowed. In this way, users who can currently observe its current state can experience the original state of the building. And also it makes the ancient city tour as enjoyable as it is educational.

At this point of the study, the AR SDK platforms were examined and some field studies were conducted. In line with the motivations determined as a result of the studies, it was decided to create an application in swift language on the XCode platform using ARkit SDK.

6.2.2 Building the Application

Although certain studies were carried out during the creation of the application, the desired results could not be obtained. In the continuation of the study, with the idea of creating an effective application, software development experts from stechome and inforce companies were studied on different versions of the application. After deciding on the working principle of the application, which device it would be compatible with, and the detail level of the models, assistance was received at the creation of the AR software. The creation of an AR application and the integration of the models previously prepared in line with the restitution drawings were provided by the software experts.

The suggested application developed for the city of Alexandria Troas was created for devices with IOS system in the Xcode program. While developing the application, the open source ARKit library was used. ARkit provides location-based AR experience to users by using the data obtained through camera, GPS, Gyroscope, and CPU sensors.

The working principle of the program can be briefly explained as follows;

The application first determines the user's position and then calculates the location and distance of the model in order to ensure that the model defined in the system comes out at the specified location. In this way, model dimensions are scaled with reference to the user position. The model grows larger as the user approaches the defined location, and becomes smaller the further away. It is a necessary stage for the experience to be realistic and to strengthen the space perception of the users.

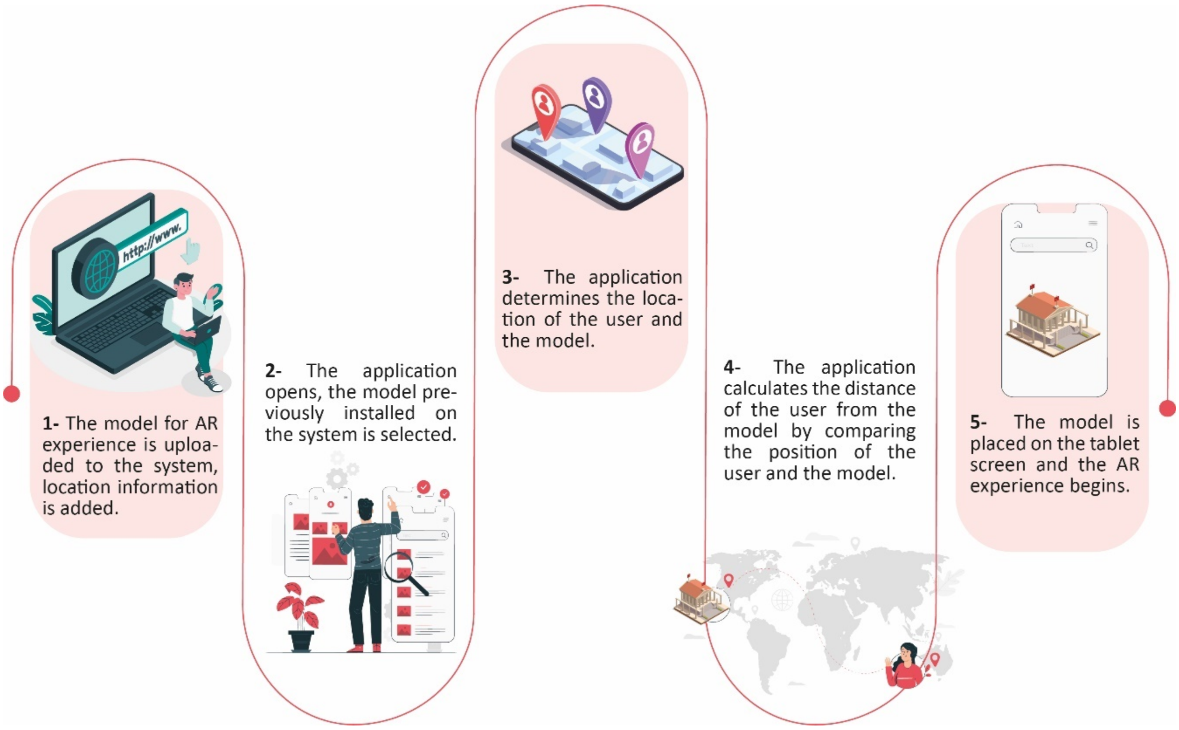

Figure 6.13.The working principle of the program (Author archive).

The working principle of the program

Within the scope of the thesis, users were asked to experience location-based AR application, but in addition to location-based experience, a QR option was added to the application during the study. The QR option is easier to add and experience than the location-based AR option. In order to provide the QR experience, the user must read the QR code previously defined on the application to the camera. The application that recognizes the QR code places the model associated with the code on the code. After the model appears on the screen, it can enlarge and shrink the model and rotate it.

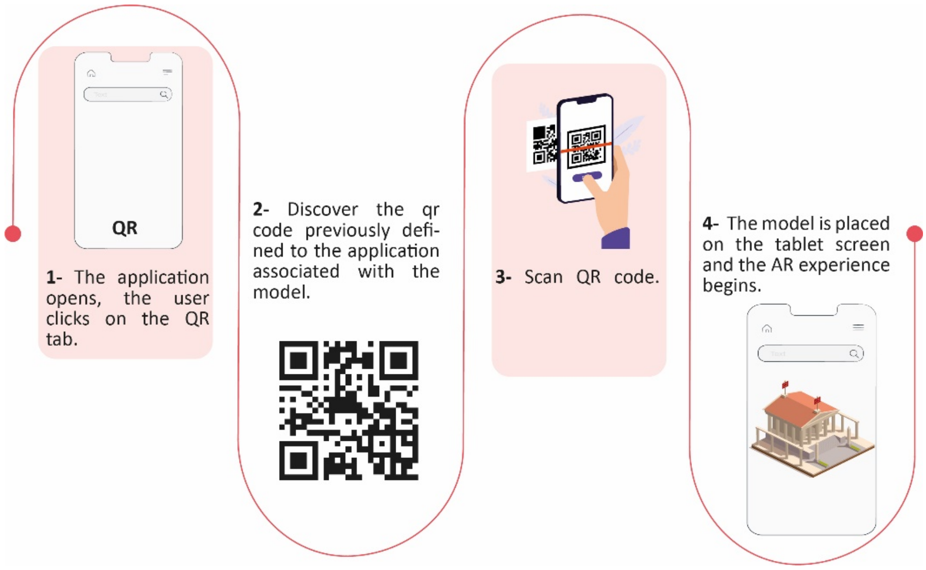

Figure 6.14. The working principle of the QR code-based program (Author archive).

With Xcode, Augmented Reality App project type was selected in swift language and application was started to be created. First of all, necessary actions have been taken to load the model into the project. For this, the previously drawn model has been added to the "art.scnassets" folder. SceneKit was used to make the render adjustments of the created application. SceneKit is the native 3D rendering engine for iOS that connects directly to ARKit. In order for the model to work in ARkit environment, the models to be used in the application must be converted to.scn format. Therefore, the dae format model was converted to the .scn format using the editor — convert to SceneKit scene file format option. Model in SceneKit environment;

• size,
• material
• position
• light-shadow adjustments were made.

The position settings of the model to be displayed on the stage were adjusted from the node inspector panel. This panel allows you to change the properties of the selected node of the model. Necessary size adjustments, position and rotation adjustments are made from this panel.

The material adjustments of the model were provided by assigning the required material to the material inspector panel. A mussel shell limestone stone material was loaded into the diffuse section of this panel. In this way, the material required for the temple to have a realistic effect in the AR environment has been added.In the material inspector area, desired material can be assigned to different nodes in the model and color adjustments can be made. Different color profiles are available here. Profiles such as Phong / Blinn / Physically Based are available, and each profile offers different color and detail.

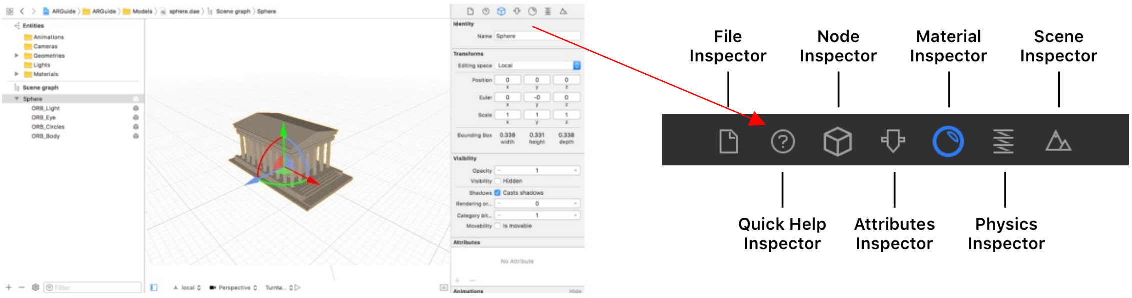

Figure 6.15. Panel where the arrangements such as material and size are made (Author archive).

Xcode library offers different lighting options such as Omni, Directional, Spot, Ambient, IES, Light Probe for lighting settings during the AR experience of the model. Model lighting is very important in order to provide a realistic experience to the users of the application. At this point, the model is illuminated with the directional light option defined in the application.

In order for the application to run the model, the added model must be defined in the code that already exists in the ARkit library. For this, the model is defined to the application by changing the name of the scene in the ViewController file. After the model is defined in the program, necessary improvements have been made to ensure that the model can be found in the desired position.

```
//          if self.modelNode == nil {
              let modelNew : String = "art.scnassets/" + model + ".scn"
              let modelScene = SCNScene(named: modelNew)!
```

Figure 6.16. Code in which the model is defined to the application (Author archive).

After the model is defined in the program, necessary improvements have been made to ensure that the model can be found in the desired position. For this, Core Location library is used, which enables to find the location, height and direction of devices with IOS operating system. The model is created by calculating the distance between two distances with Core Location.

```
    }

    func bearingBetweenLocations(_ originLocation: CLLocation, _ driverLocation: CLLocation) -> Double {
        let lat1 = originLocation.coordinate.latitude.toRadians()
        let lon1 = originLocation.coordinate.longitude.toRadians()

        let lat2 = driverLocation.coordinate.latitude.toRadians()
        let lon2 = driverLocation.coordinate.longitude.toRadians()

        let longitudeDiff = lon2 - lon1

        let y = sin(longitudeDiff) * cos(lat2);
        let x = cos(lat1) * sin(lat2) - sin(lat1) * cos(lat2) * cos(longitudeDiff);

        return atan2(y, x)
    }
```

Figure 6.17. Coding that enables model positioning (Author archive).

The working principle of the CLLocation code can be explained as follows:

• It obtains the user's location data through GPS systems.

• Determines the desired location of the model.

• It calculates the distance between these two locations in meters. Adjusts the size of the model according to the distance it finds.

• As the user location changes, the model is updated in line with the location data instantly received from the device.

Subsequently, an interface design has been made. The figure 6.18 shows the interface created for the application. The application offers 2 different AR options for the user to experience the model by reading the QR code or using its location.

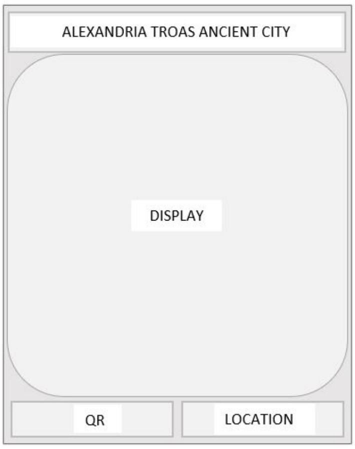

Figure 6.18. Menu plan of AR application (Author archive).

Image elements were added to the project interface using the UIKit library. Interface has been developed with elements such as UITabBarController, UILabel, SCNView, UIButton, UITextField. With the UITabBarController, the user can switch between the QR and location tabs at the bottom of the screen. Functions that are run when the application is opened with ViewDidLoad function are defined. With UILabel it has been provided to print out some results.

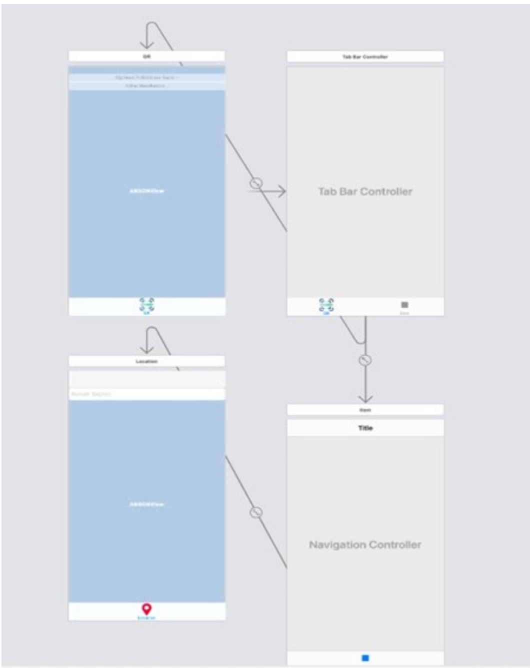

Figure 6.19. Tabs and transitions created for the application (Author archive).

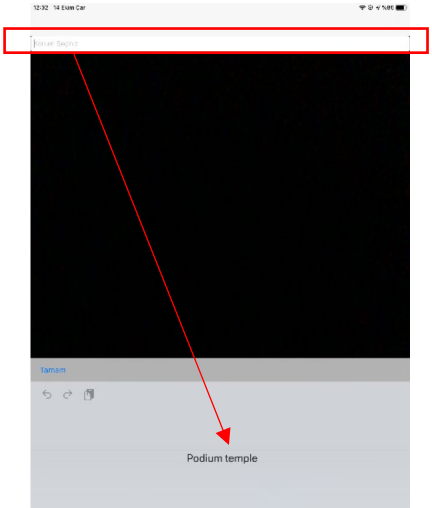

Figure 6.20. Selection of the model to be viewed (Author archive).

When the user clicks the location button, he / she has to select the model to be displayed. After the model to be displayed is selected, the user receives a notification about the model that appears on the screen and can also observe the distance to the model at the top of the screen. In order to do this, the feature of sending notifications to users has been added with "firebase" and "local notification" functions. In this way, users can receive notifications about the model displayed while the application is open or in background mode.

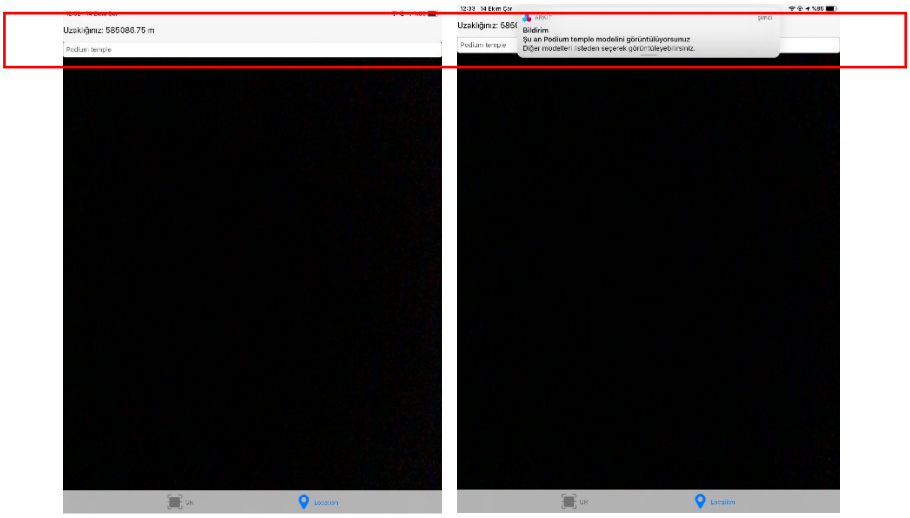

Figure 6.21. working principles of application: a) displaying the distance of the model to the user, b) the application sends the notification of the displayed model (Author archive).

A panel has been designed so that the created models and locations can be easily added to the application. The panel can be accessed through the website "http://stechome.com.tr/php2/crud.php". The application can run any model at any desired location in line with the latitude and longitude values entered on the panel and the added model. With the edited "edit" button, the added data can be changed. In order to observe the position accuracy of the entered latitude and longitude values, the "show location" option has been added. The position added in this way is displayed on the map. With the "Enter data" button, a different location-model can be added to the system. Sample data added to the panel are shown in the figure 6.22.

Figure 6.22. Panel where data entry is made (Author archive).

Figure 6.23. Code that enables data retrieval from the web address (Author archive).

The json output of the data added to this panel is taken and transferred to the application. The different location information entered into the system is listed with the "pickerView" code. The number of added data is determined by "numberOfRows" and data information is obtained with the code "didSelectRow". In this way, the data added to the panel are transferred to the program and run in the application according to the data selected in the pickerView.

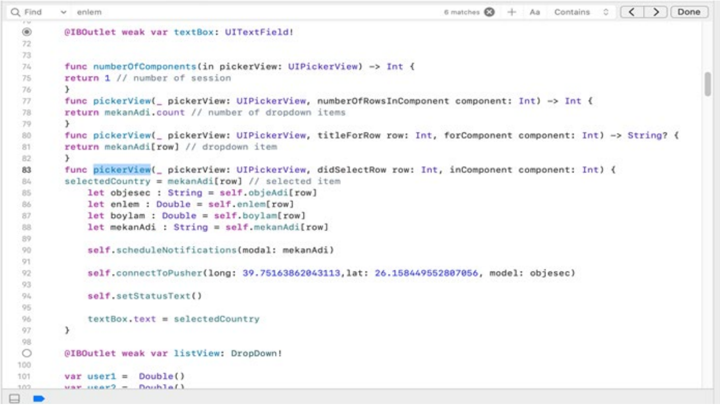

Figure 6.24. pickerView coding (Author archive).

After all transactions were completed, the location-based and QR-coded augmented reality application was completed.

6.2.3 Different version of the application

As explained in the previous section, in the application created using location services, a number of changes were made in the application, as a clear result could not be obtained at the point of determining the actual location of the temple and the location of the device used in the area. At the same time, the working principle of the application has been changed so that the users who experience the application can view the model more easily. At this stage, Unity 3D game engine was used to eliminate existing deficiencies and errors.

Unity 3D is a game engine that enables game development for mobile devices such as computers, tablets, phones and consoles such as Xbox, Playstation. A game developed with Unity 3D can run without the need for a computer setup and can be easily converted to the format of the environment to be used (computer, console, mobile devices). Personal developers can use the Unity 3D engine free of charge and publish the application they have developed. In the application developed with the personal version, the text "Made with Unity" and the Unity 3D logo are displayed on the screen when starting the application. If there is a profit from the application, there is an obligation to purchase paid versions above a certain profit. Since Unity 3D provides a 3D working environment, it also allows the creation of various VR and AR applications besides games. At this stage of the work, Unity 3D game engine was used with ARKit library for the continuation of the application.

The working principle of the application works as follows;
After the application is opened, the device camera analyzes the ambient data and determines the surfaces where the model can be positioned. At this stage, the reference point added to the application is active and visible on the tablet screen. The user can position the model on the surfaces where the reference point is located in the scanned environment. After the surface where the model will be located is determined, the user must click on the screen 2 times to display the pseudoperipteros model number 1. With a double click on the reference point of the user, the model becomes viewable on the tablet screen. In order to view the Peripteros model, which is the model number 2, it is necessary to click on the screen 3 times. After this stage, the model remains fixed at the point determined by the user, the user can navigate around the model and experience all its facades. As the environmental conditions allow, the user can get closer and farther to the model.

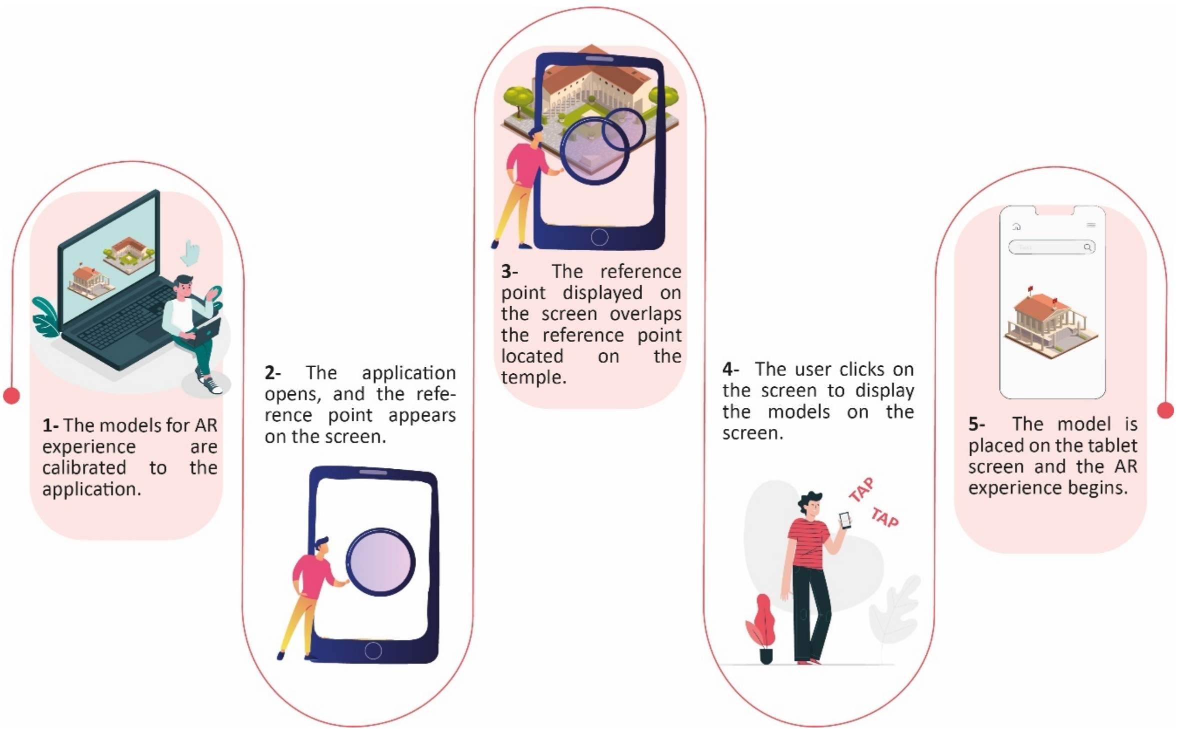

Figure 6.25.The working principle of the 2nd application (Author archive).

The first stage of creating this application is the new project created in the Unity program and started to be implemented. After the project page is opened, the Unity plug-in, which contains ready-made scenes to provide an AR environment, is included in the application. After the plugin is included in the application, the UnityARKitScene file is opened in the assets folder. In the file settings, the operating environment is changed to IOS.

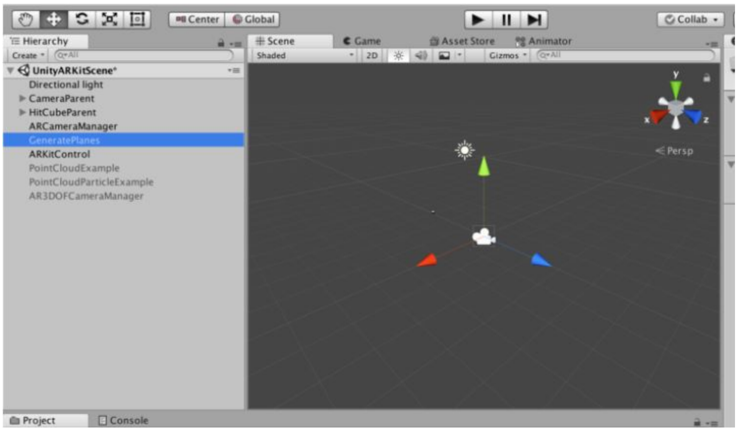

Figure 6.26. Unity ARKit AR environment (Author archive).

In the application, it is desired to place the model on a surface determined by the user. For this, the application must determine the flat surfaces. By using ARKit Visual Inertial Odometry technology, the device is able to determine the position of the user in the space by monitoring the environment with camera data while the device is in motion. With this data, it can detect the horizontal and vertical planes in the camera angle. In this way, the application determines the planes where the model can be positioned and displays it to the user on the device screen.

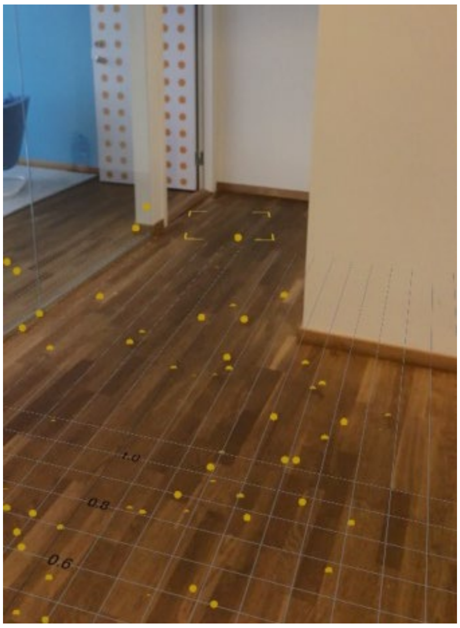

Figure 6.27. Determination of the plane with ARKit Visual Inertial Odometry technology (URL5).

The application sends many polygons to the perceived environment in line with the camera data in order to detect a flat surface. If these polygons overlap with each other and define a flat surface, the system detects that the model can be placed on this surface and defines the reference point on this surface.

```
if (raycastManager.Raycast(touchPosition, s_Hits, TrackableType.Planes))
{
    if (s_Hits.Count > 0)
    {
        var hitPose = s_Hits[0].pose;

        transform.position = hitPose.position;
        transform.rotation = hitPose.rotation;

        if (!visual.activeInHierarchy)
            visual.SetActive(true);
    }
}
```

Figure 6.28. Coding for placing to the desired model (Author archive).

When it comes to placing the model, the user is asked to experience the AR environment with a practical method in line with the working principle of the application. In order to achieve this, a system where the user can view the model number 1 on the device screen by clicking on the screen 2 times, and for the model number 2 by clicking the screen 3 times, a system has been designed. Figure 6.29 shows the script that allows the desired model to be displayed as a result of the number of times the user touches the screen.

```
rotnew.x = 0;
rotnew.z = 0;
if (touch.tapCount == 2 && touch.phase==TouchPhase.Ended)
{

    ObjIndex++;
    if (ObjIndex >= ObjSlider.Count) { ObjIndex = 0; }

    Destroy(obj);
    obj = Instantiate(ObjSlider[ObjIndex],
        pos,
        rotnew);


    break;
}
if (touch.tapCount == 3 && touch.phase == TouchPhase.Ended)
{
    Destroy(obj);
    obj = Instantiate(objectBigSpawn,
        pos,
        rotnew);

    break;
}
```

Figure 6.29. Coding for placing to the desired model (Author archive).

After these processes, the temple models that will be used in the application and that we have previously modeled are transferred into the assets folder. Since the elements of the model such as flooring, column, roof in ARCHICAD environment is drawn with different tools, they are formed in different groups in the unity environment. The limestone block material, which is the construction material of the temple, is assigned to the desired surface from these elements. In the Inspector panel, the model's height, aspect ratio and coordinate information are changed. At the same time, light adjustments can be made on this panel. When a new stage layout is created over Unity, the light setting is automatically opened with the directional light option in the Hierarchy panel. This light is a type used to make sunlight work in a way similar to the real world. The light type can be changed by selecting different light types from the area where the directional light option is available. Ready lights with different light settings such as point light, spotlight, area light, reflection probe, light probe group can be integrated into the project. At the same time, Unity provides many different settings of the selected light type, such as spreading angle, color, brightness, resolution, reflection. At this point, 2 different directional lights were added to the created AR project, preventing the shadow situation that could make the model difficult to read at different times of the day.

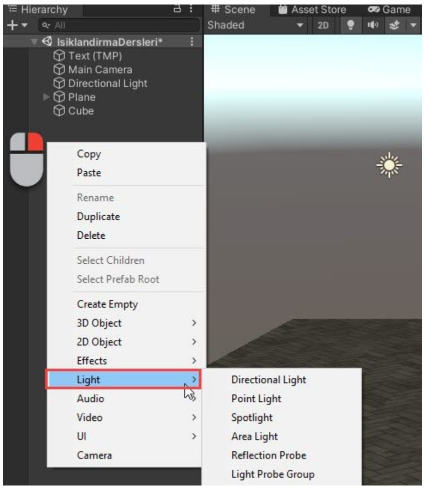

Figure 6.30. Adjusting light settings in a unity environment (Author archive).

In this version of the application, no interface has been designed, and the application is set to scan the surface as soon as the user starts the application.

Within the scope of the research, it was requested to experience the original state of the Podium temple structure of the ancient city of Alexandria Troas. With the application, the user should be able to observe the temple from all fronts and get as realistic and effective an experience as possible, while experiencing the city in an augmented environment. In this direction, various trial studies were carried out in order to ensure smooth navigation around the temple, to have a realistic experience, to observe the effect of light and shadow levels on the experience at different times of the day, to experience the feeling that the temple material arouses in the user during the experience, and to notice the disruptions that may occur while experiencing the application. Trial studies were carried out by different people in different places. When the trial studies were effective, field studies were started.

Figure 6.31. Testing the application (Author archive).

6.3 Field Studies

After the trials, in-situ studies were carried out in the ancient city of Alexandria Troas. For this purpose, first of all, the excavation director Erhan Öztepe was contacted and it was learned how the route of the visitors coming to the site was in the ancient city. According to Öztepe, when visitors enter the forum area, they first encounter the polygonal structure and the odeion, after observing this place for a while, they observe the ruins of the fountain and encounter the podium temple. The information sign at the intersection of the fountain and the podium temple attracts the attention of visitors and they spend time here for a while. While wandering around the temple, they encounter the area where important ruins unearthed during excavations are located and after observing this place, they experience the other side of the temple. Visitors return by following the same route after experiencing all the buildings and artifacts within the boundaries allowed by the excavation area. Based on this route, an information text describing the AR application that the users can experience in the field has been hung in front of the information board that the users encounter during the experience.

Figure 6.32.Experiencing the temple without application / with application (Author archive).

At the same time, the reference point where they should position the temple, which is necessary for the AR experience to take place, was placed on the temple ruin in a way that does not cause any damage to the ruin. Figure 6.33 shows the information board and reference point to describe the navigation route of the users within the area.

Figure 6.33. Navigation route in site (Author archive).

In the text, visitors were told how they could experience the temple with the tablets on which the application was already installed. For this, after the visitor opens the application on the tablet, the AR experience is started by clicking the screen 2 or 3 times -when clicked

2 times peripteros model appears on the screen, when clicked 3 times pseudoperipteros model appears on the screen- by overlapping the reference point that appears on the screen with the reference point on the temple. In this way, the users are provided with the opportunity to have a fun and educational experience in the field by experiencing 2 different models of the temple in AR environment.

Figure 6.34. a) An information text telling visitors how the AR experience will be generated b) the reference point placed on the temple (Author archive).

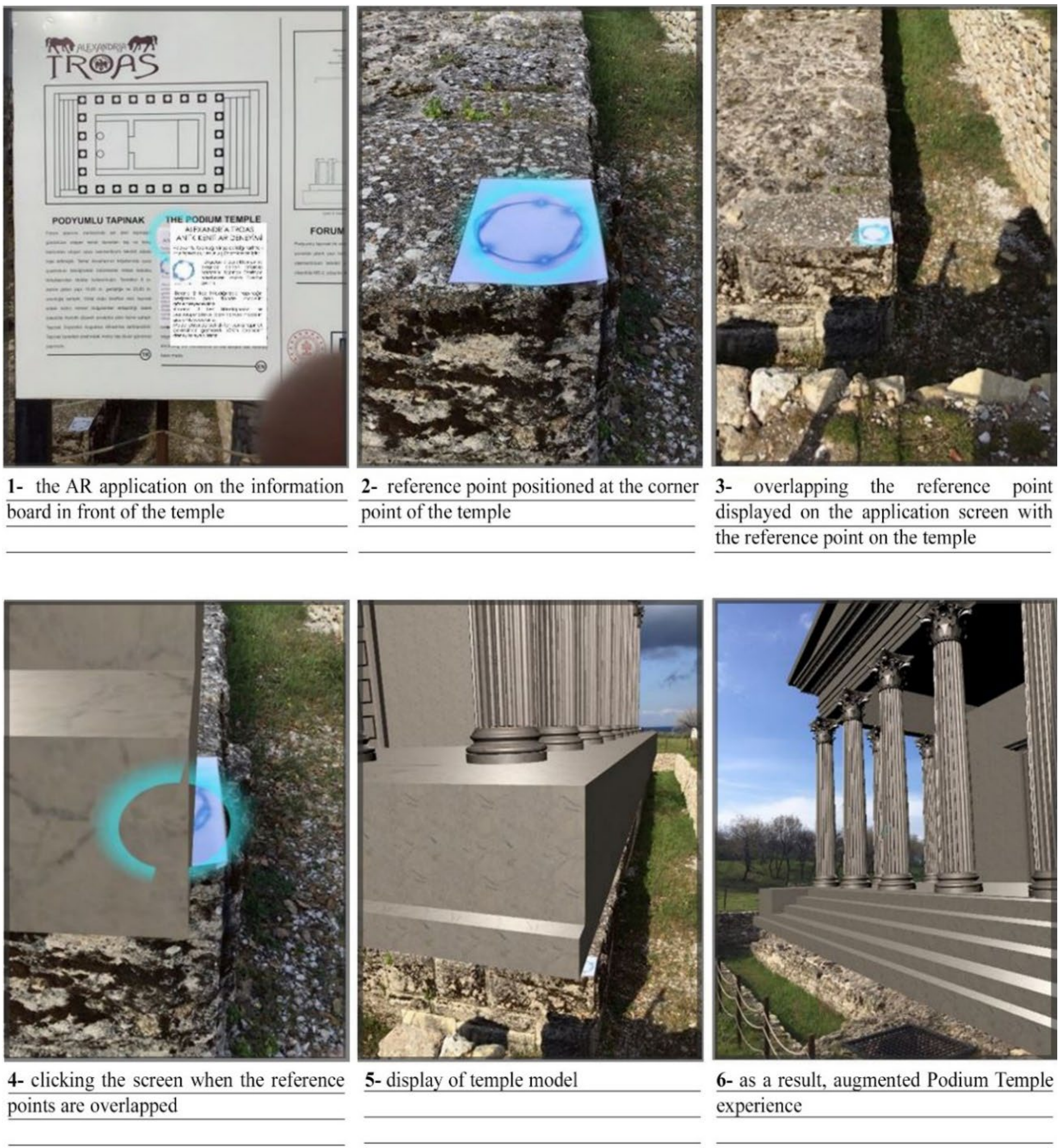

Figure 6.35. Overlapping the reference point placed on the temple with the reference point displayed on the tablet and as a result placing the model (Author archive).

Visitors to the ancient city of Alexandria Troas can both observe the current state of the ancient city and learn about the situation of the podium temple at the time it was built through the augmented environment they will experience with the application. The augmented environment to be observed by a visitor who will experience the ancient city with the application, after entering the forum area is shown in figure 6.35.

Figure 6.36. Augmented environment experienced by the visitor entering the forum area after the model is placed in application (Author archive).

Figure 6.37. Augmented views of podium temple (Author archive).

7 CONCLUSION AND RECOMMENDATIONS

"Architects create space and dwelling, archaeologists seek space and dwelling," says Prof. Dr. Cevat Erder. In order to make projections about the future, the architect must understand the past. For this reason, we have no doubts about the necessity of preserving, documenting, visualizing and experiencing the natural and cultural heritage we have from the past. There are some basic problems in keeping the cultural heritage areas that contain valuable information about social life, such as the cultural life and socio-economic status of the past societies, and transferring them to future generations by learning by the society. The study is designed to focus on this problem and to offer an alternative solution to this problem.

Some tools that have become portable and even wearable with the developing technology improve our perception of reality and undergo a serious transformation. In such an environment, AR creates a perception environment beyond the reality we know, in the real and virtual world intersection, which is formed by blending with synthetic data, beyond perceiving the physically existing. This perception environment is seen as a very effective method to focus human attention on a certain context and provides many uses with various motivations. One of these usage areas is AR applications developed for cultural heritage sites. AR technology, which allows to experience different places and time periods at the same time, is used as an effective tool for understanding the value of architectural cultural assets correctly, presenting them to the masses and transferring them to future generations.
Based on these motivations, it is planned to develop an application where virtual reconstructions of the podium temple can be experienced by using AR technology in order to keep the historical artifacts and structures of the ancient city of Alexandria Troas from centuries ago alive. For this purpose, AR development environments and software were examined and location-based systems were studied. Since the desired result could not be obtained with the created application, the user defined plane system was emphasized. This application has been created and tested using the unity game engine.

For the podium temple, which is one of the important architectural cultural assets of the ancient city of Alexandria Troas, 3D models made in line with the restitution data and virtual reconstructions have been made experienceable with the application created. The field studies of the application, whose test stages were successfully completed, were carried out in the ancient city of Alexandria Troas. The situation of the podium temple at the time of its construction and the current situation could be experienced in a comparative way.

With the applications prepared in parallel with the main problem of the study the propositions that are desired to be tested can be reached as follows:

- *AR is a tool that can enrich designs by strengthening the perception of space for architects and architecture students.*

AR has the potential to be used in the sketching and problem solving process, in the idea development stage, as a method that helps the designer to develop alternatives.In the space design process, unlike traditional methods, the designer can see the 3D organization by trying different possibilities in a short time, saving time and materials.

- *In cases where the perception of architectural space is complex and multi-layered, AR contributes to the meaning of space experience by increasing the level of perception.*

With AR applications, products can be represented in real places. Designers can see their designs on-site by providing access to enriched information during 'field trips'. This situation leads to the conclusion that AR can contribute to the perception and design of space.It is possible for architects to experience and revise their designs on a one-to-one scale in AR systems.

• *Making learning action easier and more fun*

With the interactive structure provided by AR technology, it makes users a part of the experience by removing them from the passive role. Users witness the living 3D representation of the area itself, as well as the verbal, visual or auditory 2D presentation of historical artifacts and structures presented using AR in cultural heritage areas. and it becomes part of the demonstration. Users, who become a part of the area and experience, can obtain more and permanent information about historical artifacts and structures, and the act of learning becomes fun in this direction.

• *Creating a sense of belonging to the cultural heritage sites of the user*

In the cultural heritage areas represented by AR technology, users can participate emotionally with the verbal, visual and auditory data given in the area, and by playing an active role in the experience, they become a part of the area and thus participate in the experience emotionally. Instead of learning remotely, users can feel the historical environment and space, navigate in 3D, and experience the history on display. This augmented environment allows users to assimilate the space by changing the perception of reality. This situation also increases the motivation for the continuity of learning.

• *AR applications arouse curiosity and interest on users.*

Various animations, 3D visuals and stories presented at the level of increased perception with AR technology are interesting and arousing factors for users. This environment, which has become fun for users, is a unique tool that can be used to trigger learning as well as to attract attention to the desired subject. At this point, the presentation of cultural heritage sites such as archaeological sites using AR technology is very important in terms of increasing the interest and curiosity in the field, reaching different audiences and triggering cultural heritage awareness.

• *Creating awareness that architectural works that have not been repaired yet can be evaluated and represented with a different method.*

With AR applications developed within the scope of the study and different examples developed in this field, users can touch different time layers by experiencing the historical environment and building on-site, and make a comparison of the building and the environment between the past and present. They can learn about the materials and elements of the building as they witness the process and changes over time. This situation raises awareness about the importance of preserving its cultural heritage by evaluating it. The application is not only for visitors who have experienced the site, but also as a tool that will help architects, archaeologists and art historians involved in the excavations to make an assessment and estimate for the building.

• *Ensuring the sustainability of historical environments*

Historical buildings and environments, which cannot be prevented from being destroyed as a result of climatic conditions, natural disasters and various human activities, can be kept alive with virtual reconstructions created using AR technology. In this way, many historical artifacts and environments will be transferred to future generations. In this way, the transfer of historical consciousness to future generations and its sustainability can be achieved.

• *Being able to renew itself continuously*

The fact that AR technology can protect, document, visualize and experience historical artifacts and structures without any physical intervention keeps them away from irreversible interventions. This situation also enables the reproduction of historical artifacts, buildings and the entire historical environment without any damage in the light of new scientific data. While it saves both cost and time, it can offer a solution at a very important point in terms of the protection of historical buildings and environments.

• *Promotion of cultural heritage and creating a base for other historical structures*

The applications developed within the scope of the study were created in line with the working principles of the disciplines of archeology and architecture in order to introduce different historical structures and to form a basis for future studies in this field. The applications created set an example for future studies and form a basis for the promotion of cultural heritage.

• *Contributing to the literature in the field of application and for the ancient city of Alexandria Troas.*

With the application developed within the scope of the study, it is seen that AR technology has a great potential in terms of representation of cultural heritage. It contributes to the literature in terms of creating a base for the applications to be produced in this direction in the future. At the same time, since there is no detailed scientific study carried out for the podium temple structure of the ancient city of Alexandria Troas, it constitutes a resource in this field and contributes to the literature. Moreover, since the protection work of the podium temple has not been carried out yet, it is a document for these studies in the future.

• *Introducing AR technology and disseminating its use*

Along with all these contributions mentioned above, the study contributes to the dissemination and promotion of Augmented Reality technology, which has just begun to be recognized in our country. It is thought that distribution of promotional brochures of the application created for the ancient city of Alexandria Troas in tourism centers will increase the recognition of both the ancient city and the application.

• *Contributing to tourism*

Historical buildings and environments constitute an important part of cultural tourism in developed countries. At this point, the information desired to be given to tourists with AR applications in areas such as ancient cities and museums, where intense tourism activities are carried out, ensures that the information is presented effectively during the trip. At the same time, this information can be transmitted and customized in different layers such as period, culture, purpose of use. Information data flow can be arranged in line with different parameters such as tourists' interests, ages, and knowledge levels. This situation will become attractive for tourists and will ensure the revival of tourism activities. AR technology offers new opportunities to provide a more enjoyable and enriching tourism experience in terms of learning and entertainment.

Although the objectives set for the AR application developed the podium temple in the ancient city of Alexandria Troas have been achieved, there are also aspects that can be improved in future studies. These can be evaluated as:

- By conducting group trials in field studies, an application can be developed in line with the received criticism and data.

- The study, which was limited to the podium temple in terms of time and technical competence within the scope of the thesis, constitutes the first steps of a project designed to introduce the ancient city of Alexandria Troas, revitalize history and provide users with an effective and instructive holistic experience. In the continuation of the study, it is one of the goals of an adventure that started with this thesis work, not only to limit the AR experience the podium temple, but also to continue with the addition of other structures in the area.

- In future studies, by adding auditory and literary data to the visual data already used in practice, a fiction that draws the user into the experience and encourages them to explore and learn together can be considered. In fact, in the continuation of the process, it can be made a much more interactive platform where people will interact with each other through various social media platforms and rediscover the area through the application with activities such as storytelling.

- In future studies, besides the development of the application, some changes and corrections may be required for the models used. The models were created by using the data of archaeological excavations and research studies carried out in the area. Excavations continue in the area today. At this point, there is a possibility that models may change and undergo various transformations with all kinds of new and different data obtained from the field. Temple models may need to be reproduced in parallel with these scientific data.

- A holistic view of the ancient city can be obtained by incorporating the augmented experiences starting with the podium temple structure of the ancient city of Alexandria Troas, and the inclusion of other structures and artifacts in the area. History, which is revived through the application, will bring back to life of the ancient city spirit that will prevent Alexandria Troas from remaining in the past and disappearing. This will also enable the field to be introduced and learned. The feedback obtained with this study can be used in the future with different motivations in the works such as representation, preservation and interpretation of different ancient cities and artifacts.

Considering all these evaluations, AR technology is a tool that can meet our communication and interaction expectations with its different uses. The applications of AR technology, which has a great potential in the representation of architectural cultural assets, are increasing in this field and it seems that it will open the door to different worlds with different technological possibilities in the future. With this study, it is thought that it has an important place in the representation of architectural cultural assets and the dissemination of the use of this technology in archaeological areas that contain important architectural works.

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