VIRTUAL REALITY IN THEATRE SPACES

by

Sherouk Mohamed Shehab El Din Saad Badr

A Thesis submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in

ARCHITECTURE ENGINEERING

FACULTY OF ENGINEERING, CAIRO UNIVERSTIY
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ABSTRACT

Integration of Computational intelligence to theater composition has a great impact in theater space design approach. Introducing new technologies and techniques to increase theater performances interactivity with audience affected both theater spaces interior and architecture.

One of the recent technological advances supplied by computational intelligence is Virtual Reality (VR). VR can be implemented in theater experiment through different means and for different applications. Building Virtual Environments (VE) can interfere in the theatrical experiment in different levels starting from creating a complete virtual theater and ending to be a main stenographic high interactive tool on a real theater stage.

By studying the introduction of such new technology into different theatrical fields and applications, it was found that VR can be implemented in most of theater production levels; theater education, stage setting and design, effective scenographic tool in traditional and no traditional theaters and a main scenographic tool in cyber theaters.

The main objective is to study the impact on theater space interior and exterior design while introducing VR to theater spaces.

INTRODUCTION

At the same time Japan has proposed an innovative idea for World Cup 2022, Qatar, the country who won the hosting competition, offered a very materialistic and traditional bit. While Japan was offering a new era of implementing virtual reality technology in stadiums, Qatar offered five stadiums with high mechanical solutions to be built and disassembled after the World Cup and then donated to another less developed sports infrastructures countries, as Qatar is no need for such stadiums due to its small population. Again Qatar is thinking about exchanging materialistic objects rather than Japan thinking of exchanging technology that will demolish distance and language barriers between 208 countries. Japan's proposal was not to build any new stadiums that won't be used after the world cup, but to implement technologies that will be a starting point for new entertainment industries and to spread it all over the world.

Japan's innovative proposal is simply projecting the real match, which is played in Japan, into 3d Holographic images in the pitch of other 400 stadiums across 208 countries. Each match will be filmed and tracked in real time by 200 high-definition 3D cameras. Sound will be recorded by microphones beneath the pitch from the kick of a ball to the referee’s whistle, for the ultimate authentic experience (O'Callaghan, 2010). Fans will be able to watch and hear the match in their preferred stadiums without crossing long distances. Another interesting innovation proposed by Japan is the translation machines on the neck and the earpieces on the ears to communicate with anyone who doesn’t speak the same language to cross a new boundary, the language.

The purpose of presenting such example is to emphasis the role of implementing new technologies in entertainment spaces. The projection of 3D Holographic images is still underdevelopment and is considered a highly costive technology. Japan proposal didn't only predict that such technology will be very cheap by 2022 but also assumed that it will be more cost effective than the satellite broadcasting of such matches. There are new chances for developing countries to compete in many futuristic technology industries that doesn't depend on materialistic solutions but needs highly innovative potentials and creative ideas.

It is important now to identify the new directions in communications of this century. At first humans have invented language in order to be able to communicate with each other, but later every community invented its own language, not only living languages but also social and cultural languages between different community classes which led in the end to miscommunication with other communities. Now you have to learn dozens of languages in order to communicate with others. By time, this idea will completely disappear as the interface of technology is built on destroying such boundary to be easily spread. For example, different keyboards with different languages will disappear as touch screens with highly interactive interface that respond easily to the user commands will replace them.

Communication facilities will not depend any more on the users' culture history. It will only depend on their interaction. The same applies on the theater; the communication direction from stage won't be one way direction from stage to auditorium as it used to be before. It will be a networked directed communications between stage, audience, the other audience and space. New forces will be studied in designing the theater space. New free stages will be discovered. The performance won't be an innovative production presented by a director and a cast, but also it will be invented by audiences with different cultural backgrounds and different inputs. The space of performance won't be subjected to theaters and auditoriums but other public spaces will be easily transferred into theaters stages as wherever there is a place with crowd, there can be a performance with audiences.

The implementation of Virtual Reality technology in theater spaces will have its own reflections on theater design. In some cases, it will support the traditional form of theater production with innovative tools and technology. On the other hand, it will present new directions and forms for theaters spaces by studying the new forces arising from such interactive communication tool to create untraditional performances. Sometimes it will affect the idea of performing inside performance buildings by changing other spaces into live stages where public people are the audience and the actors.

As for identifying the traditional theater space in this study, it can be a building, a part of a building or even an outdoor venue in which performances of one kind or other are presented to an audience. It has its own facilities to attract and entertain the public. The most common types of performances are musical, acting, dance, opera, oratory, movies and other visuals. The term theater comes from the Greek verb "theatai", meaning to see, watch, look at or behold. The design of a theater space is related to the type of performance that will be presented, though today many aspects of the design of different types of theaters are similar. (Christine M. Piotrowski, Elizabeth

A. Rogers, 2007, p. 244)Theater spaces are always affected by the introduction of new theater movements and in the same time theater movements are also affected by the introduction of new technologies and techniques. There is always a cumulative relationship between art, science, technology, engineering and architecture. In this study, this relationship will be tracked to study the new possibilities and approaches that will be given by introducing a very promising technology as VR.

I. Field of study

The study is divided into 2 main units. The first unit is about studying traditional theater spaces and the second is about Virtual Reality and its impact in theater spaces. The following fields will be studied and explored through the study:

- The historical development of the traditional theater form, principles that affect its auditorium and the complexity of stage design.
- The impact of introducing multimedia on theater stage.
- Introducing virtual reality on stage and its main components.
- Applications and Case studies for implementing VR in different theatrical fields.

II. Thesis Structure

UNIT ONE: THEATER SPACES

CHAPTER (1): Historical development of theater types

CHAPTER (2): Principles that influence auditorium design

CHAPTER (3): Stage Machinery & Technology

UNIT TWO: VIRTUAL REALITY

CHAPTER (4): Introduction of multimedia to theater stage

CHAPTER (5): VR applications in theatrical field

CHAPTER (6): Case Studies

CHAPTER (7): Conclusion

III. RESEARCH QUESTION

The research question is how Virtual reality technology can be enhanced in the whole theatrical experiment and to what extent it will impact the experience, the space and the exterior.

IV. RESEARCH OBJECTIVES

The main research objective is to study the impact of introducing virtual reality in different theatrical fields. Enhancing virtual reality will be studied through various stages of theater experiment starting from using VR in preproduction phase of theater and stage design, ending to enhancing virtual reality as a main scenographic element on stage. This will lead us to search for different kinds of application for VR in theater space such as:

- Creating virtual theaters with unlimited design creativity for entertainment and education by using different VR systems.
- Visualizing and examining the stage setting design during the conceptual design phase by using desktop VR Systems.
- Replacing real 3D simulations by virtual environment and reducing the high consumption of money, time and material.
- Adding new and strong stenographic tools to theater stage to develop multimedia interactive theater performances such as dancing, music, drama …. etc.
- Adding new architecture approaches to form spaces that can highly implement Virtual Reality Technology.

V. Methodology

- Studying an introduction for traditional theater space architecture and interior design.
- Studying the history of integrating computational intelligence in theater compositions and its impact in theater space design.
- Searching for different kinds of virtual Reality that can be introduced in theater experiment and space and focusing on:

- Technical data design requirements.
- Fields of applications
- Limitations and drawbacks.
- Choosing two different theater experiments as case studies and analyzing the impact of virtual reality on both theater space and theater experiment

UNIT ONE: THEATER SPACES

1. CHAPTER (1): HISTORICAL DEVELOPMENT OF THEATER TYPES

"Theater Types" is a very general term. The criterion of classifying theater types is determined according to the purpose and sequence of the study. In this study the main purpose is to analyze and predict the new forms of theaters spaces by introducing one of the latest technology technique to theater stage, which is the Virtual Reality. The main sequence is studying the main factors that influence the "physical presentation" on recent traditional and non-traditional theater stages which highly interferes the relationship between audience and performance and therefore the architecture of the theater building. After analyzing such forms and summarizing the concerns of such physical presentation in each type, a brief history will be presented of the introduction of Digital and Computer Aided performances by the influence of technology in theater experience ending by the possibility of using Virtual Reality as an alternative or partner for physical presentation on theater stage. For this purpose, and for such sequence, two criteria for theater classification are chosen to be tracked in this study.

The first criteria, is the relationship between the two main elements of any performance building (house and stage) which presents the direct or indirect relation between the actors and the audience. The development of this relation is a reflector of the surrounding society culture and their socio-material conditions that affected the theater experience and produced such forms of theaters (Eaket, 2010). Theater forms have examined a high transition from traditional to non-traditional forms in the last sixty years so as to satisfy the new demands of the contemporary society. In order to understand the shifting of the theater experience in the new century and predict the possibilities of introducing new forms of traditional or non-traditional theater spaces, in this chapter theaters types will be first studied according to the degree of the auditorium enveloping the stage with a brief history of the development of each type.

The second criteria, is the type of performance which will highly affect the main factors that influence the auditorium and stage design that will be studied in details in the next 2 chapters. Not all performance types can be performed on all theater stages. A table that compares the best types of stages to each type of performance will be presented in the beginning of the next chapter.

1.1. THEATER MAIN ELEMENTS

All theaters have common base requirements regardless of their types. The space of any performing arts building consists of four main categories as shown in **Figure 1.1-1** & **Figure 1.1-2**. (Joseph De Chiara, Michael J. Crosbie, 2001, p. 720):

- **Front House:** Places required for serving theater patrons to the performance, during intermissions, and after the performance. These spaces typically include all areas the patron will encounter from the parking lot to the interior of the audience chamber, such as lobbies, foyers, circulation, box office, rest rooms… etc.
- **The House:** It is the audience chamber. It is the area which provides the audience by high acoustic standards, watching the show without distraction and feeling comfort and safe while receiving the utmost sensory stimulation toward the maximum emotional and intellectual experience.
- **Stage:** Stage is easily defined: it is the part of the theater where the performance takes place.
- **Backstage:** Backstage areas are there to provide accommodation and support for those whose work is focused on the stage such as dressing rooms, green rooms, performer and crew lounges, shops, storage rooms, and other support spaces for the stage, performers and technical crew.

The Following table represents the spaces in each category and its design considerations:

	Spaces	Design considerations
Front house	Public spaces Service spaces	Determining the initial impression of the patron's theatrical experience. Circulation study for how the patron gets into the building the box office, and then to the seat.

	Spaces	Design considerations
House	- Auditorium Seating	Performance type Seating capacity Visual criteria Acoustical criteria Architectural goals
Stage	Stage space Orchestra pit Stage Machines & Support Spaces	The nature of performance. Visual and acoustical criteria associated with each performance type. Stage machinery and technology installations Interactive Multimedia technology for digital performances.
Backstage	Production Maintenance Accommodation	Comprising the wide variety of dressing rooms, work rooms, and storage spaces needed to support what happens on stage.

TABLE 1.1-1: THEATER MAIN ELEMENTS SPACES AND DESIGN CONCSIDERATIONS (JOSEPH DE CHIARA, MICHAEL J. CROSBIE, 2001)

Theaters are classified into different types according to the relationship between its two main elements (Stage & House) or the type of performance played on stage.

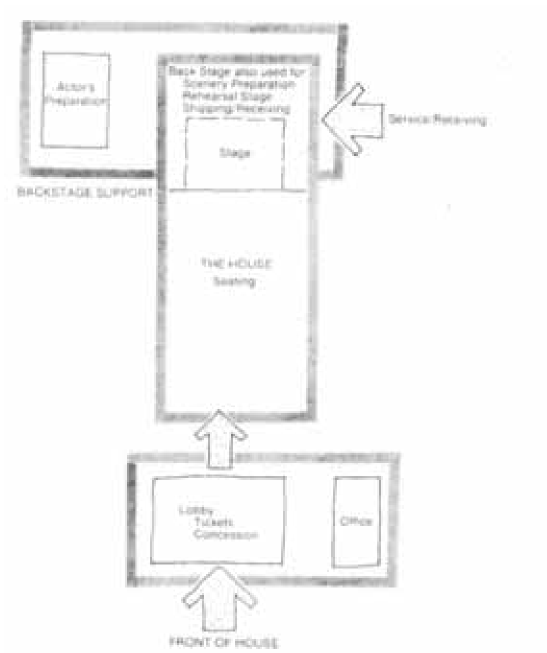


FIGURE 1.1-1: FUNCTIONAL DIAGRAM OF SMALL PERFORMING ARTS FACILITIES. (JOSEPH DE CHIARA, MICHAEL J. CROSBIE, 2001, P. 726)

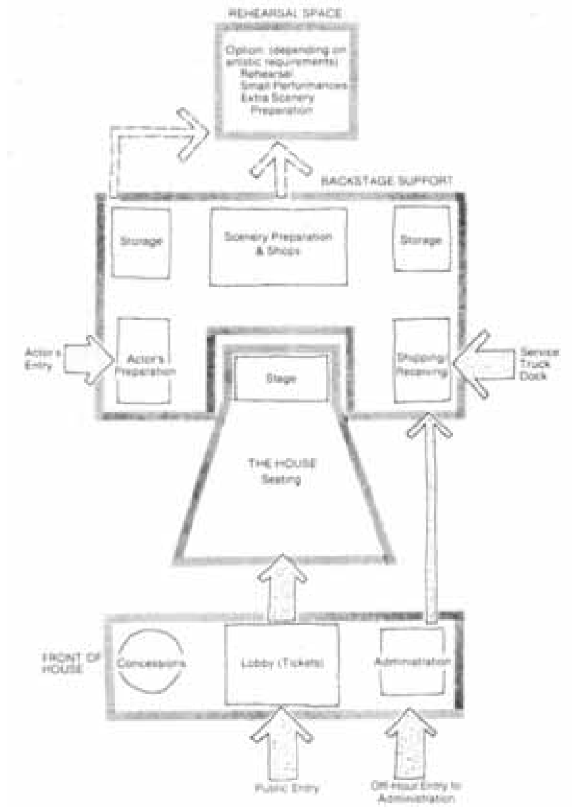


FIGURE 1.1-2: FUNCTIONAL DIAGRAM OF LARGE PERFORMING ARTS FACILITIES (JOSEPH DE CHIARA, MICHAEL J. CROSBIE, 2001, P. 725)

1.2. THEATER TYPES ACCORDING TO STAGE & AUDITORIUM

Throughout the history of traditional theaters from the primitive shape of early theaters until the most complicated forms of theater spaces in the 20th century, forces that affect the design of theater stage and auditorium can all be presented through one way direction vectors from stage to auditorium. The stage can be presented as a transmitter and the auditorium can be presented as a passive receiver. However the performance type was or even the relation between audience seating and the stage, still the direction of the forces is the same. But during the last 20 years the directions of forces completely had changed. It is no more one direction vectors, It has changed to a network relationship with new spatial vectors between the stage and the impassive audience that offered new forms of theatrical shapes that will be studied later.

In this brief historical study, such forces vectors and how they affected the theater shape will be analyzed and studied. Also, other external forces such as cultural and social factors will be taken into consideration to understand such forms and their developments throughout the history of theater design. One of the main factors affecting the issue of the form design of any performing art space is the relationship between the audience members in their seats and the performers on stage. Forces that influence such issue are:

- Type of performance (will be studied in the next chapter)
- Seating capacity.
- Historical precedents.

Since the late Renaissance until the beginning of the 20th century, the developing of theater shape technique was given to a unique stage type (The Proscenium Stage). Due to modern theatrical trials in the 19th century of the revival of earlier stage forms to accompany the traditional proscenium stage, new choices of theater stages types were given in the 20th century. (Joseph De Chiara, Michael J. Crosbie, 2001, p. 713)

In the second half of the 20th century and after the invention of electronic systems for film and television industries, both theater design and performing arts became technology driven. By introducing computational intelligence to theater stage it didn't only influence the theater performance, but also drove new shapes for the space it occupies. (Joseph De Chiara, Michael J. Crosbie, 2001, p. 1) . The development of stage technology and its affect on theater design will be studied in chapter 3.

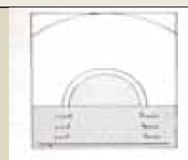
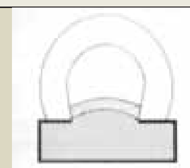
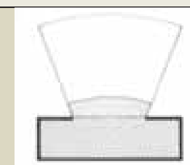
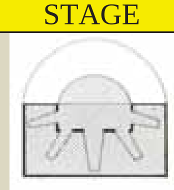
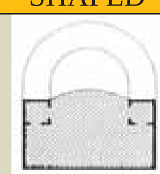
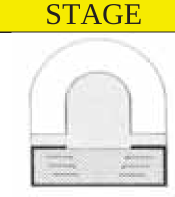
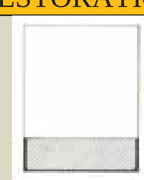
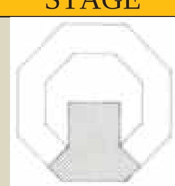
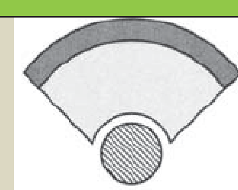
According to G.Izenor, the relation between stage and auditorium is divided into two main divisions: the open stage and the proscenium stage. These main divisions are subdivided into five auditorium configurations: three for the open stage and two for the proscenium stage. A six configure is added as multiform of more than one auditorium shapes. These six auditorium configurations are:

- Fully Enveloping Auditorium.
- Partially Enveloping Auditorium.
- Nonenveloping Auditorium.
- Horseshoe-Shaped Auditorium.

- Wedge-Shaped Auditorium.
- Convertible Auditorium and Multiform Stage. (Izenour, 1996, p. 162)

The criterion of differentiating between these categories is the arrangement of seating and the degree of auditorium enveloping the stage. The following is a brief study for each theater type and historical introduction for the development of each type up to contemporary and modern theaters.

The following is a graphic reference table to show the basic ground plans for ancient and modern plans not to scale. It emphasizes the shifting of shape and position among auditorium, orchestra and stage in order to understand the historiography of theater design. (Izenour, 1996):

Ancient plans	**Modern plans**		
Classical	**Late Renaissance**	**Baroque & New Baroque**	**Contemporary**
?BC-400AD	1550-1650	1650-1870	1870-1990
			
PREMITIVE	SINGLE VISTA STAGE	HORSESHOE-SHAPED	FAN-SHAPED AUDITORIUM
			
GREEK ANCHAIC IKRIA	MULITIPLE VISTA STAGE	THEATER OF RESTORATION	APRON, CALIPER STAGE
			
GRECO-CLASSICAL	PROSCENIUM STAGE	SHOE BOX HALL	THRUST STAGE
			

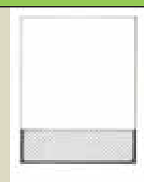
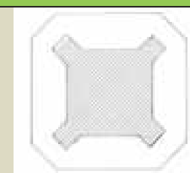
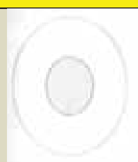
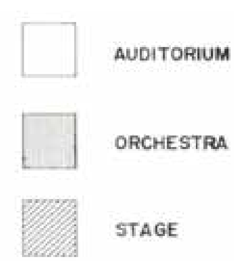
Ancient plans	**Modern plans**		
Classical	**Late Renaissance**	**Baroque & New Baroque**	**Contemporary**
?BC-400AD	1550-1650	1650-1870	1870-1990
GRECO-HELLENISTIC	THEATER OF SHAKESPEAR		CORNER STAGE 90 ° ARC
			
ROMAN	SHOE BOX HALL		IN-THE-ROUND-STAGE
			
GRECO-ROMAN-ODEUM			
			
ROMAN COLOESSEUM			
	FULLY ENVELOPING		
	PART.ENVELOPING		
	NONENVELOPING		
	HORSESHOE-SHAPED AUDITORIUM		
	FAN-SHAPED AUDITORIUM		

TABLE 1.2-1: GRAPHIC REFERNCE TABLE FOR THE RELATIONSHIP BETWEEN STAGE, ORCHESTRA AND AUDITORIUM ILLUSTRATED BY (IZENOUR, 1996, P. 33)

1.2.1. FULLY ENVELOPING AUDITORIUM:

1.2.1.1. THEATER-IN-THE-ROUND

I. Primitive theater:

"The first recognized theater shape is theater-in-the-round. In pre-historic days, villagers gathered and formed a circle to watch the primitive dance rituals of Shaman priests." (Ogawa, 2001, p. 17)

The stage was fully enveloped with audience. It reflected the primitive and intimate state between the audience and the performer with no boundaries in between. The only forces that reacted on the theater form were the direct forces from the center (the actor) to the circumference (the audience) disturbed equally with no racism between the audience which resulted in the pure circle form as shown in **Figure 1.2-1**.

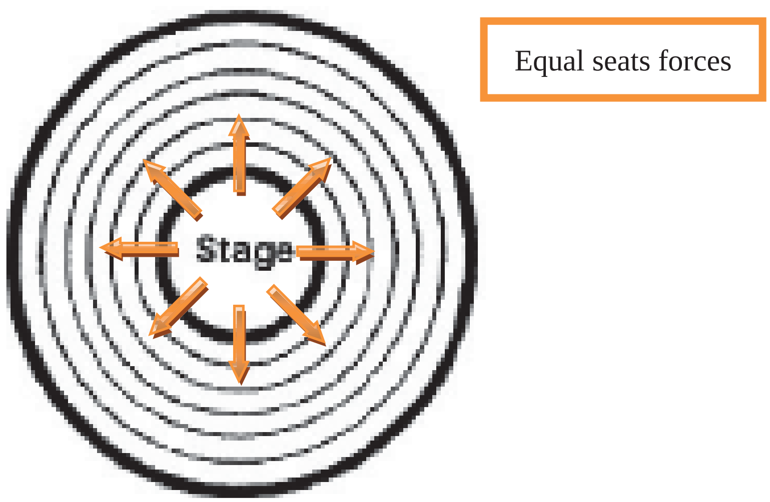


FIGURE 1.2-1: THEATER-IN-THE-ROUND(OGAWA, 2001, P. 13)

II. Roman Colosseum (AD 70 - 81):

It is considered, after the circus Maximus and the Hippodrome, the largest structure for audience seating in the ancient world as it has a seating capacity of about 40,000 people. It is one of the most impressive Roman amphitheaters with excellent sightlines from any seat. Its circulation design is still used in modern stadia (See **Figure**

1.2-2). It was an ideal shape for featured events performances such as combats between humans, or between animals and humans. (Long, 2006, p. 4)

So the main force acted on such form was increasing the number of spectacles with a high degree of visual sightlines more than high degree of speech intelligibility. This Force acted on one of the main axis of the circle to change the form from circle into oval shape as shown in **Figure 1.2-2** which led into three degrees of visual sightlines. Although these degrees were not equal but still offered clear sightlines for all seats.

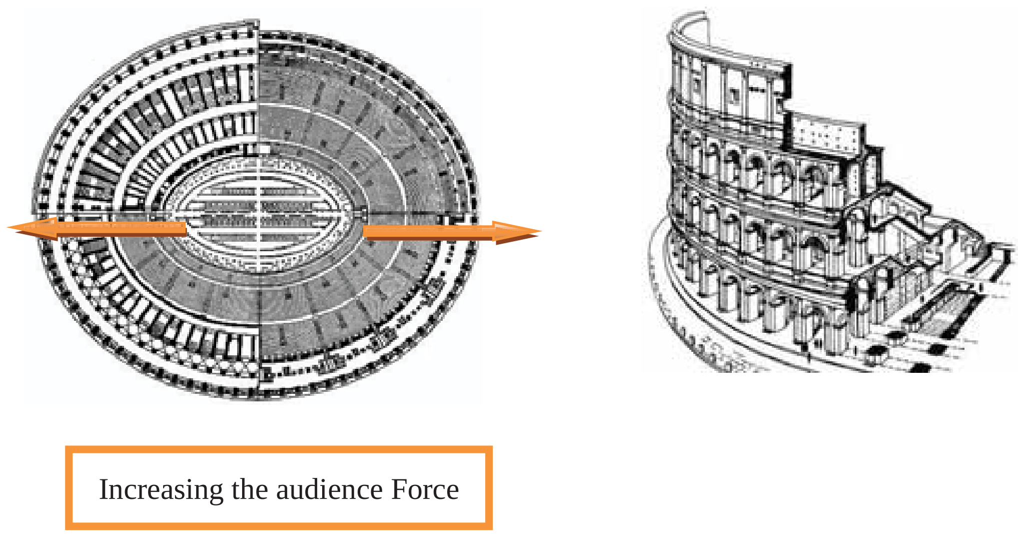


FIGURE 1.2-2: COLOSSEUM PLAN AND ILLUSTRATED 3D (GREAT BUILDINGS)

The intermediate stage floor was covered with stand without any fixed or movable sceneries. Due to the lack of stage technologies, in order to mock sea battles the floor was caulked and filled with water to a depth of about a meter (Long, 2006). But that doesn't mean the total absence of high-tech features as stage elevators and tap doors. They allowed performers to enter the stage unexpectedly. Such techniques are used now in modern arena theaters, as rock concerts, to present unexpected event for audience. (Holloway, 2010, p. 3)

III. The arena stage in Washington, D .C, (1961):

According to Izenour, one of the main reasons that led to drastic change in architecture and theater design came after the fact of technical innovation. The invention of the optical spotlight led to the burst out of the proscenium stage to new restoration of ancient theater forms, such as the three-quarter and theater-on- the-round inside a building. As a result of such invention, theater stage tended to be 3D- dimensional rather than the static 2D image of the proscenium stage. A practical means of controlled area lighting was essential for concentration of the light beam that kept light out of the eyes of the audience seated around the stage. In this way an existing engineering reality provided the physical means essential to artistic impression---not the other way round. (Izenour, 1996, p. 158)

After World War II, America was ripe for a "cultural explosion". There were several trial for theater-in-the-round makeshifts. One of the succcessful theater projects was the arena stage in Washington in 1961 by Harry Wesse. It was actually theater-in-the-rectangule, but the principle of an audience surrounding the stage was identical (See **Figure 1.2-3**). In such project, architects worked to solve the technical problems and limitations of such a theater shape. (Joseph de Chiara, John Callender, 1987, p. 355)

So the acted force on such shape to change it from circule into square is an external architectural direactions force at that time to avoid curve natural ines and to replace it with sharp ones even though the limitations that arised by using rectangular forms rather than circular ones.

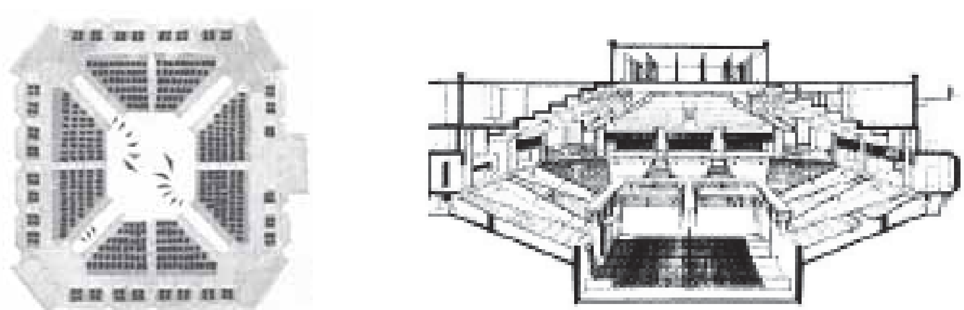


FIGURE 1.2-3: THE ARENA STAGE IN WASHINGTON, D .C, DESIGNED BY ARCHITECT HARRY WEESE IN 1961, IS AN EXEMPLARY MODERN (JOSEPH DE CHIARA, MICHAEL J. CROSBIE, 2001, P. 355)

There are many arguments regarding using such stage type due to its advantages and disadvantages. Still, new practical means and technical inventions are needed to improve its economical benefits and in the same time to overcome its limitations. The following table lists the benefits, limitations and suggested means for improvement:

Benefits	Expediency:	The arena arrangement, achievable in any large room, makes a rudimentary theater possible in a variety of found spaces.
	Economy:	Seating maximum audience in the minimum enclosure. Effective limitation of scenery—there can be no scenery or properties that the audience cannot see over, under, or through.
	Intimacy:	Even with 1,000 seats, the most distant member of the audience need not be much more than 32 ft from the nearest part of the stage
Limitations	Visual limitations:	Because the audience is seated all around the acting are, it is unavoidable that viewpoints will be maximally different, and it becomes impossible for the director and actor to compose the performance so as to produce a uniform effect. Furthermore, because the conditions of one actor blocking audience vision of another actor are also maximized.
	Stage limitations:	There are restrictions of scenic elements to paint or other coverings on the stage floor, very low platforms, devices suspended above the acting area, outline representations of such objects as must set on the stage for use by the actors (doors, windows, and similar architectural details), and low pieces of furniture Lighting is more difficult in arena staging because of the mandatory economy.
Means of Improvement	Visual Improvement:	Increasing the pitch of the seating area. The director must constantly change his axis to prevent one group of viewers from being presented with poorer images than other sections of the audience. Actors, as well as the director, must use entirely different attacks on performance and movement In choosing a repertory for an arena stage company, certain plays-such as the classical plays of Sophocles, Euripides, Shakespeare, Moliere, and Sheridan-succeed while, on the other hand, some plays written for the proscenium stage must be omitted .
	Stage Improvement:	Although it is possible to use traps and to fly elements overhead from a modified grid above the center of the stage, scenic investiture is ordinarily reduced to only the most expressive and economical forms of lighting and projection, costumes, props, and simple portable scenic elements that do not mask the actor from any part of the surrounding audience. Alternative forms of presentation than uneconomical physical ones should be presented by using computer aided technologies, which are predicted to be highly economical by the time going and can be easily installed and uninstalled according to the performance type.

TABLE 1.2-2: THEATER-IN-THE-ROUND BENIFITS, LIMITATIONS & MEANS OF IMPROVEMENT ILLUSTRATED BY (JOSEPH DE CHIARA, JOHN CALLENDER, 1987) & (JOSEPH DE CHIARA, MICHAEL J. CROSBIE, 2001)

The theater in-the-Round is one of the untraditional shapes that were restored from ancient theater types to fulfill the modern theater experience demands of more economical and intimate spaces between audience and actors.

1.2.2. PARTIALLY ENVELOPING AUDITORIUM:

1.2.2.1. GREEK AMPHITHEATERS

The Greek Amphitheaters is a great presenter for Greek Culture that is built on philosophy basics. It reflects the relation between the polis of Athens and its democratic institution by its semi-circular structure. (Eaket, 2010) It presents the democratic form of the government.

The earliest Greek-style theaters took advantage of existing hillsides to form a sloping audience area that curved around a circular performance area. Pre–Industrial Revolution technology did not provide their culture with heavy earth-moving equipment to form the slopes from scratch, and often large amphitheaters were somewhat asymmetrical as a result of following the existing terrain. (Holloway, 2010, p. 1)

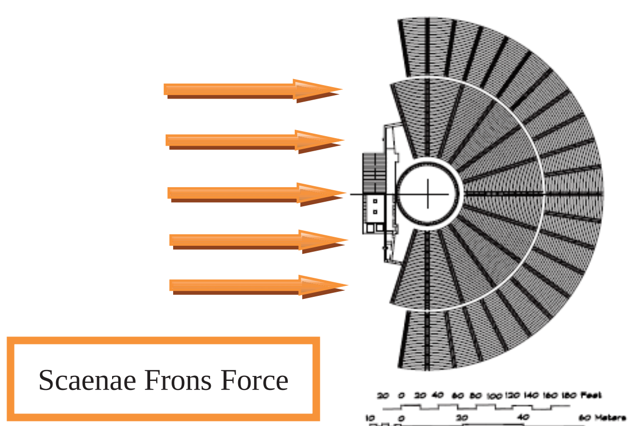


FIGURE 1.2-4: ANCIENT THEATER AT EPIDAURUS, GREECE (IZENOUR, 1996)

The seating plan was in the shape of a segment of a circle, slightly more than 180, often on the side of a hill facing the sea. One of the best-preserved examples of the Greco-Hellenistic Theater is that built at Epidaurus in the northeastern Peloponnese in 330 BC, about the time of Aristotle (See **Figure 1.2-4**.). The seating was steeply sloped in these structures, typically 2:1, which afforded good sight lines and reduced grazing attenuation. Even with these techniques, it is remarkable that this theater, which seated as many as 17,000 people, actually functioned. (Long, 2006, p. 2)

According to the illustrated 3D virtual theater model by THEATRON Project[1], the stage was enveloped from one side by a primitive shape of skene[2] It didn't act as a back stage zone for illusion facilities for theater performance as in more recent theaters but it was supposed to be just for actor entrance and egress to the stage from their dressing room facilities, but it would also have facilitated in the production of an *ekkukleyma*[3]. Introducing such element with its Scaenae Frons[4] and its primitive decoration had its own direct force from stage to audience as seen in **Figure 1.2-4**. It eliminated a quarter of audience seating in order to create a backstage space which led to unequal views for audience with respect to the stage and the Skene.

FIGURE 1.2-5: THE SKENE VIEW FROM THE AUDITORIUM. IT IS 3D VIRTUAL THEATER MODEL FOR THE EPIDAURUS ILLUSTRATED BY (THEATRON VERSION II)

[1] THEATRON is an acronym, it stands for: **Theater H**istory in **E**urope: **A**rchitectural and **T**extual **R**esources **On**line. The project was sponsored by the Esprit programme of the European Commission. The THEATRON Project has developed an educational multimedia application geared towards the history of European theater building making extensive use of 3-dimensional computer models of historical and contemporary venues. (Eversmann) It will be studied later in chapter 6 as a VR application in theater education

[2] The Greek term for the *scaena* (Latin): A temporary building or booth for players behind the acting area in the ancient theater; later the permanent back building of the theater.

[3] It is a sort of wheeled trolley on which important visual spectacles were produced for the audience to see from within the stage building at special moments of the play).

[4] The richly decorated front of the *scaena*, facing the audience

Modern outdoor theaters are generally known as amphitheaters, especially if they resemble the original Greek model. Modified versions are very popular for outdoor historical dramas that run only in the summertime. (See **Figure 1.2-6**)

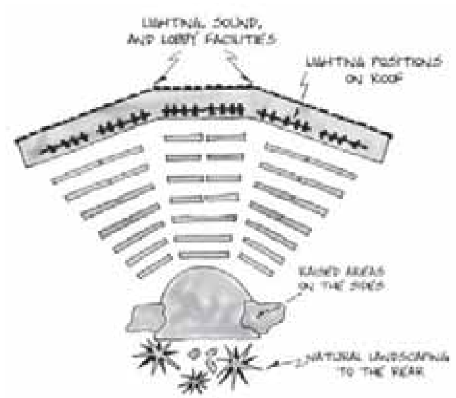


FIGURE 1.2-6: MODERN THEATERS (HOLLOWAY, 2010, P. 2)

1.2.2.2. **OPEN TRUST STAGE**

I. Globe Shakespeare Theater, London (1600)

Following the first permanent theater built in 1576 by James Burbage, the open Trust theater was popular in Elizabethan times, and the reasons for its success now and then were largely the same. This style became the model for many public theaters, including Shakespeare's Globe. The galleries surrounding the central court were three tiers high with a roofed stage, which looked like a thatched apron at one end (See **Figure 1.2-7** & **Figure 1.2-8**). Performances were held during the day without a curtain or painted backdrop.

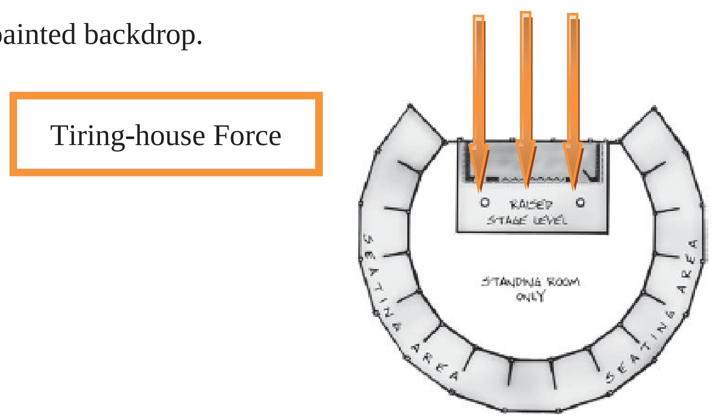


FIGURE 1.2-7: EARLY EXAMPLE OF TODAY'S TRUST THEATER SHAKESPEARE THEATER) (HOLLOWAY, 2010, P. 6)

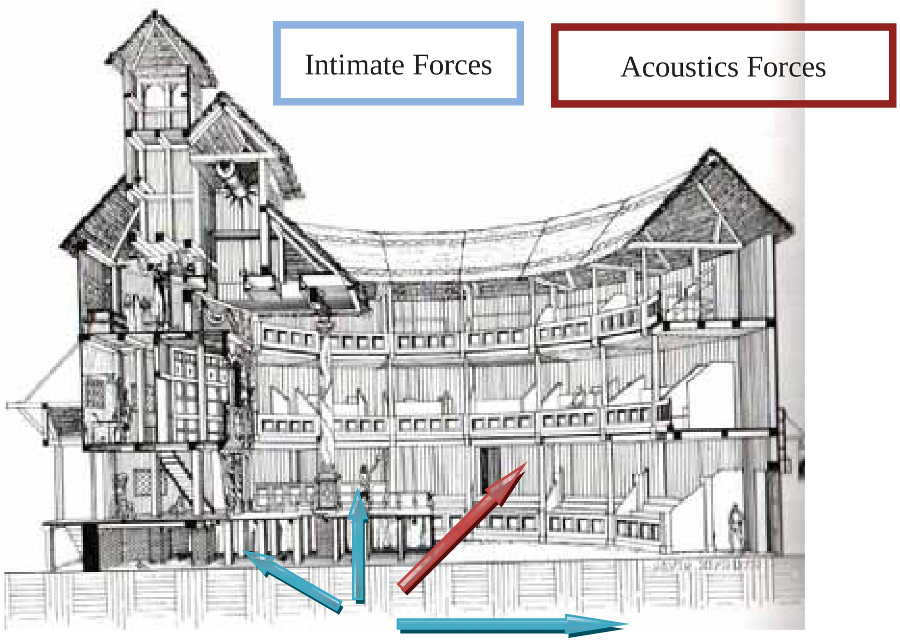


FIGURE 1.2-8: PRESPECTIVE SECTION FOR SHAKESPEAR THEATER (IZENOUR, 1996, P. 176)

Forces that affected the Globe theater form can be divided into three main forces. The first force was the *tiring-house*[5] as a backstage for the Globe Platform as seen in **Figure 1.2-7**. It had a scenic wall that was considered the focus of the stage. The performance took action on the platform and in the inner stage in the first floor level. Another focal point in this scenic wall was the music gallery [6] which took place in the second floor unlike more recent theaters and operas where the orchestra pitch is the place for the musicians.

The second was the acoustics force due to the complex dialogue in Shakespeare plays. Good speech intelligibility was required to be provided by this type of construction. The side walls provided beneficial early reflections and the galleries yielded

[5] A large roofed and enclosed structure built into the playhouse frame; three stories high, comprising the *inner stage*, the *music gallery*, the *lord's rooms*, storage rooms, dressing rooms, the stage cover, the hut and the playhouse flag.

[6] The room reserved for live musicians playing for the performance, situated on the upper level of the *tiring-house* flanked on both sides by two Lord's rooms.

excellent sightlines as shown in **Figure 1.2-8**. The open-air courtyard reduced reverberation problems and outside noise was shielded by the high walls. It is remarkable that such simple structures sufficed for the work of a genius like Shakespeare. (Long, 2006, p. 15).

The Third force was the intimate relation required between the audience and the actor. By studying the illustrated 3D views presented by THEATRON Project from different audience locations in the Globe theater to the stage (see **Figure 1.2-9**), it is noted that the main concern of the theater design was the short distance between the audience and the stage. Another remarkable point was the view from the lord's room in the tiring-house. Although it was considered as a great privilege that only the very rich could afford, it have the poorest view for the stage as the inner stage was hidden. It was used employed by their patrons as symbols of status and wealth, not as ideal vantage points for viewing the play. (THEATRON version II)

The spatial arrangement of the trust theater reflected this concern with public visibility. It was also discovered later that thrust theaters are best suited to the production of intimate dramas. Plays that depend on the accurate understanding of words and/or the transmission of small emotional moments were well served by the close proximity of audience and actor found in thrust theaters. (Holloway, 2010, p. 6).

	
View from the lower level of the auditorium With acceptable visual sight lines for the comman	View from the second level of the auditorium which is considered the best view sight lines.

	
View from a lord's room, the poorest visual sightlines but only offered by the rich.	View from the platform to the auditorium

FIGURE 1.2-9: DIFFERENT VIEWS IN THE GLOBE THEATER TO STUDY THE INTIMITE FORCES ILLUSTRATED BY (THEATRON VERSION II)

II. The open stage of Jacques Copeau's Vieux Colombier, Paris (1913)

Another revival for the open –thrust stage was by Davioud and Dourdais' in 1875 for their proposal of designing an opera house with extreme thrust of 50 ft extension surrounded by the audience from three sides.

In the twenties, the Parisian actor-director Jacques Copeau conceived a truly open theater chamber of intimate proportions in his Theater Vieux Colombier . His open stage had multiple Thrust theaters began a surge in popularity in the 1960s and 1970s in an effort to break through to a more actor-friendly type of space. (Joseph De Chiara, Michael J. Crosbie, 2001, p. 716). It was an experiment with open staging via unit setting improvised within fixed limits of a room restricted in every way such as length, height, and seating capacity. Although there is no doubt about its being an artistic success in the twentieth century, it was considered by Izenour a commercial failure. This is because of the restricted scenic permanent elements he used which was one of the disadvantages of the scenery treatment in an open trust-stage.(See **Figure 1.2-10**)

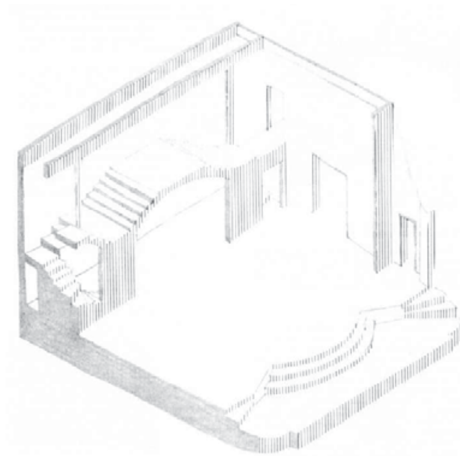


FIGURE 1.2-10: THE OPEN STAGE OF JACQUES COPEAU'S VIEUX COLOMBIER, PARIS, HAD MULTIPLE LEVELS AND A FLEXIBLE BUT PERMANENT ARCHITECTURAL SET. (JOSEPH DE CHIARA, MICHAEL J. CROSBIE, 2001, P. 717)

III. The Stratford, Ontario, Shakespeare Festival Theater (1957)

Another revival for the trust open stage by American educator who believed that the proper method to teach the Shakespearean theater was to observe performances of his plays on the same type stage it used to be with the same intimate mood of audience surrounding the stage from three sides and sit very near to the actor where all his facial and body language impressions are highly observed and the strong intelligible speech is heard by the audience (See **Figure 1.2-11**). In this phase traditional scenery of the proscenium stage was virtually eliminated in an open-thrust stage craft. And ultimately permanent open-thrust stage theaters were constructed by the producers of Shakespeare festivals (Joseph De Chiara, Michael J. Crosbie, 2001, p. 716)

By studying the plan of such theater, it is noted that the forces that affect its form is the combination between the forces of the Greek Amphitheaters which affected the audience seating and the forces of Globe Theater which formed the thrust stage form and the acustics considerations of the space.

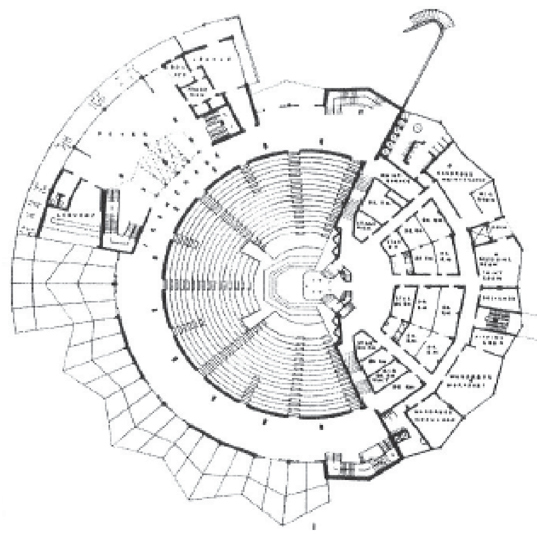


FIGURE 1.2-11: THE STRATFORD, ONTARIO, SHAKESPEARE FESTIVAL THEATER HAS BEEN AN INFLUENTIAL INTERPRETATION OF THE OPENTHRUST (OGAWA, 2001, P. 25)

1.2.2.3. **CORNER STAGE 90 ° ARC**

IV. Olivier Theater, Royal National Theater, London

One of the main limitations in the trust stage where the audience sitting within an arc of 135°,as in the previous example, was that the actor had only about 2m back from the front of the stage where he can command the attention of a whole audience without moving his head. That led to the plan of the theater as a square with the stage at one corner such as the Royal National Theater (See **Figure 1.2-12**). (Barron, 2010, p. 316) Such plan was a development of the Greek Amphitheaters and the Open-Trust Stage Theaters. It combined the circular sitting arrangement of the Greek Amphitheaters which led to equally sightlines to all the audience with the 3d-dimesional theater experience of the open-thrust stage.

Due to the absence of Proscenium opening and the stage fly tower, the original ceiling is screened from the view by the suspended ceiling to satisfy visual, stage lighting and acoustic considerations.

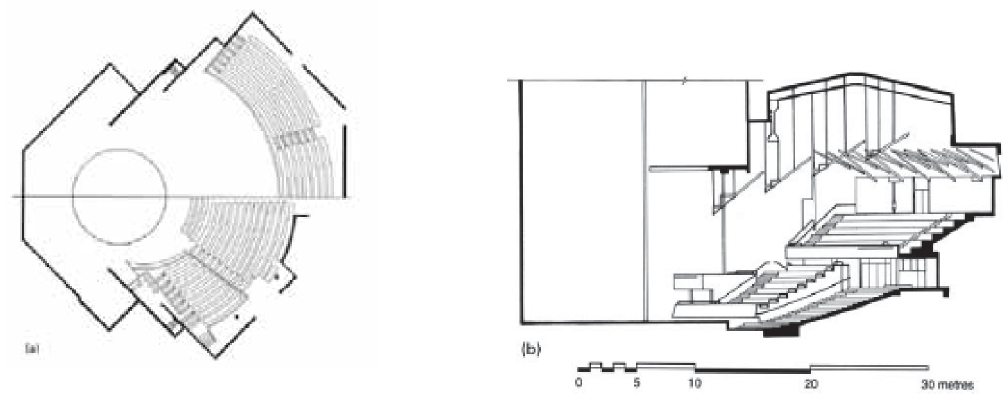


FIGURE 1.2-12: (A) PLAN AND (B) LONG SECTION OF THE OLIVIER THEATER, NATIONAL (BARRON, 2010, P. 317)

Unfortunately the fan shape in plan led to poor intelligibility as it didn't encourage useful reflections to the center of the audience as **Figure 1.2-13**. For this reason, this surface, which is black in the theater, was made predominantly absorbent acoustically.

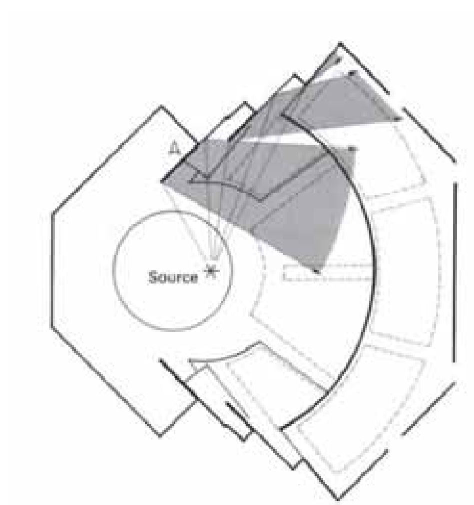


FIGURE 1.2-13: PLAN OF THE OLIVIER THEATER SHOWING AREAS WHICH RECEIVE REFLECTIONS FROM THE SIDE WALL. THE REFLECTION FROM WALL SURFACE A ARRIVES TOO LATE TO ENHANCE INTELLIGIBILITY (BARRON, 2010, P. 320)

The following table lists the benefits, limitations and suggested means for improvement:

Benefits	Expediency: The audience seating wraps around three fourths of the stage area, giving the stage the appearance of "thrusting out" into the spectators. This, in effect, makes the front of the stage longer, making it possible to fit a larger number of seats into a small number of rows.
	Intimacy: It places the performers in the same space envelope as the audience. This is said to produce a unity of experience between performers and audience. The thrust stage offers a three-dimensional experience in which the actor can be at the focal point of an enclosing audience rather than the two-dimensional arrangement of spectators looking at a screen. It places more spectators closer to the performance than does the proscenium arrangement and in this way contributes to good seeing.
	Economy: high degree of flexibility in staging Most thrust theaters have an exposed ceiling or grid that allows for multiple lighting positions throughout the theater. Unlike the traditional proscenium house in the excessive care of hiding the machines of lighting, the modern thrust theaters tends to the concept of "form follows function"
Limitations	Stage limitations: It contains inherent difficulties in the entrance and the exit of the actors It places a burden of diffused orientation upon directors and performers.
	Sightlines limitations: The layout of the stage leads to some rather difficult sightline problems. The audience view from the far left is completely the opposite of that from the far right. Patrons seated at the downstage edge of the stage see the action from straight ahead. Designers must be careful not to place too much emphasis on scenic units in that location, because they may not be entirely visible to a portion of the audience.
Means of improvement	Stage improvement: Providing entrances beneath the seating area.
	Sightline improvement: Care must be taken not to use visual elements downstage that might block the view of persons sitting in that area. This may lead to some serious staging issues, and require a bit of technique to overcome. Some means of technology may be applied to the theater stage to replace the physical presentation of scenic elements.

TABLE 1.2-3: OPEN THRUST STAGE BENIFITS, LIMITATIONS & MEANS OF IMPROVEMENT ILLUSTRATED BY(JOSEPH DE CHIARA, MICHAEL J. CROSBIE, 2001)(BARRON, 2010) & (HOLLOWAY, 2010)

1.2.3. NON ENVELOPING AUDITORIUM:

1.2.3.1. ROMAN THEATERS

I. Roman Theater at Aspendus, Turkey

Roman theaters for plays were constructed in much the same manner as the Greek ones were, but limited the seating arc to 180° The most remarkable item developed by the Roman is the skene used as a stage house with its "Scaenae Frons". As studied in Greek theaters, it had its own force on the audience seating but in the Roman theaters it had complex of forces in the theater form that could be translated into four main forces as seen in **Figure 1.2-14**. (Long, 2006, p. 4)

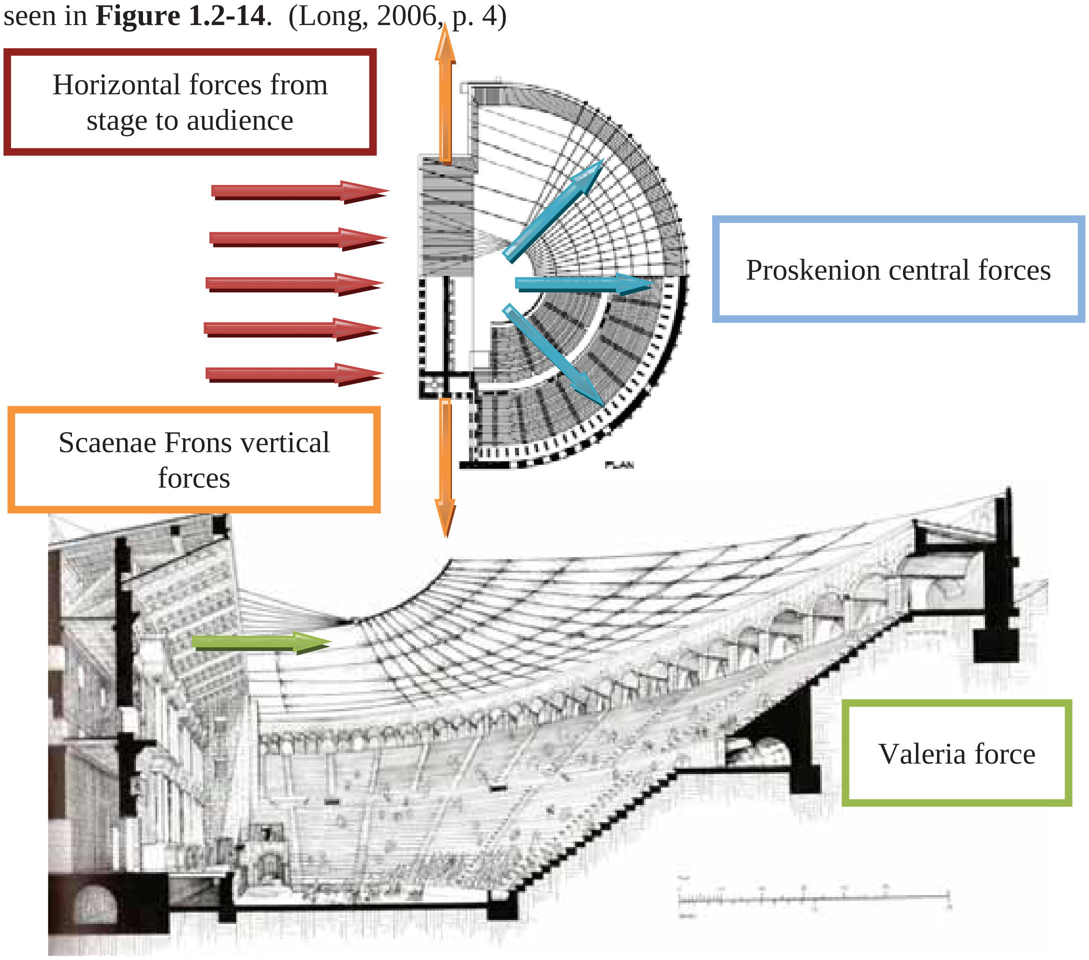


FIGURE 1.2-14: ROMAN THEATER AT ASPENDUS, TURKEY PLAN AND SECTION BY (IZENOUR, 1996, P. 182)

First, is the introduction of horizontal forces between the stage and the audience in one direction which resulted in enveloping the stage by the audience from one side only. Second, is the vertical force of eliminating half of the audience which lessened the degree of intimate between the stage and the audience. The front wall or *scaena* extended out to the edges of the semicircle of seats and was the same height as the back of the seating area. It formed a permanent backdrop for the actors with a palace decor. (See **Figure 1.2-14**).

The introduction of such vertical force perpendicular to the horizontal force direction between the audience and the stage was a very vital point in the history of theater design. It created an imaginary line between the stage and the audience which will be translated into different forms for centuries as will be studied till the end of this chapter.

One of the main innovative forms for the Roman also in this imaginary line was the introduction of a front curtain that could be used to mask the stage from the view of the audience (See **Figure 1.2-15**). As these early theaters were open-air, daytime-use structures, there was no way to hang a curtain from above as in a modern theater. In at least one instance, the Romans used instead a series of poles coming out of the stage floor to hold up the drape. When these poles were lowered, the stage and its occupants were revealed. (Holloway, 2010, pp. 3-4)

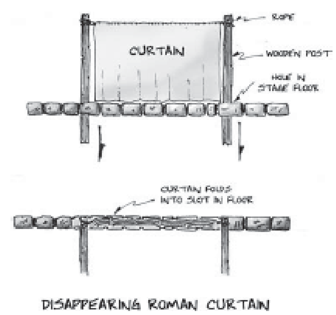


FIGURE 1.2-15: THE INTRODUCTION OF INFORNT CURTAIN (HOLLOWAY, 2010, P. 4)

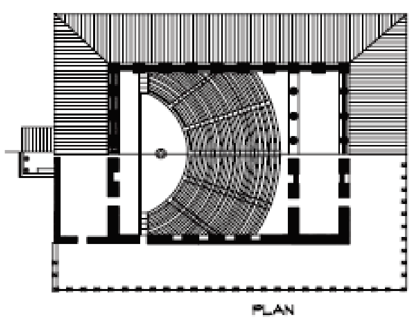
Third is the introduction of the proskenion (a raised acting area) in the middle of the Scenic wall as a central focal point where the chorus spoke from a hard-surfaced circle (orchestra). This led to central forces of forming the audience seating in semi circular form.

And last was the introduction of the valeria[7] which was supported by the scenic wall and the arches behind the audience. This led to the shift between outdoors and indoors theater.

II. Odeon of Agrippa at Athens, Greece (12 BC)

One of the remarkable buildings in Athens in Roman period is The Odeon of Agrippa. According to Izenour, these type of Structures, which ranged from 200 to 1500 seats are found in many of the ancient Greek cities. What was remarkable about this type of theaters was the large wood-trussed span of 25 meters as shown in **Figure 1.2-16** and the square box that enveloped the auditorium and the stage area. He speculated that the name "Odium"- 'Place of the Ode' came because of the most of the performance where accompanied by music (Long, 2006, p. 5).That's why the Orchestra had its lead focal intimate point in the center of the circular audience seating.

The imaginary line between audience and stage was presented again by the high scenic wall. In this type of theaters, the audience chamber ceiling was much higher and more important than the stage ceiling. The absence of mechanical and electronic means gave a simple shape for the stage box rather than the more sophisticated shapes of the modern traditional theaters such as the proscenium stage.



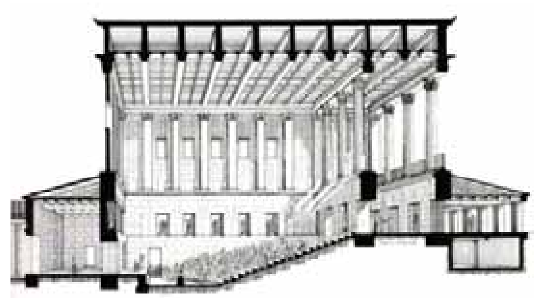


FIGURE 1.2-16: ODEON OF AGRIPPA AT ATHENS, GREECE (IZENOUR, 1996, P. 184)

[7] It is the awning sheltering the seats in an ancient Roman theater of *amphitheater* from the sun and rain.

1.2.3.2. **VISTA STAGE**

III. Teatro Olimpico, Vicenza, Italy (1580)

After thousands of years from the Roman Period, the first permanent theater was constructed in 1580. Following the classical pattern, the seating plan was semi-elliptical and the stage configuration was just as the old Roman theater. One of the remarkable issues of such theater was how the designers' imagination and crafted stages discovered the new art of perspective captured image. Stage terms such as upstage and down stage evolved from this early design practice. Later, five painted vistas were added by Scamozzi in forced perspective angling back from the *scaena* (See **Figure 1.2-17**). (Long, 2006, p. 15).

It was the first step for a traditional theater to imitate virtually the real life on a stage by using vanishing points where streets, city, buildings were constructed distorted on stage. This resulted into a perspective force that extended the theater stage to backwards and introduced a new function for the stage.

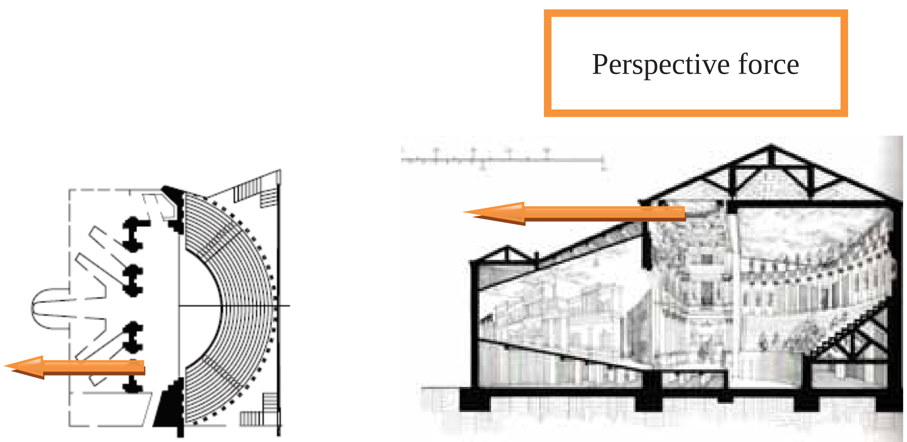


FIGURE 1.2-17: TEATRO OLIMPICO, VICENZA, ITALY (IZENOUR, 1996)

IV. Sabbioneta Theater, Italy (1588)

After the 5 vista stage, Scamoozi desgined the single static vista stage of Scamozzi's Teatro design for tragic scene (See **Figure 1.2-18**). Similar schemes used extensively in court festival all over northern Italy. (Izenour, 1996, p. 43)

Another modification in plan was presented by Scamozzi in his new theater the Sabbioneta. From a semi-elliptical plan to a push back U shape plan where the Duke sat in the top of the U shape, the only point than could see the stage perspective correctly. This is another added force to the Vista stage which transformed the theater chambers from square forms into rectangular ones as seen in **Figure 1.2-18**

There was no stage wall separating the audience from the actors and he used only single-point perspective backdrop rather than the earlier multiple-point perspectives. A little acoustical support was presented from the beamed ceiling reflections and the small volume of the auditorium but the seating capacity was still yet small. (Long, 2006, p. 15) In this type of theater, again the audience and the actors were not separated in one chamber with the same ceiling height.

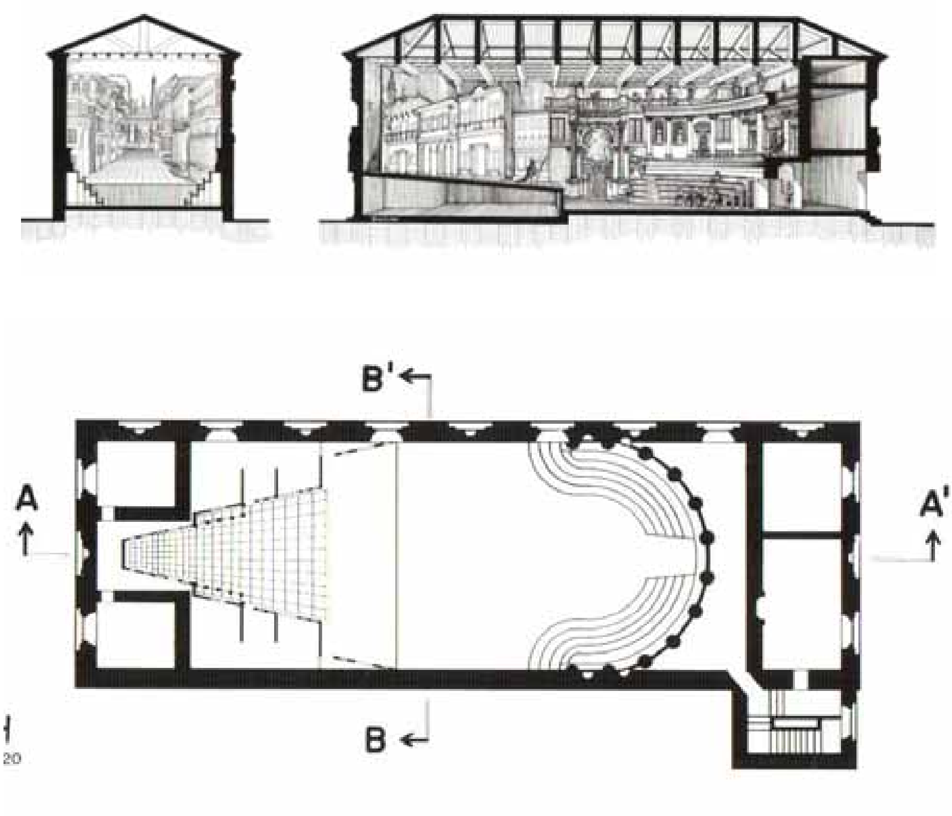


FIGURE 1.2-18: SABBIONETA THEATER, ITALY(IZENOUR, 1996, P. 189)

V. Cockpit-in-court, Whitehall Palace, London, England (1632)

FIGURE 1.2-19: COCKPIT-IN-COURT, WHITEHALL PALACE, LONDON, ENGLAND (IZENOUR, 1996)

The design of this theater was the result of early Italian influence on English theater design, Teatro Olimpico, particularly in the arrangement of the permanent stage setting. As shown in **Figure 1.2-19** the relation between apron stage and the auditorium resembled the Public Elizabethan theater of Shakespear more than Olimpico Theater, which was studied before in the open thrust stages. (Izenour, 1996, p. 268) .

1.2.3.3. SHOEBOX HALL

I. Redoutensaal, Schloss Hofburg, Vienna, Austria (1631)

The Redoutensaal was first built in Vienna, Austria as a ballroom but opera was also performed there amid improvised temporary surroundings. It was remodeled many times since then, passing by the Baroque period up to recent contemporary period with different functions as ballroom, opera house in the eighteenth century (see **Figure 1.2-20**), open Stage Theater in the twentieth century (see **Figure 1.2-21**) and finally conference hall that serves international diplomatic conferences. It was considered as one of the very first, if not the first, of classical Shoebox-shaped hall. This room was also one of the first that had witnessed many premiere performances for Beethoven's Seventh Symphony, and others. The force that resulted in the narrow rectangle form seemed to be the limitations in structural span, rather than empirical or rational acoustical considerations. This Shoebox-hall was built during the rise of the first origins of sound theory. There are believes that over the next century, empirical acoustical considerations derived from the continuous use of similar halls through Germany and Austria. (Izenour, 1996)

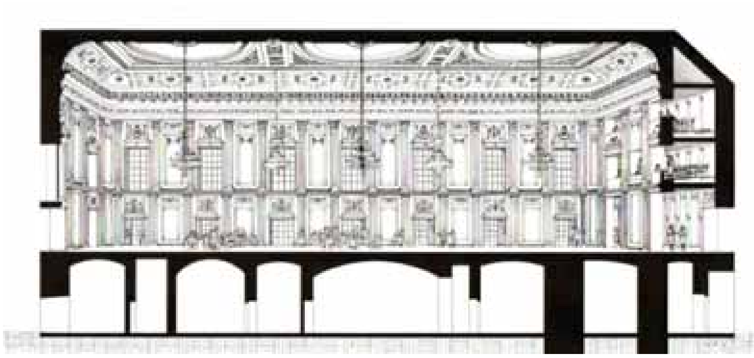
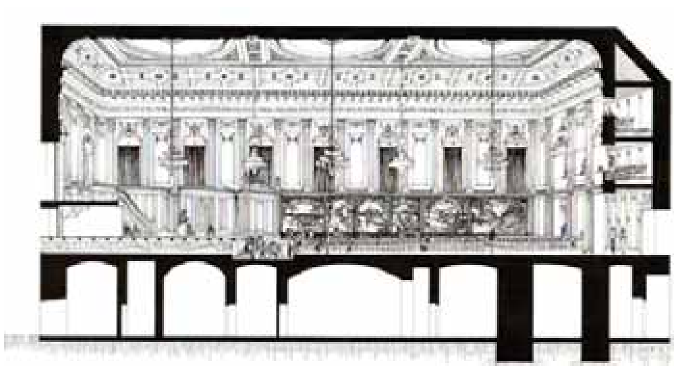


FIGURE 1.2-20: REDOUTENSAAL, VENNA, AUSTRIA 18TH CENTURY SECTION (IZENOUR, 1996)



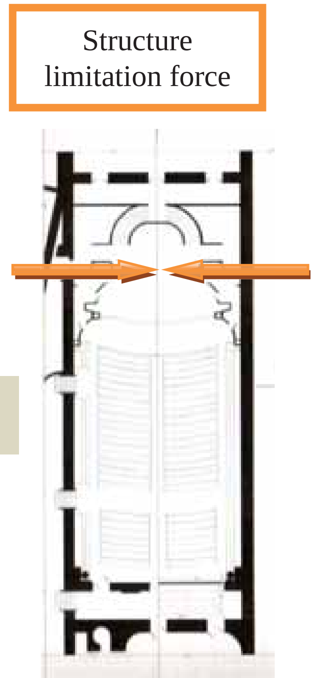


FIGURE 1.2-21: REDOUTENSAAL, VENNA, AUSTRIA 20TH CENTURY SECTION & PLAN (IZENOUR, 1996)

The audience chamber and the stage were still combined in one space having the same flat ceiling without any separators. This didn't help the trial of implementing Drama Theater in such open-theater stage, as acoustically, it didn't succeed for speech.

II. Grosser Musikvereinssaal Vienna, Austria (1870)

Grosser Musikvereinssaal in Vienna, Austria, which is still in use today, is considered one of the top three or four concert halls in the world. It was opened in 1870 with relatively small seating capacity and had a long (50.3 m) and narrow (19.8 m) rectangular floor plan with a high (15 m), heavily beamed ceiling. (Long, 2006, p. 29) The main force that affected the form and interior of such hall was the remarkable consideration of its acoustics. For the form, it took the rectangular shape with more consideration to reverberation time. Its reverberation time was long, just over 2 seconds when fully occupied, and the narrowness of the space provided strong lateral reflections that surround or envelop the listener in sound.

As for the interior, the walls were constructed of thick plaster that supported the bass, and the nearness of the reflecting surfaces and multiple diffusing shapes gave an immediacy and clarity to the high strings. It is this combination of clarity, strong bass, and long reverberation time that is highly prized in concert halls, but rarely achieved (Long, 2006, p. 30).

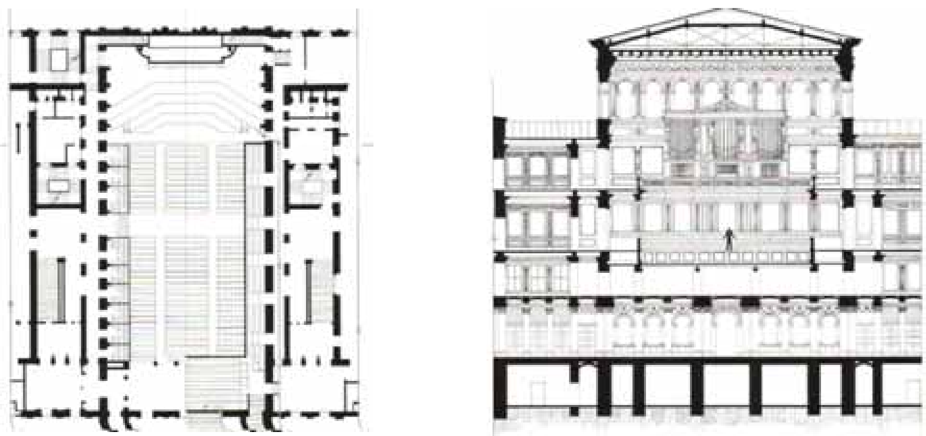


FIGURE 1.2-22: GROSSER MUSIKVEREINSSAAL, VIENNA, AUSTRIA (IZENOUR, 1996)

1.2.4. HORSESHOE-SHAPED AUDITORIUM:

1.2.4.1. PROSCENIUM STAGE

III. Theatro Farnese, Parma, Italy (1500-1650)

The Farnese Theater is the oldest surviving permanent theater with a proscenium arch[8] and with moveable scenery. Both inventions marked the beginning of a new period

[8] Proscenium Theater is a shape in which the audience faces the performing area on one side only and sees the performing area through an architectural opening that often has an elaborated architectural frame-although that is not an essential element. (Joseph De Chiara, Michael J. Crosbie, 2001, p. 713)

in theater history for they will be the two main factors that will affect the form of such theater and the latest theater. Here the imaginary line separating audience from stage took the form of proscenium arch, would become a standard feature in the theater until the twentieth century. The scenery and the theater machinery would be ever more elaborate until the theater became a veritable illusion machine, a staging practice that would last until the end of the nineteenth century and the beginning of the twentieth. (THEATRON version II)

By introducing such frame, the last intimate degree between the audience and the actor was lost. Although the ceiling of the auditorium and the stage were on the same level as used to be in former theaters, the proscenium arch isolated the interior of both stage and the auditorium totally. The theater form here was completely transferred into one directional experience where the stage was the transmitter and the audiences were the passive receivers. This transmitter took further development through the history of theater design and had further forces on backstage zone as seen in **Figure 1.2-23** and **Figure 1.2-24**.

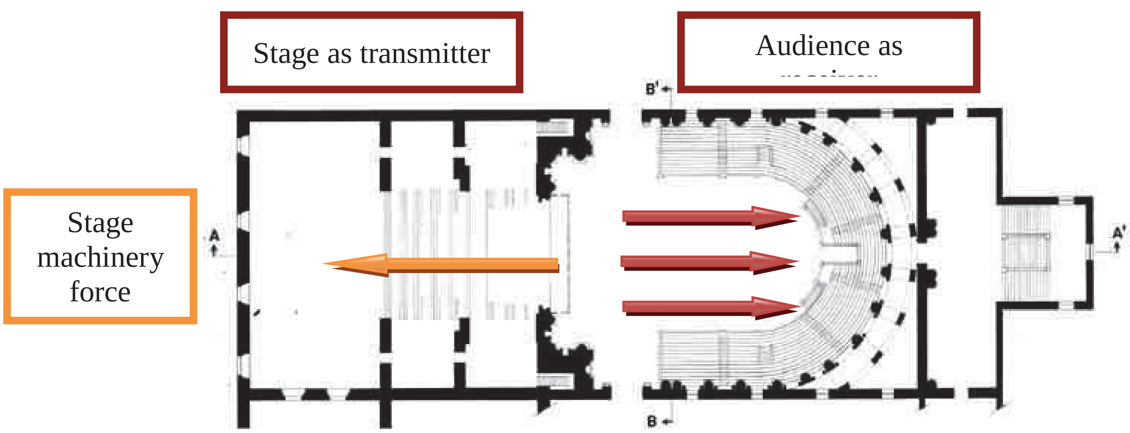


FIGURE 1.2-23: FARNESE THEATER GROUND PLAN BY (IZENOUR, 1996)

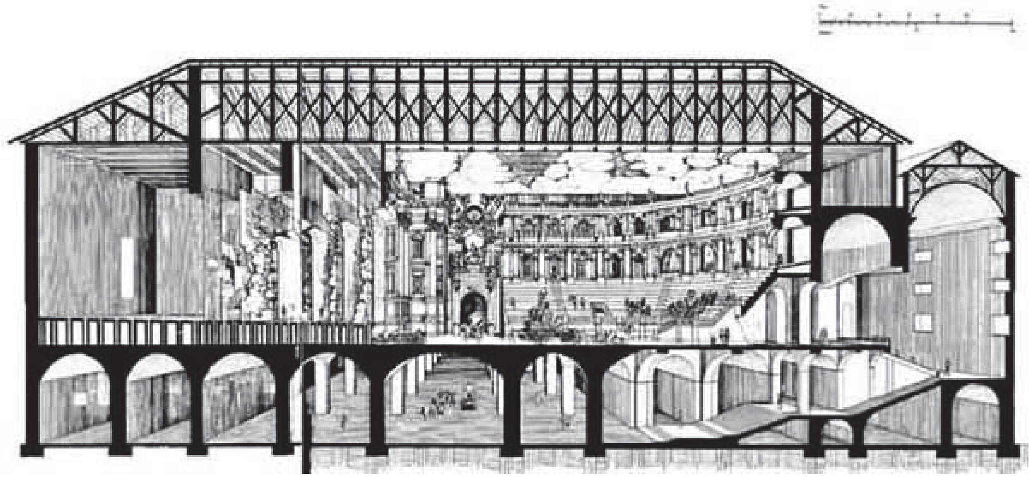


FIGURE 1.2-24: FARNESE THEATER CROSS SECTION AFTER BY (IZENOUR, 1996)

The proscenium arch which looked like Roman Scenic wall, as seen in **Figure 1.2-25**, was also useful for hiding the machinery and apparatus for the scenery changes from the audience. Two other frames or 'arches' were placed towards the back of the stage. This created the opportunity to use settings of varying depths in one performance. The use of more than one frame became more popular during the Baroque period when the stage settings grew in importance. (THEATRON version II)

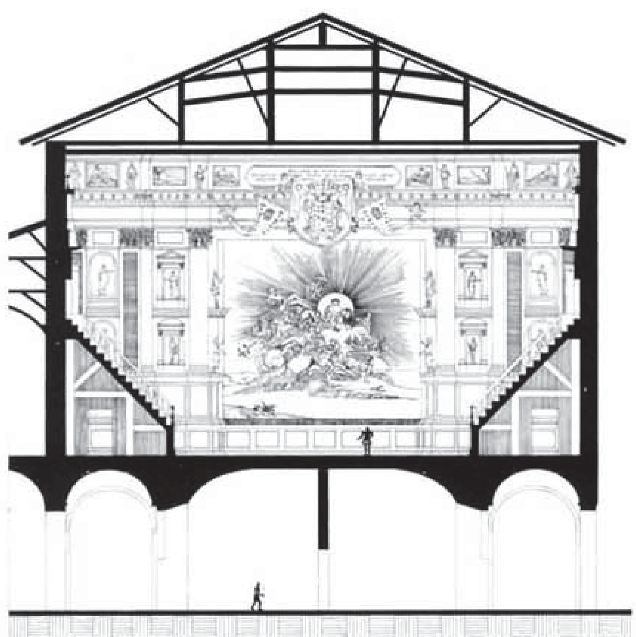


FIGURE 1.2-25: FARNESE THEATER TRAVERSES SECTION BY (IZENOUR, 1996)

Due to the political character of such theater, there were other factors that affected its form. It wasn't used only for theater performances but also for special events as the weddings in the Farnese family, which created the event zone in the middle of the audience as in **Figure 1.2-23**. Also, the introduction of the ducal box, led to the U- shape of audience seating. It should have the perfect view for the perspective of the scenery, the orchestra and the stage and no one of the audience gives his back to the Duke. (THEATRON version II).

1.2.4.2. **HORSE-SHOE SHAPED AUDITORIUM:**

IV. Theater of SS. Giovanni e Paolo, Venice, Italy (1637)

By 1637, when the first public opera house was built in Venice **Figure 1.2-26**, the operatic theater had become the multistory U-shaped seating arrangement of the Theatro Farnese, with boxes in place of tiers. There are three main developments in the opera theater form. First, the seating layout further evolved from a U shape into a truncated elliptical shape. Second, the orchestra which had first been located at the rear of the stage and then in the side balconies, was finally housed beneath the stage as is the practice today (Breton, 1989). And third, the stage had widened further and now had a fly loft with winches and levers to manipulate the scenery. This became the typical Baroque Italian opera house, which was the standard model replicated throughout Europe with little variation for 200 years. (Long, 2006, p. 18)

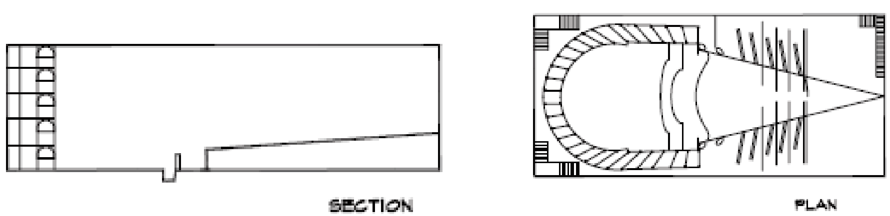


FIGURE 1.2-26: THEATER OF SS. GIOVANNI E PAOLO, VENICE, ITALY (FORSYTH, 1985)

V. Theatro Alla Scalla, Milan, Italy (1778)

Meanwhile in Italy little had changed. Opera was the center of the cultural world and opera-house design had developed slowly over two centuries. In 1778 La Scalla opened in Milan and has endured, virtually unchanged, for another two centuries. Shown in **Figure 1.2-27**, it had the form of a horseshoe-shaped layer cake with small boxes lining the walls. The sides of the boxes were only about 40% absorptive (Beranek, 1979). The sightlines in this type of auditorium were not primarily directed towards the stage, but to the other boxes. For the audience in these theaters to see other theater goers and to be seen themselves was more important. (THEATRON version II). On the other hand, they provided a substantial return of reflected sound back to the room and to the performers. The orchestra seating area was nearly flat, reminiscent of the time when there were no permanent chairs there. The seating arrangement was quite efficient (tight by modern standards), and the relatively low (1.2 sec) reverberation time made for good intelligibility.

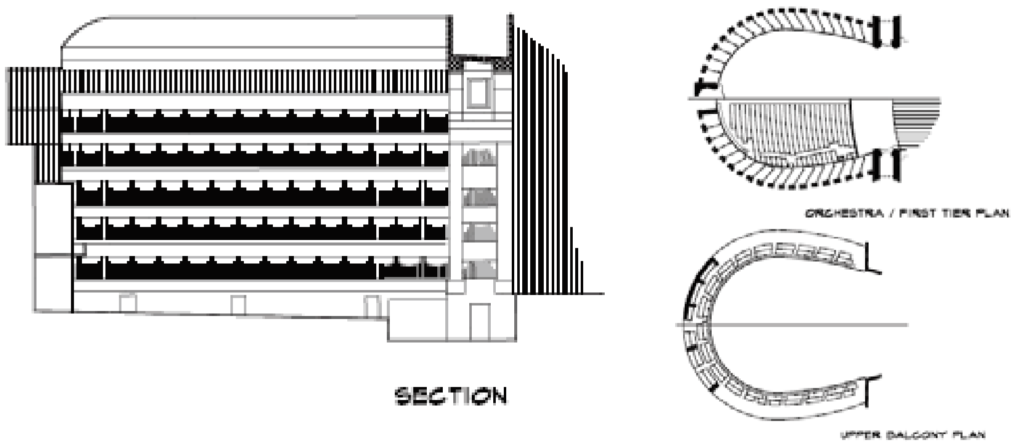


FIGURE 1.2-27: THEATRO ALLA SCALLA, MILAN, ITALY (BERANEL, 1979)

1.2.5. FAN-SHAPED AUDITORIUM:

1.2.5.1. FAN-SHAPED AUDITORIUM

I. Festspielhaus, Bayreuth, Germany (1872)

One of the most interesting theatrical structures that was built in the 19th century, Wagner’s opera house, the Festspielhaus in Bayreuth, Germany built in 1876, was a close collaboration between the composer and the architect, Otto Brueckwald, and was designed with a clear intent to accomplish certain acoustical and social goals. (Long, 2006, p. 25) It was specially designed for the performance of Wagner's operas and was envisaged as an 'illusion machine' in which the spectator would experience a mythical world. (THEATRON version II)

The Bayreuth Festival introduced a new way of watching a theatrical event. In Bayreuth the audience was supposed to sit quietly in the dark and to be overwhelmed by the complete experience Wagner hoped to instill by his '*Gesamtkunstwerk*'[9] on stage. (THEATRON version II). The main force acting on such theater form was to achieve high focus on the performance without any outer or inner interruptions. This was achieved by four major changes in theater form rather than the traditional Baroque Theaters.

The first remarkable change was the introduction of fan-shaped seating. The seating arrangement in itself was an innovation, since it was the first opera house where there was not a differentiation by class between the boxes and the orchestra seating as used to be in the horseshoe shape with layered boxes Baroque theaters. (Long, 2006, p. 25). To Wagner, however, only the performance, and hence stage visibility, mattered. He could not, however, break from tradition completely and that is why there is a Royal Box for King Ludwig who, after all, made the Festspielhaus financially possible. (THEATRON version II). But still the introduction of the Royal Box didn't have any impact on plan as seen in **Figure 1.2-28**. Audiences could sit with their back to the King.

The second change was the absence of any decorative features in the auditorium to distract the eye, nor boxes to attract the attention. Because all seats are directed towards the stage and the galleries are inserted in the back wall, they are not visible to the spectator. (THEATRON version II)

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[9] It is Wagner's idea of 'pure art', the ideal performance integrating poetry, music, the pictorial and the dramatic arts. (THEATRON version II)

The third change was dipping the orchestra in a pitch in front of the stage to be invisible and at the same time to create a physical barrier between the audience and the staged world of the play. Wagner considered the distance between reality and fiction as a 'mystical abyss' with the orchestra pit. (THEATRON version II)

The fourth change was the introduction of the idea of darkening the auditorium completely during the performance. This was unusual in the nineteenth century but absolutely necessary for Wagner because he wanted all attention to be directed towards the performance. The darkening of the auditorium has become standard practice in present day theater. (THEATRON version II) IT was the first time to introduce light as main factor on stage.

And last, is the introduction of complicated stage house with enormous flytower as seen in **Figure 1.2-29**. It accommodated the many sets of wings, backdrops, and curtains that were used in an opera performance. To change sets the scenery could be pulled up, down, or shifted horizontally. The present-day flytower is enlarged and there are three storeys of machinery available. The Bayreuth machinery was elaborate and complicated in order to produce the illusionistic effects Wagner desired for the staging of his operas. Also the stage platform has creative items such as the double proscenium to create an important optical illusion which visually enhances the distance to the stage. All objects on stage appear larger than they are. (THEATRON version II)

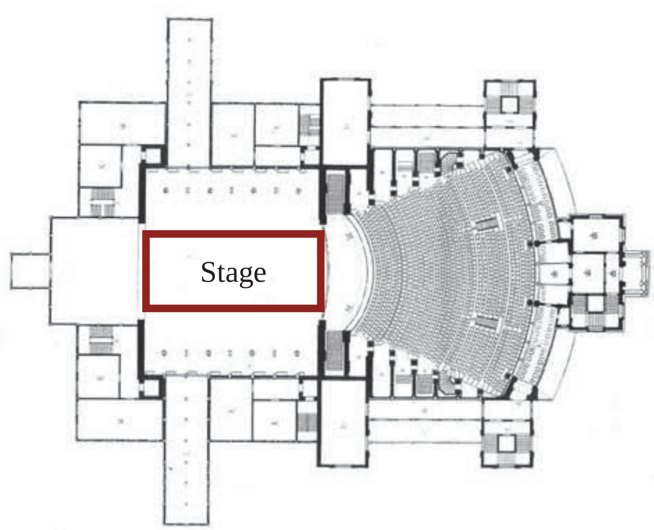


FIGURE 1.2-28: FESTSPIELHAUS GROUND PLAN BY (SACHS, 1898)

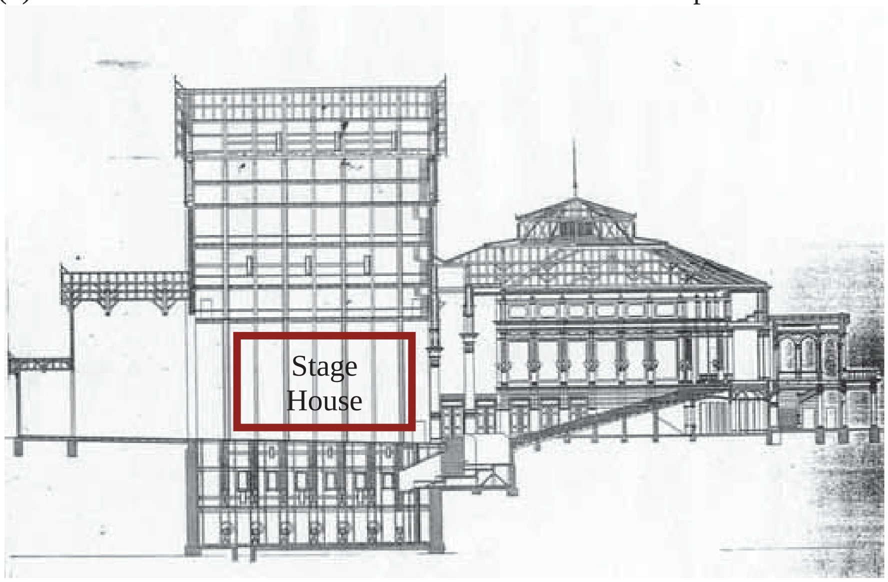


FIGURE 1.2-29: FESTSPIELHAUS LATERAL SECTION BY (SACHS, 1898)

1.2.5.2. APRON, CALIPER STAGE

The introduction of such form of theaters was due to the lack of intimate relation between the audience and the actors in the proscenium stage. As a result, the performing area was not always limited by the proscenium arch opening; it could project out a nominal distance into the auditorium in the form of what is called a forestage or apron. (Joseph De Chiara, Michael J. Crosbie, 2001, p. 713) The forestage in proscenium stage can be considered a step of breaking the districted line of the proscenium arch for combining epic scenic effects with intimate scenes played well forward, especially in modern performance. (Strong, 2010, p. 67)

It is important to note that the apron stage is different than the open-thrust stage although they may look the same. The main difference between them is that a true thrust stage is a platform extending into an open auditorium in which the audience truly surrounds the stage on three sides. But for the Proscenium Apron stage, it has extended forestages, which utilize techniques of acting, direction, and designing that do not differ room standard proscenium stagecraft. Another difference is that a thrust stage is an area deep and wide enough on which to play a full scene, when an apron or forestage is only an adjunct to a proscenium stage; it should not be considered a thrust stage. (Joseph De Chiara, Michael J. Crosbie, 2001, p. 716)

I. Holftheaterm, Weimar, Germany.

It was designed by Max Littman and was considered one of the last Court theaters in Germany. The main innovation in such theater was the introduction of the first mechanized multiple sized flexible proscenium with an articulated mechanized convertible stage apron-orchestra. The orchestra pit was used to be converted into an apron which made the stage perfect for both opera and music drama performances as seen in **Figure 1.2-30**. Also the size of the auditorium made it successful for both of them with slightly less for spoken drama in two styles: proscenium and apron stage. (Izenour, 1996, p. 287)

The Theater was considered a hybrid form between the traditional horseshoe opera theaters and the radical new ideas of the Bayreuth Theater. That was because of the demand of the theater's client, Duke of Weimar, who required holding on the same vestige of the horseshoe auditorium by extension of the ring balconies forward along the side walls and the inclusion in the first ring of the grand dual private box and suite as seen in **Figure 1.2-31**. This resulted in bad vertical sightlines from the balconies for the apron as the sightline section where calculated for the proscenium. (Izenour, 1996, p. 288)

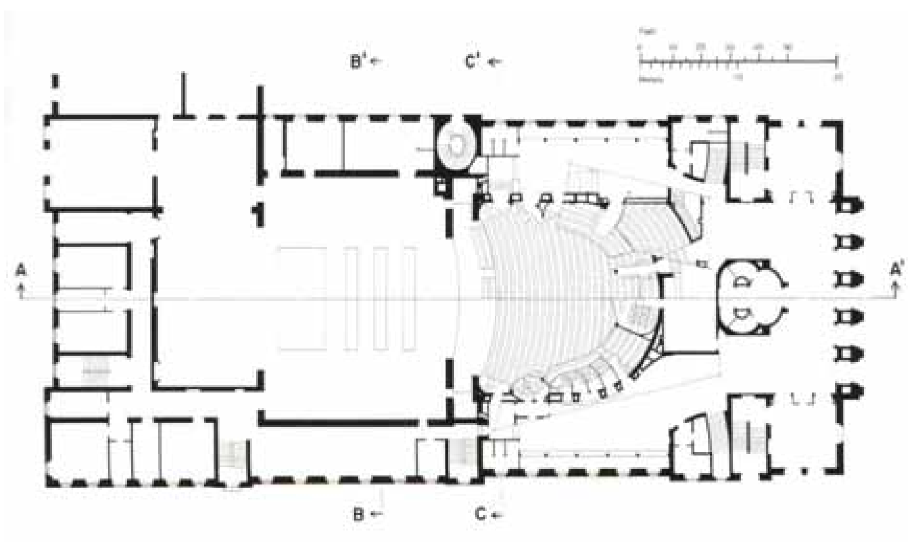


FIGURE 1.2-30: HOLFTHEATERM GROUND PLAN BY (IZENOUR, 1996, P. 233)

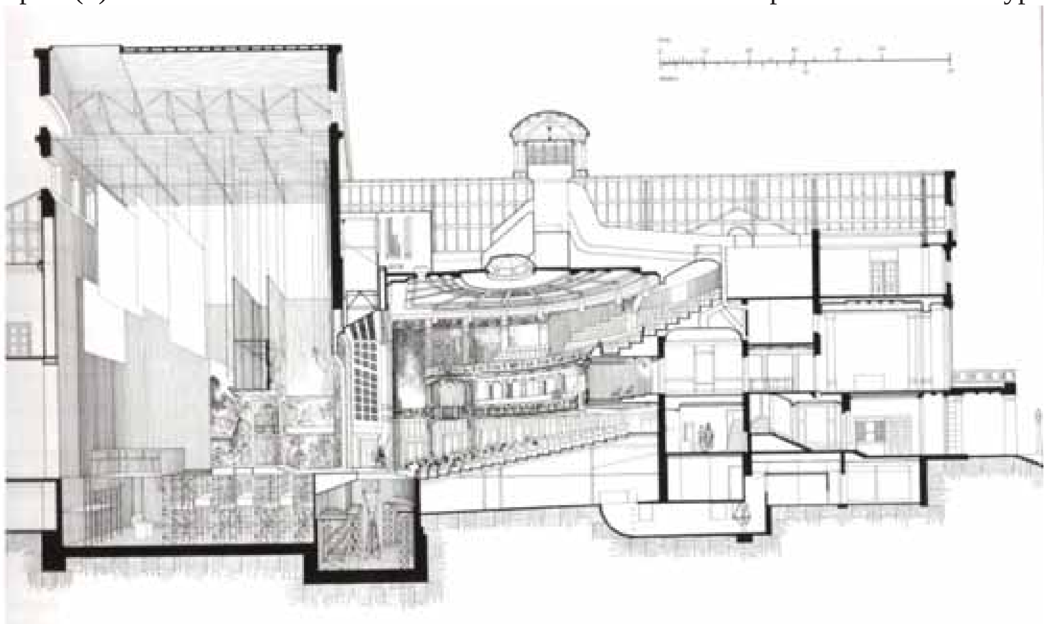


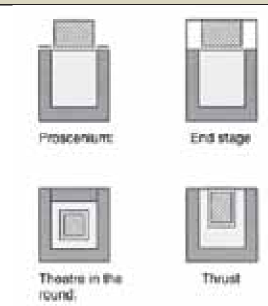
FIGURE 1.2-31: HOLFTHEATERM CROSS SECTION BY (IZENOUR, 1996, P. 233)

The introduction of such flexibility between the stage and the orchestra pit and the use of highly mechanized tools, not only for stage machinery but also for stage adjustments, gave new ideas and possibilities for transferring the relation between the stage and the auditorium from fixed and rigid relation into more flexible and innovative forms as will be shown next in the convertible auditorium and multiform stages.

1.2.6. CONVERTIBLE AUDITORIUM AND MULTIFORM STAGE:

One of the main theater design modern directions in the twentieth century is the Multi-propose use Theaters for economic reasons where demand does not justify separate facilities. To ensure that auditoria are adequately used, and to minimize capital expenditure, it may be useful to combine users as well as uses. (Appleton, 2008, p. 110)

The following table presents the different categories of multi-purpose layouts:

<table>
<tr><th colspan="2">Multi-format: single production type</th></tr>
<tr><td>The same type of production with more than one arrangement for the relationship between audience and performance, such as the black box theater. This type of theater is generally housed in a large, black, rectilinear room. Audience seating chairs may be moved around and set up in whatever configuration is desired. It is introduced on modern theater experiments because of its:
Low cost.
Extreme intimacy.
Ability to conform to more experimental genres of performance.</td><td>
</td></tr>
<tr><th colspan="2">Single format with flexibility</th></tr>
<tr><td>Reference to a relationship between audience and performers which accommodates more than one type of production and requires some physical adaptation. This can be achieved by lifting the orchestra level into different levels according to the performance type.</td><td>
</td></tr>
<tr><th colspan="2">Multi-format</th></tr>
<tr><td>More than one type of production and format, such as both opera and drama combined in a single auditorium and stage arrangement. Mechanical and technological means are needed to achieve such forms as the arrangement of auditorium seats and the stage can freely replace each other according to the type of theater stage required. Many concerns aroused about such type as it doesn't considered an economical theater.</td><td></td></tr>
<tr><th colspan="2">Multi-use</th></tr>
</table>

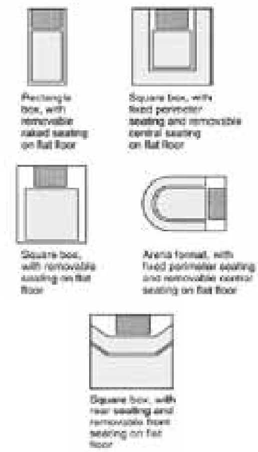
<table>
<tr>
<td>Combination of one or more type of production with activities which are not performing arts such as indoor sports. These include:
Activities with compatible requirements requiring a modest level of physical change of the auditorium and stage (this relates to those activities which benefit from a raked floor such as conference, lectures, films and slide shows);
Activities which require adaptation of the auditorium and stage to satisfy their requirements (adaptation tends to relate to the accommodation of those activities requiring a flat floor, where the raked seating needs to be removed: such activities include dancing, banquets, exhibitions, indoor sports and keep fit classes).</td>
<td>
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TABLE 1.2-4: DIFFERENT CATEGORIES OF MULTI-PURPOSE LAYOUTS ILLUSTRATED BY (APPLETON, 2008)(HOLLOWAY, 2010)

1.3. CONCLUSION

All through theater history, the relationship between Audience Chamber and the Stage was greatly affected by surrounding culture and the development of the theater experiment itself. In ancient theater forms, there were many trials to search for a proper relation between the audience and the actor regardless of the acoustics principles, as they started by outdoors theaters where the main objective was that the audiences receive high intimacy feeling and good visual sights. That’s why semi circular and elliptical forms were dominant in theater plans and high stepped flooring for audience was formed for good sightlines.

By presenting the wooden roof ceiling over the audience chamber at first in the Roman period, the auditorium ceiling was built higher than the stage ceiling, to get use of daylight as there weren't any tools for artificial light. The aim of the roofed ceiling was just to protect the audience from direct sunlight. Still less care was given to the Stage Box which was free and its ceiling was much lower that the audience. Mechanicals tools were very primitive and limited such as those used in the Coliseum. Although ancient forms were so primitive and simple, they presented a variety of relationships between audience and actor as they weren't stuck to one tradition form where all acoustics and sightlines are achieved. But they were a series of free innovation forms that inspired non-traditional forms in modern theater later.

Buildings designed for art performance disappeared for a long period due to religious and war reasons. The church was a dominating force at that time and considered theater art as work of evil. All religious music and performances were performed in churches and other kinds of performances were performed in princes' and dukes' palaces.

At the end of the Renaissance period and by the decrease of the church force, the first theater since the Roman period was built in Italy. It was inspired by the Roman amphitheaters. At first, the seating of the audience was affected by the purpose of good and equal sightlines for all the audience to the stage. However, this purpose gradually disappeared by the introduction of another purpose for theater buildings. Theaters became in Baroque period a social event where all the members of high class audiences gathered not only to see the performance but to look at each other. Unequal seats started by the introduction of the Horse-shoe shaped auditorium. The best sightlines were the head of the Horse-shoe shape and of course it was always reserved for the Duke. At the sides sat the audience with a poorer sightline to the stage and a strong view for the Duke and the other side audiences. The auditorium was well decorated as it became a part of the performance. Even the performances were to present the fantasy and luxurious life in places, cities, streets and gardens. The painted sceneries depended on the vanishing point to give a perspective view. Some stages were built with raked streets in the background to imitate a real city. The floor stage were rake perpendicular to the curtain line also to give that perspective look. Real life was presented virtually on theater stage. The proscenium arch that separated the audience and the actors was presented and became an important item in traditional Drama theaters and Opera houses till present time.

Another form of the theater that was well known in such period, was the rectangular concert hall. At first these halls were for multipurpose use such as ballrooms and small music concerts and then it became the traditional shape for a concert hall. Although it was discovered later that the thin rectangular form was one the best acoustical forms for music concerts, It wasn't built for that purpose at first. It was designed to be very luxurious and fanciful. The ceilings over the orchestra and the audience were at the same level and very well decorated. There wasn't any separating wall between the audience and the orchestra as the main purpose of such halls was to feel surrounded by the music. It became very popular in the Romantic and Baroque period.

By the machine revolution, the proscenium stage took advantage over all theater forms. Audience chamber was totally separated from the stage. The main purpose is to present a superior performance with the aid of stage machinery. Audiences had to sit in the dark to watch the fascinating performance with all its light and magical effects presented by mechanical and technological tools. The stage house became more complicated and turned to be a small factory for presenting very realistic sceneries on stage. The audience seating was changed from horse-shoe shape to fan-shape in Drama Theater to return to equal sightlines for all the audiences. As for Classical Opera, Shoe-horse shape was still ideal for giving more seats; also acoustical limitations were more important than visual sightlines.

The machines use wasn't restricted only in the theater stage but it also had a great influence on the auditorium design. By the nineteenth century, for economic reasons, multipurpose theaters were introduced to gather different types of performances in one building. The adaptation of stage and auditorium shape and volume to such purpose was aided by machines and high technology. The economic use of multipurpose theater is still debatable.

2. CHAPTER (2): PRINCIPLES THAT INFLUENCE AUDITORIUM DESIGN

In this chapter a more detailed study will be given for the one-directional forces from the stage that affect the form of most recent traditional auditoriums. It will be translated into principles that should be taken into consideration specially while studying comparative analysis case studies between traditional theaters that don't enhance Multimedia or VR technologies with others. These principles are generated from a long history theatrical practices as studied in chapter one. They are now influenced by a main factor which is the type of performance.

As with any building, the design of all performing arts spaces is driven by the program of the activities that are housed within. Because of this specialized function, an architect who has been commissioned to design a performing arts building is well advised to engage the services of specially consultants, particularly in the areas of theater planning, theatrical equipment, acoustics, sound systems and codes.

Performing art spaces fall broadly into two categories. The first includes spaces that are intended primarily to house one type of performance activity, such as the following:

- Drama theaters
- Opera houses
- Concert halls
- Ballet and other dance theaters
- Film theaters
- Musical theaters

The second category of spaces includes those designed to accommodate two or more such activities within a single space. Such spaces are typically referred as multipurpose or multiple-use performing arts centers in major urban centers to small-scale community theaters seating a few hundred persons. (Joseph De Chiara, Michael J. Crosbie, 2001, p. 713)

The following table presents the general characteristic and required stage shape for each performance type:

	General Characteristic	Stage shape
Drama	The greatest emphasis upon the scale of the human actor. Dominance of plot, locale, and characterization requires verisimilitude in the size and relationship of scenic objects.	Proscenium Thrust Stage Arena
Opera Houses	Large numbers of performers (up to 100) on the acting area at one time Movement is martial processions and group dances and the costumes are elaborate. Soloists perform downstage center, close to the footlights. Group scenes perform in the area near the audience, and choruses and supernumeraries require space upstage. The performance is viewed objectively by the audience and does not benefit by intimate contact	Proscenium
Musical Theater	Dramatic episodes, processions, marches, dances, and crowd scenes. Masses of performers engaged in simple but expansive movements before very large audiences.	Proscenium
Full concert halls	These forms embody on a smaller scale (less than 50) the production elements of grand opera, plus a certain freedom and a quest for novelty which encourage the development of new performance devices. Big scenes involve many dancers, singers, and showgirls, often with space-filling costume and movement.	Single Volume music room (traditional) Arena (20-century innovation)
Ballet and other dance theaters	Graceful and expressive movements of human figures in designed patterns, chiefly in two dimensions but with the third dimension introduced by leaps and carries. Occasional elevation of parts of the stage floor. Singles, duets, trios, quartets, groups. The movement demands maximal clear stage space.	Proscenium
Film Theaters	Different from stage theaters due to design requirements, including auditory and visual considerations combined with showmanship and economy of structure. Success depends on its ability to present good films in an effective manner; proper vision of the screen image, true reproduction of sound effects, and such comforts as will enable the patrons to give undivided attention to the presentation.	Own Archetype

TABLE 1.3-1: GENERAL CHARACTERISTIC AND REQUIRES STAGE SHAPE FOR EACH PERFORMANCE TYPE ILUSTRATED BY (JOSEPH DE CHIARA, JOHN CALLENDER, 1987)

The three-dimensional volume of an auditorium is conditioned by the limitations set by all members of the audience able to hear and see a performance, and for the performers to be able to command the audience. (Appleton, 2008, p. 112). In this chapter, a brief study will be presented for the principles that affect the auditorium design in general and specific studies according to type of performances (speech, music and multipurpose) and also the type of stage. These principles are categorized in this study according to the following:

- Positioning and seating of the audience.
- Acoustic considerations.
- Lighting and sound in the audio.
- Ventilation and air handling.

The main purpose of this study is to understand and summarize the sets of limitations that influence the auditorium design in traditional and non-traditional theaters, and compare it - later in chapter (6)- by the new sets of limitations that will be presented by the introduction of Virtual Reality Technology on theater stage.

2.1. POSITIONING AND SEATING THE AUDIENCE

The main purpose of positioning and arrangement of the audience is to provide the maximum number of audience the feel of comfort, good sightlines for the stage and high acoustical quality. It is highly affected by the seating capacity that needed to be achieved and visual limitations in plan and section more than aural limitations. According to this, the main points that will be studied in this section, that affect the audience seating, will be as follows:

- Seat count.
- Plan arrangement of audience seating.
- Vertical arrangement of audience seating.

2.1.1. SEAT COUNT:

Seats generate income, but deciding on the optimum number of seats is not a case of the more the better. Although modern technology can create a space which can accommodate tens of thousands of people, it won't be effective for all types of performances where visual and aural limitations should be considered. Such type of space will only be effective for large scale, noneconomic electronically enhanced productions. (Strong, 2010, p. 66). Each type of performance is affected by visual and aural limitations in different levels. The following table presents the level of aural and visual limitation for each type of performance and the maximum distance preferred from stage:

	Limitation Level		Max. Distance from Stage	Seating Capacity	Factors affect limitations
	Aural level	Visual Level			
Drama	High	High	20 M	1200–1500	Details of the actor's facial expression and small gestures
Opera & Musicals	High	Medium	30 M	1600–2000	Discerning facial expressions is less critical.
Dance	High	High	20 M	1200–1500	The audience need to appreciate the body and feet of the dancers, and also to discern facial expressions
Full concert halls	High	Low	60 M	1500–2000	The visual definition may not be a critical factor with the rear row being more a function of acoustic limitation rather than visual.
jazz/pop/rock concerts	High	Low	20 M	1200–1500	The visual limitations seem not at all critical particularly with the addition of video screens to aid vision especially from the rear sections of the auditorium.
Film Theaters	High	High	Double the screen width	600-1500	Picture shape and viewing patterns are determined by fixing visual standards that enable each viewer to see the picture satisfactorily. The picture must appear undistorted, its view must be unobstructed, and its details discernible.

TABLE 2.1-1: DIFFERENT PERFORMANCE TYPES AURAL AND VISUAL LIMITATIONS LEVEL AND MAXIMUM DISTANCE FROM STAGE. ILLUSTRATED BY (JOSEPH DE CHIARA, MICHAEL J. CROSBIE, 2001) & (APPLETON, 2008)

According to this reversible relation between the need of high seat count and keeping the average patron within a reasonable viewing distance to the performer on a single level, another seating level or levels are introduced to theater layout to resolve that kind of problem. The use of balconies to vertically distribute seating and preserve a more intimate audience experience of the performance introduces both challenges and opportunities to theater planning. .(Joseph De Chiara, Michael J. Crosbie, 2001, p. 728)

2.1.2. PLAN ARRANGEMENT:

Vision and acoustics criteria define the horizontal proportions (plan shape) of the room with references to the stage configuration and proscenium width. Sight lines need to balance the desire to keep as many patrons as possible close to the centerline of the room with the goal of minimizing the average viewing distance to the stage. The objectives logically should be to minimize the number of seats in the center front region. (Joseph De Chiara, Michael J. Crosbie, 2001)

The following points present the main factors that affect plan seating arrangement in traditional proscenium theater:

2.1.2.1. DISTANCES

The maximum distances in plan arrangement is determined according to visual and aural limitations (See **Table 2.1-1**) for each performance and the angle degree of viewing the image that may require neck craning. The normal cone of optimum vision covers 30 degrees vertically and 40 degrees horizontally. A 45-degree pivot is considered the maximum tolerate (See **Figure** 2.1-1).

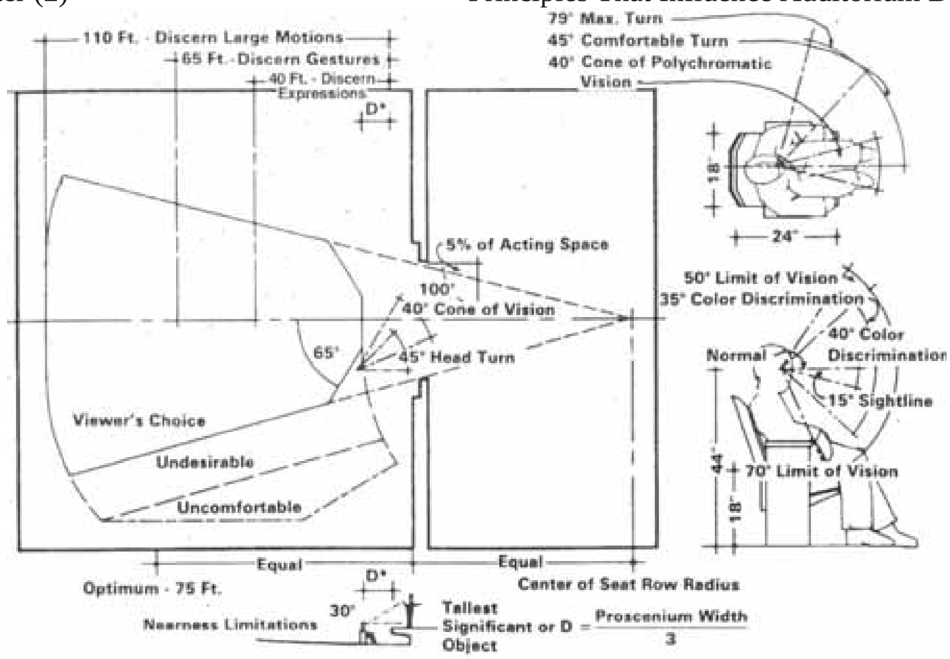


FIGURE 2.1-1: CRITICAL DIMENSIONS IN PLAN ARRANGEMENT IN A THEATER (JOSEPH DE CHIARA, MICHAEL J. CROSBIE, 2001, P. 729)

As for Film Theater, the first row of seats should be no closer to the screen than a position determined where the angle formed with the horizontal by a line from the top of the projected picture to the eye of the viewer in a front-row seat, should not exceed 33 deg. (Joseph de Chiara, John Callender, 1987)

2.1.2.2. HOUSE WIDTH

To ensure maximum effectiveness, the dimension of proscenium width is determined according to the proscenium arch opening which is a function of the kind of production contemplated for the theater (See **Table** 2.1-2).

	Maximum	Usual	Reasonable Maximum
Drama	8 M	9 - 10.5 M	20 M
Dance	9 M	10.5 M	13.5 M
Musicals	9 M	12 M	15 M
Opera	12 M	15-16.5 M	20 M

TABLE 2.1-2: PROSCENIUM WIDTHS FOR KINDS OF THEATRICAL PRODUCTIONS BY (JOSEPH DE CHIARA, MICHAEL J. CROSBIE, 2001)

The width of the film theater is subjected to the width of screen. The maximum width of the last row is 1.3 the screen width and the first row is equal to the screen width.

2.1.2.3. **SEATING GEOMETRY**

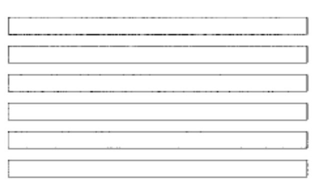
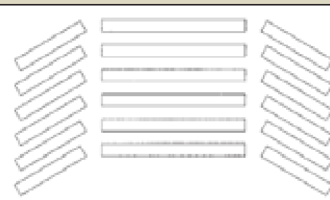
Seating geometry is affected by the following factors:

- The row orientation. (straight, curved or angular)
- The presence of aisles.
- Seating Staggering.

Seating is usually laid out in straight or curved rows focusing towards the performance. Further forms are the angled row, the straight row with curved change of direction. Curved rows are slightly more efficient in terms of numbers within a given area and orient all the audience towards the stage but may increase construction costs.

According to building codes, continuous row seats legally mustn't exceed 14 seats in every section. In large auditoriums, aisles serve the side seats. Aisles perpendicular to the curtain line often have the accidental result of making side-section seats undesirable because people using the aisle interrupt the view toward the stage and this results in creating undesirable seats. Also a center aisle wastes the most desirable seating area in the theater. That’s why radial aisles are the best choice for large auditorium. (Joseph De Chiara, Michael J. Crosbie, 2001, p. 729)

The following table shows the different rows orientation with or without aisles:

	Continuous	**With aisles**
Straight rows		
	Straight rows without aisles	Straight rows, with side blocks of seats angled and focused towards the platform/stage

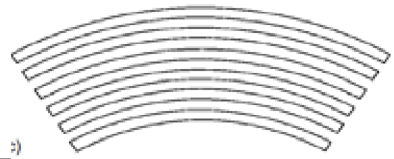
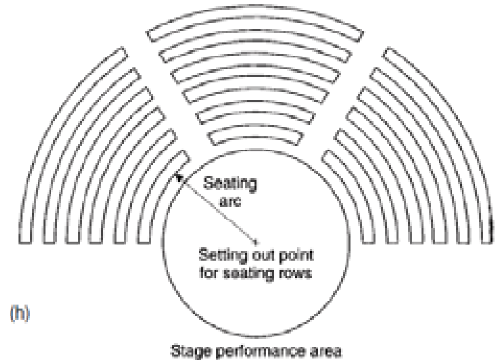
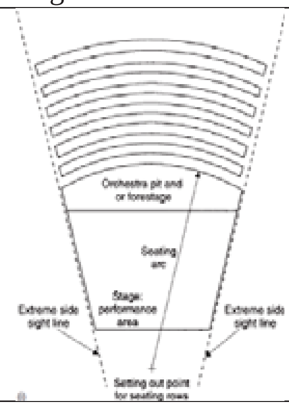
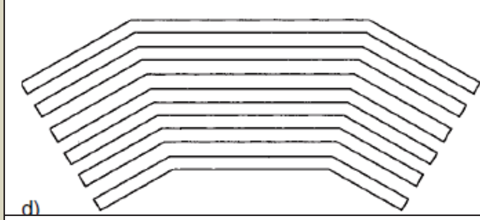
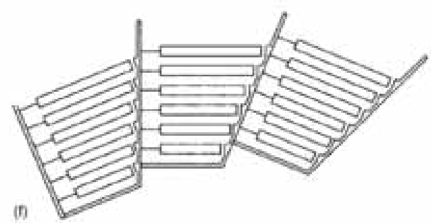
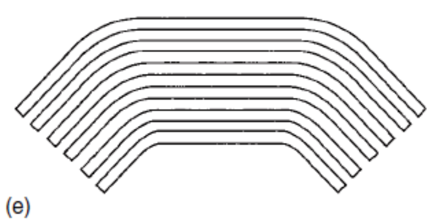
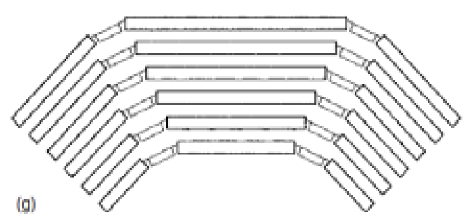
	Continuous	With aisles
Curved rows		
	Curved rows: rows focused towards platform/stage.	
		
	Setting out point for seating rows distinct from geometry of performance area and extreme side sightlines: this arrangement tends to be a characteristic of proscenium formats.	Setting out point for seating rows same as centre of performance area: this coincidence of seating out points tends to be a characteristic of open stage layouts.
Angular rows		
	Angular rows: straight sections to each row, angled and focused towards the platform/stage.	Distinct blocks of seating focused towards platform/stage.
		
	Angular rows: as previous but with curve at change of direction	Straight rows angled and focused towards platform/stage with blocks of seats and gangways located at change of direction.

TABLE 2.1-3: ROW ORIENTATONS WITH AND WITHOUT AISLES ILLUSTRATED BY (APPLETON, 2008, P. 121)

To provide best visibility from any seats, audience shouldn't be aligned to sit in front of each other especially in large auditorium, within the aural and visual limitations, maximum seating capacity are needed. If the seats are staggered then better open view will be given to each seat (see **Figure 2.1-2**) which will affect the angle of floor rake as shown later in the vertical arrangement. This implies a balance between sightlines, height of the auditorium and seating capacity: a reduction in the accumulative height of the lower level of seating allowing more height for balconies.

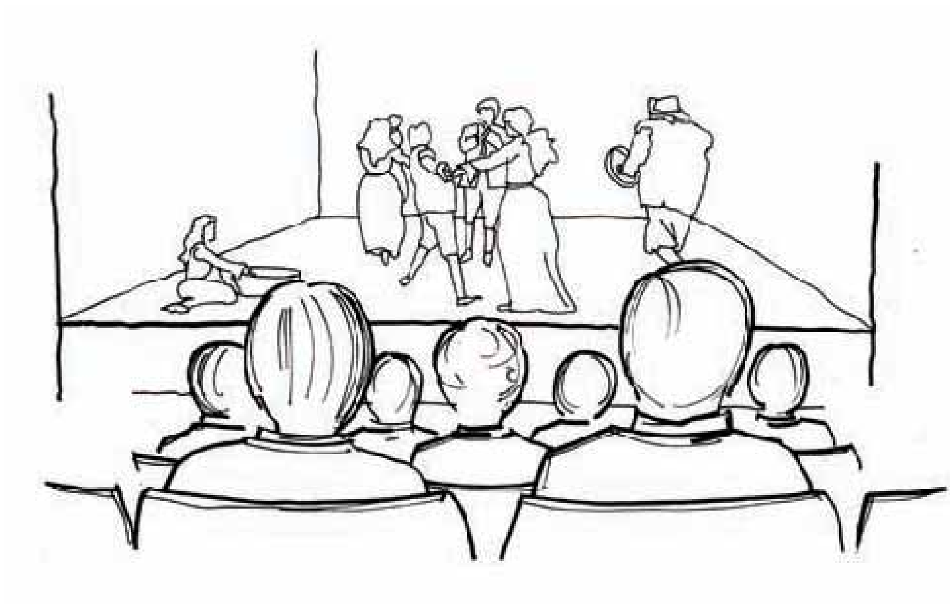


FIGURE 2.1-2: STAGGERED ALIMENT: SKETCHING SHOWING THE VIEW OF THE STAGE BETWEEN HEADS (STRONG, 2010, P. 78)

2.1.3. VERTICAL ARRANGEMENT:

If the floor is flat, patrons have a hard time seeing over the people in front of them. For this reason, most theater floors slope gently upward toward the back of the house. Floors may be ramped (a continuous slope) or stepped. (Joseph De Chiara, Michael J. Crosbie, 2001)

There are some factors, which will be studied in this section, affect the angle of the auditorium floor rake:

- Stage elevation.

- Vertical sightlines.

2.1.3.1. **STAGE ELEVATION**

The stage, or even a screen in Movie Theater, should always be below eye level of patrons sitting in the first row. The stage height, when raised, can range from 0.6 M to 1.1 M above the lowest level of the auditorium. . The viewing angle of the audience varies according to the art form. In

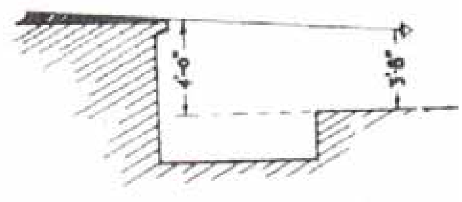


FIGURE 2.1-3: ZONE OF INVISIBILITY CAUSES STAGE TO BE TOO HIGH FRONT SEATS TOO LOW (JOSEPH DE CHIARA, MICHAEL J. CROSBIE, 2001)

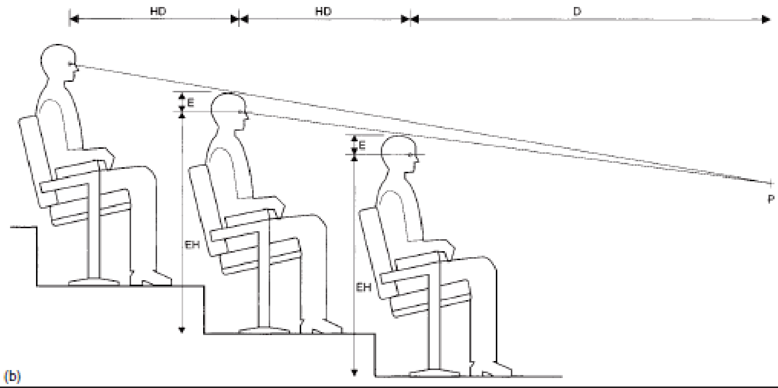
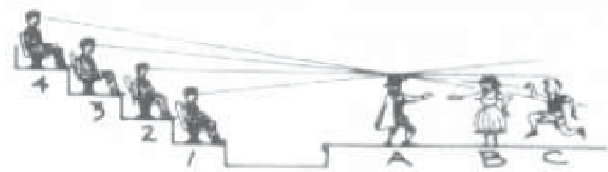
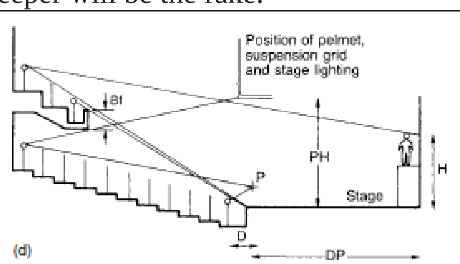
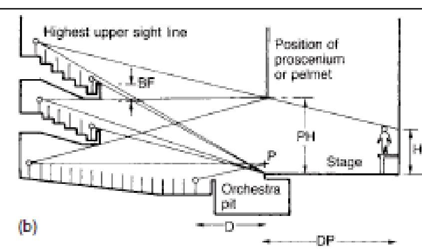
dancing, for example, patrons must be able to see the dancers' feet. (See **Figure 2.1-3**).

2.1.3.2. VERTICAL SIGHTLINES

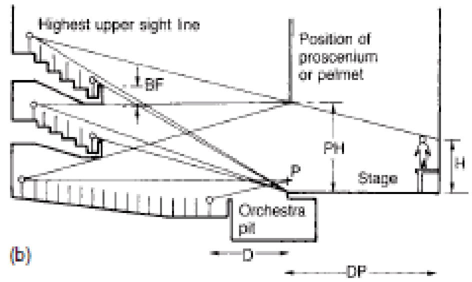
There are general considerations for vertical sightlines illustrated by (Joseph De Chiara, Michael J. Crosbie, 2001):

- The vertical angle of 30 degrees at the spectator's position establishes the distance from the closest seat to the screen or to the highest significant object on the stage.
- The lowest seat in the orchestra (typically the first row) must be located where the patron can just see the stage floor (or the bottom of a movie screen).
- The highest seat in the balcony must be on a line which is not more than 30 degrees to the horizontal from the stage floor at the curtain line.
- The standing patron at the back of the orchestra level should be able to see the top of a screen or as high as any significant portion of a stage setting.
- Each spectator must see the whole stage or screen over the heads of those in front. Within these limits the floor slope of orchestra and balcony can be laid out: the first step in determining auditorium section.

Vertical sightlines may be calculated by the following parameters:

<table>
<tr><th></th><th colspan="2">Vertical Sightlines Relations</th></tr>
<tr><td rowspan="10">Lower Level Seating</td><td colspan="2">
</td></tr>
<tr><td colspan="2">Graphic representation of vertical sightlines in lower level seating in proscenium or open – thrust stage.</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td colspan="2">Graphic representation of vertical sightlines in lower level seating in arena stage. The sight line problem inherent in the arena form: A hides B and C from first two rows. it is necessary to elevate successive rows of seats more than in proscenium form to minimize the problem of actors covering other actors from some points in the room</td></tr>
<tr><td colspan="2">The slope for a Movie Theater requires a more steeped pitched floor due to the sightline requirements of the screen without any obstructions caused by the front seats.</td></tr>
<tr><td colspan="2">P: Lowest and nearest point of sight on the platform/stage for the audience to see clearly. It is calculated according to stage or performance type as Table 2.1-5</td></tr>
<tr><td colspan="2">HD: Horizontal distance between the eyes of the seated members of the audience, which relates to the row spacing (from 0.76 to 1.15 M or more)</td></tr>
<tr><td colspan="2">EH: Average eye height at 1120 mm above the theoretical floor level: the actual eye point will depend on seat dimensions.</td></tr>
<tr><td colspan="2">E: Distance from the centre of the eye to the top of the head, taken as 125 mm.</td></tr>
<tr><td colspan="2">D: Front row of seats: the distance from point P to the edge of the average member of the audience in the front row. The closer the first row to the platform/stage, the steeper will be the rake.</td></tr>
<tr><td rowspan="2">Balconies</td><td>
</td><td>
</td></tr>
<tr><td>2.1- Vertical sightlines through auditorium with an open stage.</td><td>2.2- Vertical sightlines through the auditorium with proscenium stage.</td></tr>
</table>

Vertical Sightlines Relations



2.3- Vertical sightlines through auditorium with concert platform: sightlines require including choir stalls and any architectural setting behind the platform as well as the conductor, soloists and orchestra on the platform. Note, however, that acoustic requirements of direct and reflected sound may override sightline calculations.

P: Nearest and lowest part of the stage which must be within the unrestricted view of all members of the seated audience as previously described.

DP: Depth of the performance area.

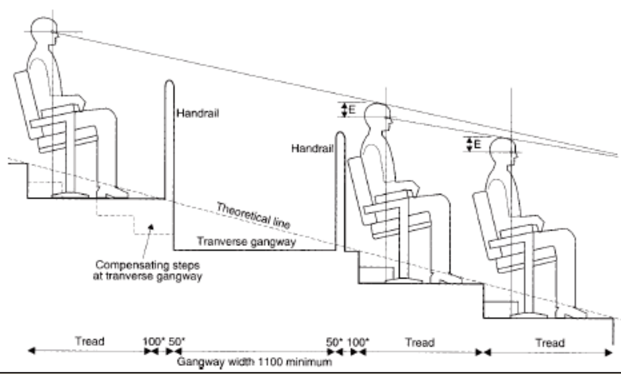
H: Height of the performance area at the rear.

HO: Height of the proscenium opening,

BF: Height of balcony front. The placement of the balcony railings should not interfere with a clear view of the platform/stage.

D: Distance to front row, as previously described.

Transverse Aisles



3.1- Sightlines at traverse gangway/aisles. Theoretical line of rake requires to continue across the gangway

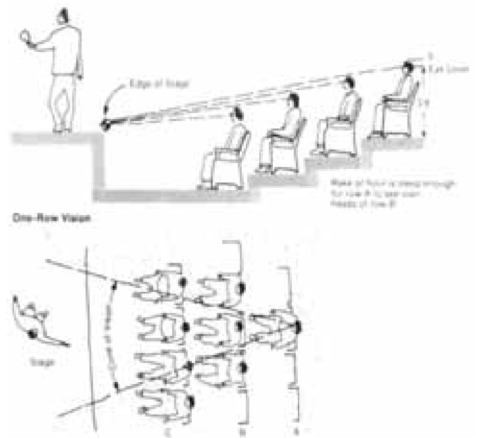
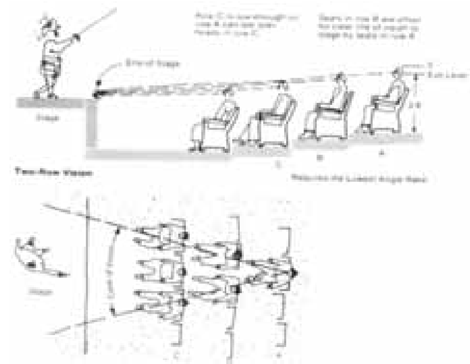
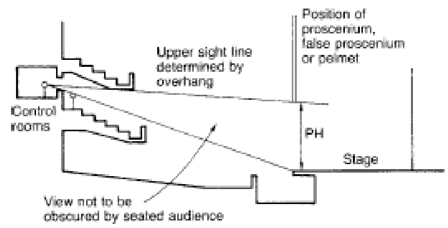
	Vertical Sightlines Relations	
Seats Positioning		
	4.1- One-row vision, in which seats in each row line up directly with those in front, requires a very steep rake to allow for proper viewing angles.	**4.2-** Two-row vision involves staggered seating and permits an unobstructed view between the two seats in front of the patron. Because this arrangement does not involve a steep rake, it is highly recommended.
Control Room		
	5.1- Vertical sightlines from control rooms at rear of auditorium.	

TABLE 2.1-4: CALCULATION OF SIGHTLINES IN DIFFERENT PARTS OF THE AUDITORIUM ILLUSTRATED BY (APPLETON, 2008) & (JOSEPH DE CHIARA, MICHAEL J. CROSBIE, 2001)

	Theater and performance types	Determination of point P
Stage type	Apron Proscenium stage/ Thrust stage	P is determined according to forestage
	Stage with Orchestra pit	P is the height of the conductor's Head
Performance type	Concert	P is from 0.6 M above the front stage
	Dance	P is the setline of stage.
	Opera Musical & Drama	P is from 0.45 to 0.6 M maximum above the front stage

TABLE 2.1-5: CALCULATINTHE HEIGHT OF P POINT ACCORDING TO STAGE AND PERFORMANCE TYPE ILLUSTRATED BY (APPLETON, 2008) & (STRONG, 2010)

2.2. ACOUSTIC CONSIDERATIONS

Acoustical design plays an important role in developing many features in a performance facility. The task of the acoustician is to ensure that the construction, geometry and finish of an auditorium is such that every member of the audience can hear the performance clearly without coloration and that the performances also hear each other well to enable them to play ensemble. (Strong, 2010)

Acoustics impact everything from the size and shape of the house, the location of mechanical rooms, and the selection of sound equipments to the density of materials enclosing the performance hall, the size of ducts, and the requirements for doors and windows. (Joseph De Chiara, Michael J. Crosbie, 2001). In this study a brief study will be presented for the acoustical considerations points that directly affect the auditorium design regarding the performance type which is categorized according to the following:

2.2.1. TYPE OF PRODUCTION

- Speech (Drama Theater and Movie Theater)
- Music (Opera houses, Music halls and Dance Theater)
- Multipurpose (Forms of theater that presents more than one performance)

2.2.1.1. ROOM FOR SPEECH AUDITORIUM

Intelligibility depends on the masking effects of extraneous sounds on the speech we hear. Masking can be caused by noise from background sources or by reflections of the original spoken words. Speech combines the quick high-frequency sounds of consonants with the broader tones of the vowels. It is the recognition of consonants that correlates most closely with speech intelligibility, so the transmission of undistorted high-frequency information is critical. (Long, 2006)

2.2.1.2. ROOM FOR MUSIC AUDITORIUM

Rooms designed for unamplified music are the most visible and interesting spaces in architectural acoustics. The design blends the science of acoustics and the arts of architecture and music. Unlike the limited options for concert halls given by the acoustical design, sound system design gives more flexible hall designs where a loudspeaker configuration can yield a very predictable result. It also dives the ability to control the original sources, whose type, position, loudness, directivity, and number can change with every performance, or in some cases, with every note. In this case, the main concern for the acoustician is the room surfaces that reflect, diffuse, or absorb the primal energy. (Long, 2006)

Although Music and speech have similar characteristics, as both consist of bursts of sound separated by quietness, they have different characteristics in the way our ears interpret the physical sound waves that lead to the need of different acoustical design consideration for music and speech auditoriums. For speech, tone is only used for recognition purposes and phrasing. As for music, tonality and harmony are fundamental aspects. Another more important issue than tonality is interpreting the complex temporal pattern of reflections. For speech, Intelligibility is paramount and this is known to be associated with the proportion of energy which arrives early, both in the direct sound and early reflections. The corresponding quality for music is clarity or definition, which can be related to a similar energy proportion. But many other qualities are also important for concert hall listening. (Barron, 2010) See also (Appendix A: Musical terms definitions) as they will be used later.

2.2.1.3. **ROOM FOR MULTIPURPOSE AUDITORIUM**

The acoustical properties that make a room good for speech are often the same as those that make it poor for music, and vice versa. For good speech intelligibility, room volumes and reverberation times should be low. The first reflections should be primarily from the ceiling, and there is little need for diffusion. Conversely, rooms designed for listening to unamplified music require longer reverberation times, higher volumes, lateral rather than overhead reflections, and high diffusion. Rooms designed for mixed uses require a judicious compromise between the needs of speech and music. Buildings of this type, including auditoria, theaters, churches, and synagogues, are among the most architecturally diverse of all spaces and the most challenging to design. (Long, 2006) The following are general consideration regarding speech, music and multipurpose:

	General Acoustics Considerations
Speech	Providing optimum reverberation time. Eliminating acoustical defects such as echoes and flutter echoes. Maximizing loudness in the audience. Minimizing the noise level in the room. Providing a speech reinforcement system where needed.
Music	Providing strong lateral reflections from the side to let the audience feel enveloped by the sound. Supporting instrumental sound by providing a reverberant field, whose duration depends on the type of music being played Providing clarity and definition in the rapid musical passages so that they can be appreciated in detail. Providing adequate loudness that is evenly distributed throughout the hall Supporting wide bandwidth Controlling exterior noise sources and mechanical equipment. Eliminating acoustical defects such as echoes, shadowing and coloration. Reflecting to the performers from the space a reverberant return that is close to that experienced by the audience.
Multi purpose	Providing a sound system capable of reproducing the full program frequency range. Integrating reflective surfaces both overhead on either sides of the singers and musicians where unamplified music is a part of the program by suspended ceiling or movable shell. Controlling sound absorption to achieve a reverberation time consistent with the program to minimize the differences between the empty and occupied conditions. Room reverberation must be controlled to limit the loudness of large groups. Minimizing the background noise level in the room.

TABLE 2.2-1: GENERAL CONSIDERATIONS FOR SPEECH, MUSIC AND MULTIPURPOSE ACOUSTICS (MADAN MEHTA, JAMES ALLISON JOHNSON, JORGE ROCAFORT, 1999) & (LONG, 2006)

2.2.2. REVERBERATION TIME

There is difference in time between direct sound to each member of an audience and the reflected sound from all surfaces of the auditorium, which requires to be short for speech and long for music. The aim is to balance these two sound sources by eliminating distortion and distributing sound evenly across the audience. (Appleton, 2008)

Many factors contribute in the acoustical design. Audience close to the stage hears mostly direct sound, which dominates the weaker late reflections, while audience far from the stage hear a combination of direct and indirect sound and reflected sound arriving as a series of discrete reflection spaced in time. In order to achieve high quality acoustics, the reflected sound should arrive in an ordered way, maintaining the realism of the direct sound, reinforcing it and not containing strong long delayed reflections or echoes. (Strong, 2010)

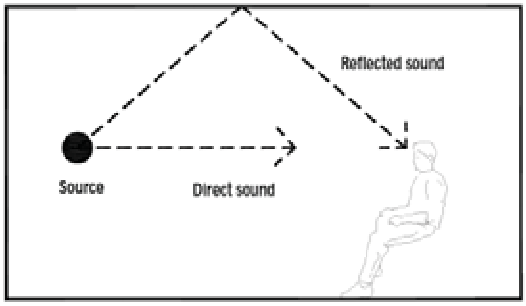


FIGURE 2.2-1: DIRECT & REFLECED SOUND (STRONG, 2010)

The appropriate reverberation time for an auditorium should be determined principally on the basis of program

Performance type	Reverberation time
Opera music	more than 2.5
Romantic classical music	1.8-2.2
Early classical music	1.6-1.8
Opera	1.3-1.8
Chamber music	1.4-1.7
Drama theater	0.7-1.0

TABLE 2.2-2: RECOMMENDED OCCUPIED REVERBERATION TIMES (SECONDS) (BARRON, 2010)

2.2.3. FINISHES

Extent, size, shape and location of surfaces required for reflection, absorption and diffusion of sound to the walls, ceiling and floor, including the seat design, which can all affect the reverberation time. (Appleton, 2008)

	Interior Finishes Consideration
Walls & ceilings	Heavy plaster is the most commonly used in concert and opera halls. When wood is used it should be heavy, at least 1” (25 mm) thick, and be backed with a solid masonry or concrete structure.

Floors	Floors are constructed of concrete or wood on concrete. When floors are concrete, the aisles are covered with a thin carpet walking surface. Wood floors are applied in two layers, for example a 3/4” (19 mm) finish floor on 3/4” plywood subfloor on wood sleepers over concrete.
Seating	It is considered the biggest absorbing surface. It is most important to use seats, whose absorption characteristics closely resemble that of a seated occupant. The chairs or pews should have thick padding on both the seats and backs.

TABLE 2.2-3: INTERIOR FINISHES CONSIDERATIONS ILLUSTRATED BY (LONG, 2006)

2.2.4. QUALITY OF THE SOUND

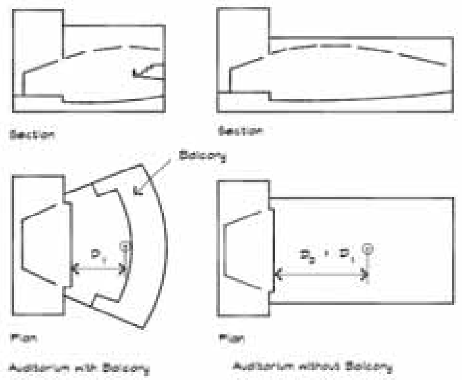
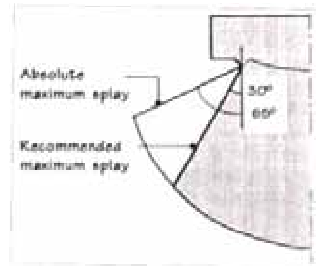
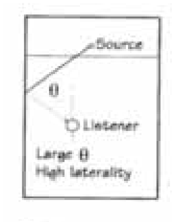
Expectations vary according to speech and different types of music, and relate to such factors as the extent to which each member of the audience may feel surrounded by sound, respond in an intimate or detached manner, and experience a balance between sounds from different performers. (Appleton, 2008)

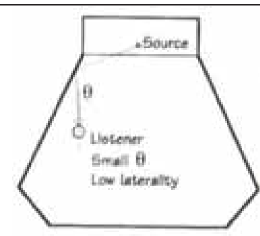
2.2.5. ROOM ACOUSTICS

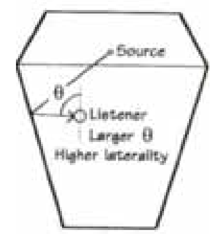
The extent to which the audience surround the platform/stage; seating capacity; number and depth of balconies; rake of the seating; for concerts, the proportion of length to width and height to width; for opera, dance and musicals, the location of the orchestra pit; location of performance lighting and sound equipment and lighting bridges. Setting for the performance: such as permanent architectural setting, within audience, proscenium stage and so on. This will be studied in details in (section 2.2.1.).

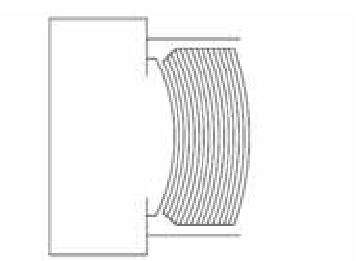
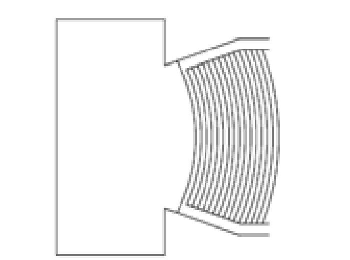
2.2.5.1. ROOM SHAPE

The following table presents the recommended basic shapes for each type of production:

<table>
<tr><th></th><th colspan="3">Recommended Room Shapes</th></tr>
<tr><td rowspan="2">Speech</td><td colspan="2">
</td><td>
</td></tr>
<tr><td colspan="2">The main concern is to bring the audience close to the talker. A fan-shaped room, particularly one with balconies, allows a larger number of people to be close to the stage, than a rectangular room. Also the reflection from side walls is directed toward the rear of the room, where they are most needed.</td><td>Considering the directionality of speech, the suggested maximum side-wall splay for a room is 30, the absolute maximum being 65.</td></tr>
<tr><td rowspan="2">Music</td><td>

(a) Rectangular hall</td><td>

(b) Fan-shaped hall</td><td>

(c) Reverse fan-shaped</td></tr>
<tr><td>A rectangular hall is more favoured than a fan-shaped hall as the side wall reflections reach the listener more from the frontal direction.</td><td>A fan –shaped hall usually is not favored for a concert hall as the laterality of sound is poor .</td><td>A reverse fan shape provides a greater degree of laterality than a rectangular hall.</td></tr>
<tr><td rowspan="3">Multi purpose</td><td colspan="2">
Rectangular seating plan - Poor side wall reflections
Potential flutter echo on the thrust stage</td><td>
Angled seating plan - Better side wall reflections</td></tr>
<tr><td colspan="3">This scheme provides useful early reflections from the walls near the stage or platform, while allowing regular aisles and constant width seating sections at the rear.</td></tr>
<tr><td colspan="2">The side walls at the rear of the room are parallel</td><td>The side walls at the rear of the room are flared at a shallower angle than at the front.</td></tr>
</table>

	Recommended Room Shapes
	Small general-purpose auditoria: are typically rectangular, with the walls near the front of the room angled out from the stage.
	Large multiuse theaters: it becomes increasingly difficult to accommodate the audience with good sight lines. A fan shape is the usual choice, truncated on the sides, with one or more balconies. The distance to the farthest viewer depends on the type of performance.

TABLE 2.2-4: RECOMMANDED ROOM SHAPES FOR SPEECH, MUSIC & MULTIPURPOSE ILLUSTRATED BY (LONG, 2006)& (MADAN MEHTA, JAMES ALLISON JOHNSON, JORGE ROCAFORT, 1999)

2.2.5.2. ROOM VOLUME

Minimizing room volume is another critical requirement; the smaller the volume per seat, the greater the sound energy available to each listener. A smaller volume also means that a smaller amount of absorption is needed to obtain a given reverberation time, since the reverberation time is directly proportional to room volume Consequently, a greater proportion of a room's surface area can be reflective, which helps to boost the loudness. (Madan Mehta, James Allison Johnson, Jorge Rocafort, 1999)

The room volume is calculated as the number in the audience multiplied by a ratio of volume to person, according to the type of production:

Performance type	Volume per Seat cu ft (cu m)		
	Min.	Mid	Max
Rooms for Speech	2.3	3.1	4.3
Concert Halls	6.2	7.8	10.8
Opera Houses	4.5	5.7	7.4
Multipurpose Auditoriums	5.1	7.1	8.5
Motion-picture Theaters	2.8	3.5	5.1

TABLE 2.2-5: RANGE OF VOLUME PER SEAT BY TYPE OF AUDITORIUM (DOELLE, 1972) BY (LONG, 2006)

2.2.5.3. FLOOR SLOPE

Although a raked (sloped) floor is important for visual reasons, it is also acoustically desirable. Sight lines are set so that the audience can see the lowest point of interest on stage; point (P) as determined before in section 2.1.3.2, over the head of a person sitting in front of them. Even though it is theoretically desirable to design a theater with every-row clearance, from a practical standpoint this yields floor slopes that are too steep. The following table presents the acoustical benefits of floor slope and raised stage:

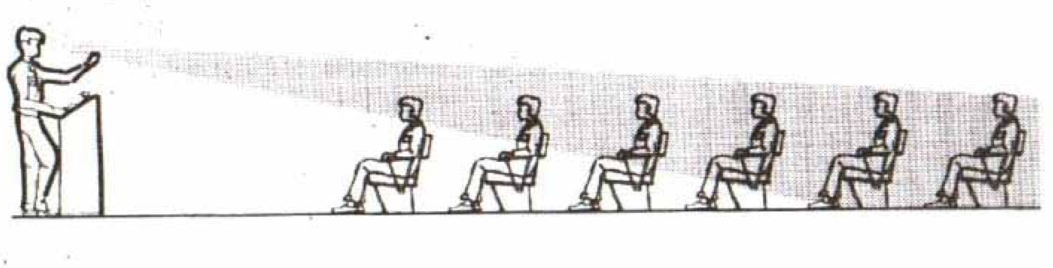
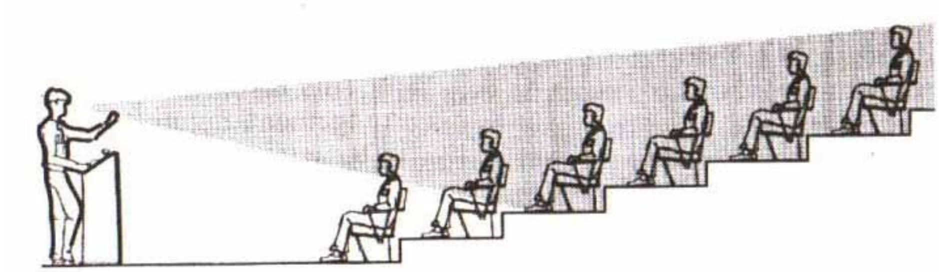
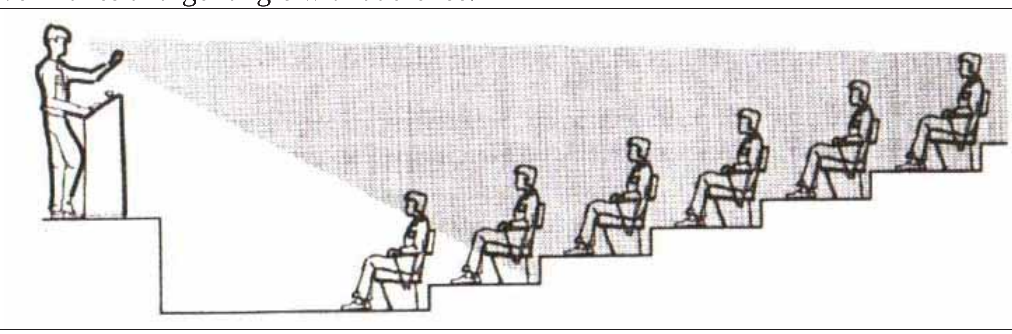
Different floor slope and raised stage

An audience seated on a flat floor with the speaker at the same elevation receives very little direct sound, as shown by the narrow sound beam. Also they will be more absorptive to direct sound energy than audience seated on slopped floor

If the floor is sloped, thus raising the listeners, the sound beam is boarder, indicating a greater amount of sound energy received by the audience. Also it is helpful in reducing excessive audience absorption, since sound that travels over the audience with a small angle of incidence (referred to as grazing incidence) gets absorbed more than the sound whose direction of travel makes a larger angle more than the sound whose direction of travel makes a larger angle with audience.

A sloped floor and an elevated stage (speaker) are necessary to maximize the direct sound energy over the audience.

TABLE 2.2-6: ACOUSTICAL BENEFITS OF FLOOR SLOPE AND RAISED STAGE IILUSTRATED BY (MADAN MEHTA, JAMES ALLISON JOHNSON, JORGE ROCAFORT, 1999)

2.2.5.4. BALCONIES

A balcony brings the audience closer to the musicians and improves sight lines, while dividing the room vertically into separate spaces. Under a deep balcony there is less reverberant energy and the listener has less sense of envelopment and a lower reverberation time. (Long, 2006)

To improve the flow of reflected sound under the balcony, the under-balcony soffit and the room's ceiling must be appropriately profiled. If the ceiling and soffit profiles are not correctly designed, the under-balcony space may not receive much-needed reflected sound due to shadow formation, See **Table 2.2-7:** comaprison between correct and incorrect profited ceiling. (Madan Mehta, James Allison Johnson, Jorge Rocafort, 1999)

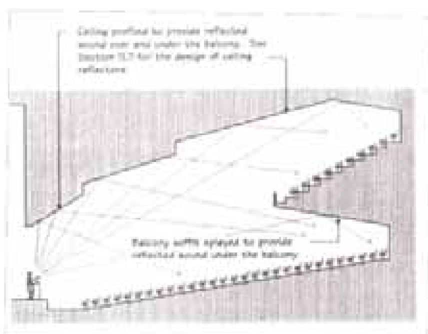
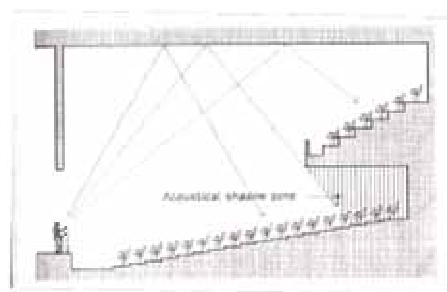
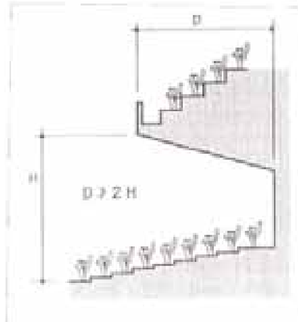
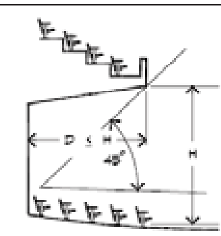
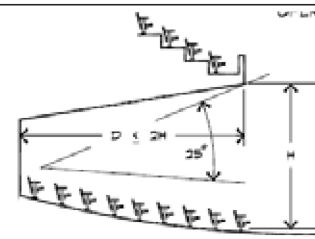
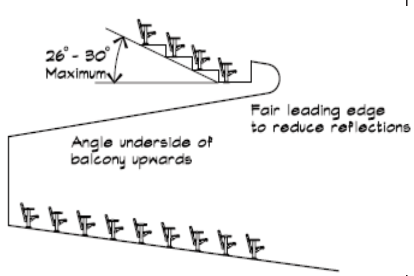
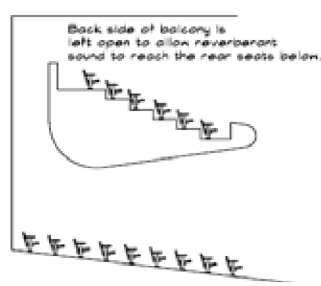
A hall with ceiling and balcony soffit profilled	A hall with incorrectly profited ceiling
	

TABLE 2.2-7: COMAPRISON BETWEEN CORRECT AND INCORRECT PROFITED CEILING

The following table represents the recommended balcony dimensions in each performance type:

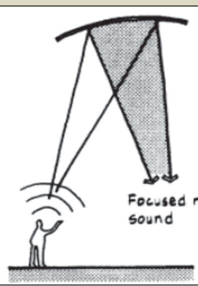
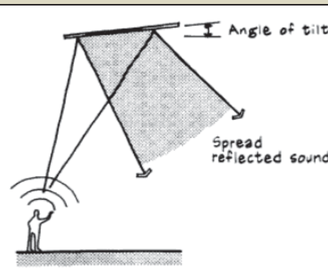
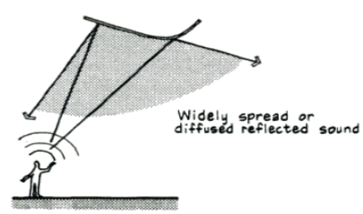
<table>
<tr><th></th><th colspan="2">Recommended Balcony Dimensions</th></tr>
<tr><td rowspan="2">Speech</td><td colspan="2"></td></tr>
<tr><td colspan="2">The depth of the balcony overhang (D) should be no more than 2 times the height of the balcony opening (H)</td></tr>
<tr><td rowspan="3">Music</td><td></td><td></td></tr>
<tr><td>2.1- Designs for Opera houses</td><td>2.2- Balcony design for concert halls</td></tr>
<tr><td colspan="2">The greater the balcony over hang, the more it cuts the listener off from the reverberant energy in the main portion of the hall, and the shorter the early decay time.
A semi-cylindrical cavity under the balcony can help offset the lack of reverberant sound by creating some local reverberant focusing.
A rising extension of the front part of the balcony can also be helpful for gathering acoustic energy and reflecting it to the rear.</td></tr>
<tr><td rowspan="2">Multi purpose</td><td>
</td><td>
</td></tr>
<tr><td>A typical balcony configuration</td><td>Flying balcony, separated from the rear wall of the room</td></tr>
</table>

	Recommended Balcony Dimensions	
	A slightly convex under-balcony ceiling can help redirect sound into the shielded area. A rising leading edge at the front of the balcony is helpful. A sound system can augment the direct sound, using loudspeakers located on the underside of the balcony.	Allows the sound to flow around the upper balcony to reach the rearmost under-balcony seats. It is an expensive solution, since it presents structural challenges, even when beams support the balcony from the rear.

TABLE 2.2-8: RECOMMANDED BALCONY DIMENSIONS ILLUSTRATED BY (LONG, 2006) (MADAN MEHTA, JAMES ALLISON JOHNSON, JORGE ROCAFORT, 1999)

2.2.5.5. **CEILING DESIGN**

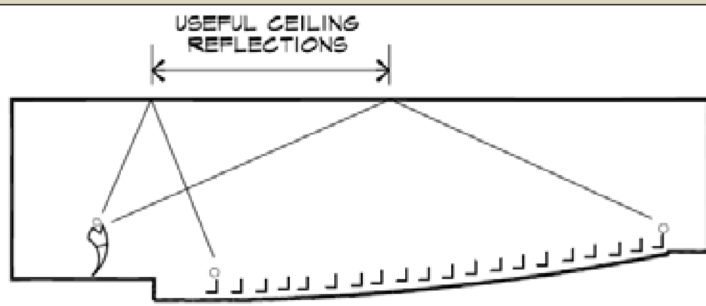
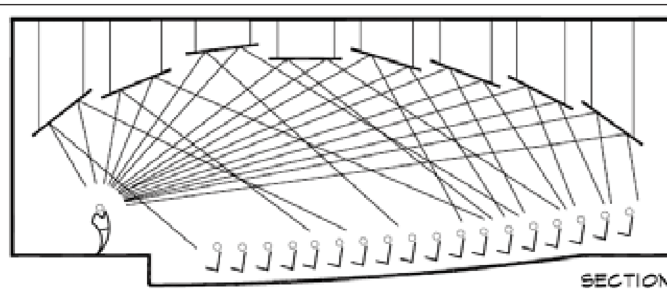
Unamplified speech can be augmented by physically placing hard surfaces in positions where they can distribute sound to the audience. Reflectors must have sufficient size that they scatter the frequencies of interest and should be close enough so that the reflection delay time is less than 30 to 50 msec. The orientation of a reflective element is determined by the required coverage area of the scattered sound. For specula reflection, the deflected angle is determined by locating the mirror image point of the sound source and then by drawing a line from the image point through the point of reflection toward the receiver. (Long, 2006) The following table presents different kinds of reflector patterns that can be used in theater auditorium:

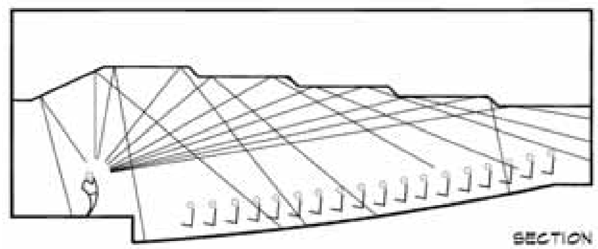
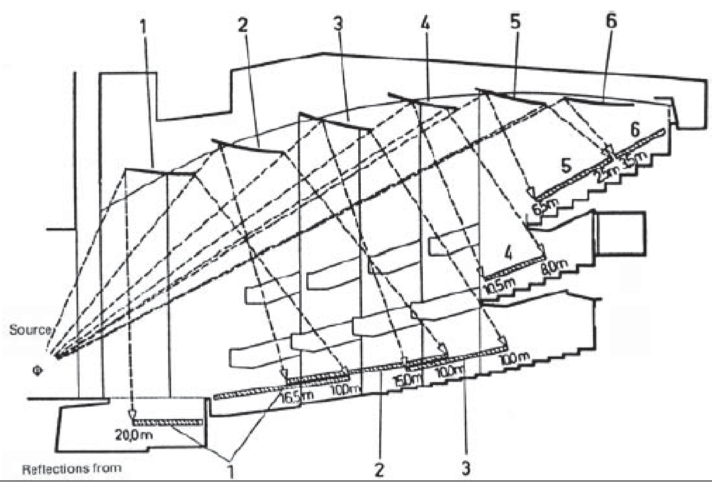
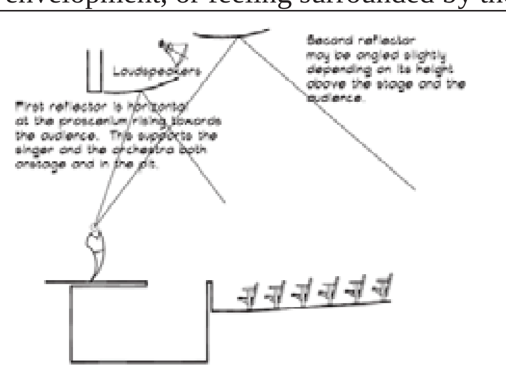
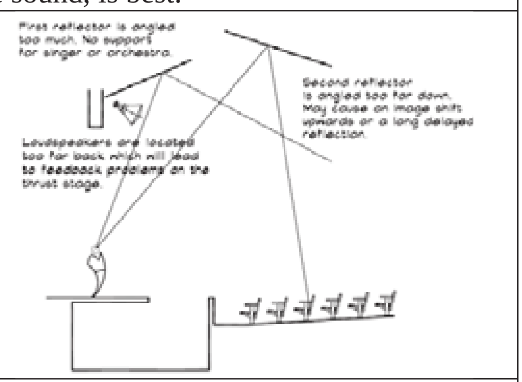
Patterns of reflected sounds		
		
Concave Reflector	Flat Reflector	Convex Reflector

Patterns of reflected sounds		
Ex.:Vaulted ceilings Causes hot spots and echos Poor sound energy distributors Avoided near stage, or any source locations	Hard-surface building elements. Effectively distribute reflected sound if well oriented and large enough. Desirable for Speech listening.	Hard-surface building elements. Effectively distribute reflected sound. Desirable for music listening. Reflected sound is distributed across a wide rang of frequency.

TABLE 2.2-9: PATTERNS OF REFLECTED SOUNDS ILLUSTRATED BY (EGAN, 2007)

The shape of the ceiling can be used to distribute sound evenly throughout an auditorium as follows:

	Ceiling shape for sound distribution
Speech	
	Reflections from a Flat Ceiling Section
	The reflected rays illuminate the front and middle portions of the space but much of the energy falling on the rear portion of the ceiling is grounded out on the absorptive rear wall. A flat ceiling can yield excellent results for speech if it is not too high and if the floor rake is sufficient.
	
	Reflected Sound from a Segmented Ceiling

<table>
<tr><th></th><th colspan="2">Ceiling shape for sound distribution</th></tr>
<tr><td rowspan="4"></td><td colspan="2">The ceiling can be segmented to improve the ceiling design. Convex panels may be used to provide additional flexibility. Panels should not be used to reflect sound directly down, or back to the listener from behind, since this shifts the perceived source location overhead.
Suspended panels are usually preferred since they allow easier access to air conditioning, lighting and other services located in the ceiling, apart from being aesthetically pleasant.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">Reflected Sound from a Stepped Flat Ceiling</td></tr>
<tr><td colspan="2">The seatings are raised and the ceiling is stepped to provide useful specula reflections since the ends of the segmented reflectors are diffusive.</td></tr>
<tr><td rowspan="2">Music</td><td colspan="2"></td></tr>
<tr><td colspan="2">A ceiling with convex pattern that diffuses the sound and aids in the sense of envelopment, or feeling surrounded by the sound, is best.</td></tr>
<tr><td rowspan="2">Multipurpose</td><td></td><td></td></tr>
<tr><td>3.1- An example of good proscenium design</td><td>3.2- An example of poor proscenium design</td></tr>
</table>

	Ceiling shape for sound distribution
	- The first reflective surface should be convex and horizontal at the proscenium wall. Such a shape aides in the reflection of sound to the seats in the center of the orchestra section, which is the most difficult to cover. It is also more forgiving of changes in the source position than a sharply slanted reflector. By controlling the curvature the clusters, loudspeakers can be nested above the reflector where the shielding helps control feedback. One or more rows of theatrical lighting must be accommodated, located at 45° and 55° from a downstage actor. Consequently, there is a scramble for the ceiling space in the third of the ceiling closest to the proscenium, which must include passive acoustical reflectors, loudspeakers, catwalks, and theatrical lighting.
	Movable ceilings are the most common solution for this type of variable-volume hall.

TABLE 2.2-10: DIFFERENT CEILING SHAPES FOR SPEECH, MUSIC AND MULTIPUROSE ILLUSTRATED BY (LONG, 2006) & (BARRON, 2010)

2.2.5.6. **REAR WALLS**

As the volume per seat increases, the need to use sound absorption on the room surfaces increases in order to obtain the required reverberation time. To ensure that the rear wall does not provide delayed reflections, it is usual to treat the wall with a sound absorbing material. If the rear wall absorption is considered undesirable, the rear wall should be made diffuse. (Madan Mehta, James Allison Johnson, Jorge Rocafort, 1999). **Figure 2.2-2** shows the rear walls that need to be treated as absorbing surfaces and the others that need to be treated as diffusing or reflective surface.

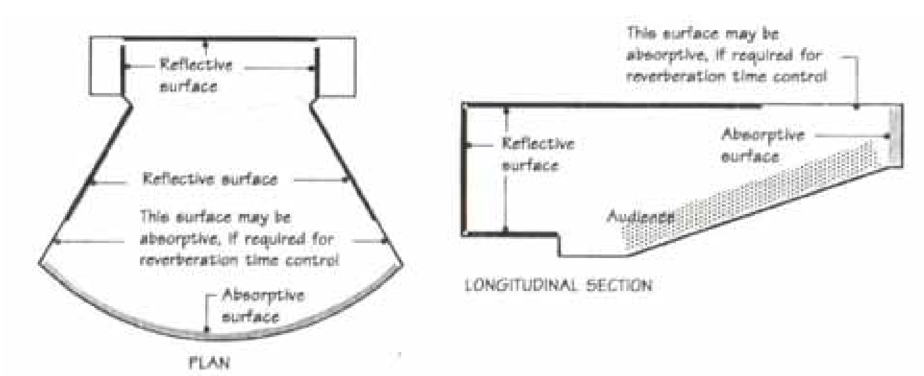


FIGURE 2.2-2: GENERAL RECOMANDATIONS FOR SOUND REFLECTING AND ABSORBING PARTS OF A ROOM (MADAN MEHTA, JAMES ALLISON JOHNSON, JORGE ROCAFORT, 1999)

Generally, rear walls are treated as absorbing surfaces except in small halls it is treated as a reflective diffusing surface as shown in **Figure 2.2-3** .

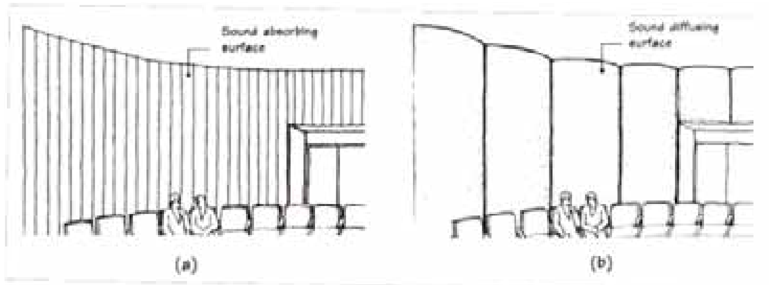
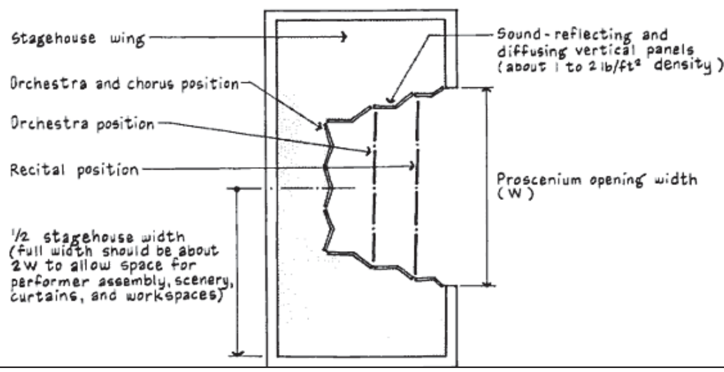


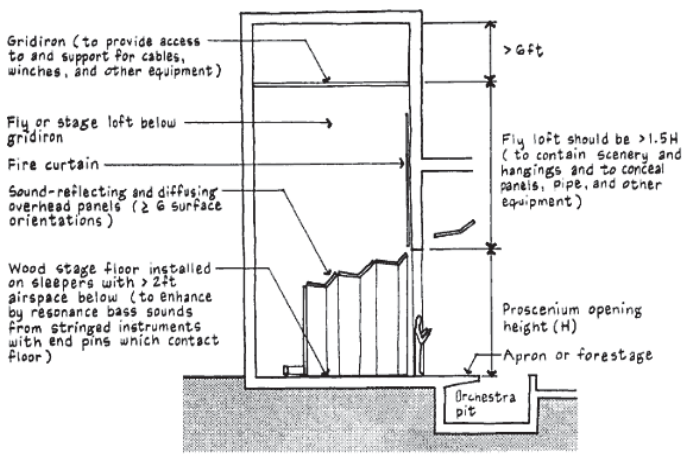
FIGURE 2.2-3: REAR WALL TREATMENTS (MADAN MEHTA, JAMES ALLISON JOHNSON, JORGE ROCAFORT, 1999)

2.2.5.7. **ORCHISRA SHELLS**

Types of Orchestra shells



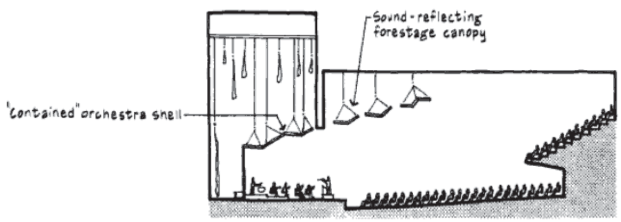
Plan of stage Enclosure



Stage house Section

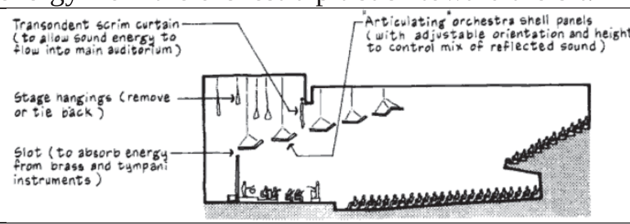
Types of Orchestra shells

Panels constructed of thick plywood, damped sheet metal, or heavy gypsum board can be used on stages to surround (or enclose) the sources sound. These sound-reflecting and diffusing panels can help distribute balanced and blended sound uniformly throughout the listening area by connecting or coupling a portion of the stage house cubic volume to the volume within the main hall. They increase loudness by preventing them from being absorbed by scenery in the fly loft and wings.
The surfaces surrounding the orchestra should also contain small-scale irregularities to blend and reflect the high frequency sound energy from the various instruments. The enclosure can contribute to good music listening conditions on stage.



Forestage Canopy closed

Forestage canopies are sound-reflecting panels suspended in front of the proscenium, reflect sound energy from the stage to the audience and decrease the initial-time delay gap. These panels extend the orchestra shell into the auditorium.
This extension can enhance the direct sound needed for intimacy when closed and can also reflect sound energy from the orchestra pit back toward the bit.



Coupled Stage house with open articulated shell

In case the Coupled stage house canopies have an opening between the panels they allow sound energy to follow into the upper volume so it can continue to the low frequency reverberance in the main auditorium bellow (needed for warmth).

TABLE 2.2-11: TYPES OF QRCHESTRA SHELLS ILLUSTRATED BY (EGAN, 2007)

2.2.5.8. ORCHESTRA PIT

An orchestra pit is not normally part of a pure concert hall, but is quite important in opera halls and multiuse facilities. The following are general functional and acoustical requirements for Orchestra pits illustrated by (Long, 2006):

- Reducing the loudness of the orchestra relative to the singers.

- Providing a place where the musicians can be viewed by the conductor while being out of the sight of the audience.
- The musicians in the pit should be able to hear each other as well as the singers. The singers in turn must be able to hear the orchestra so that each can adjust their level to the other.
- Pit levels can be very high, particularly when the pit is partially enclosed. Absorbent materials lower the pit levels but also lessen the communication between players.

Pit design is difficult since the desired amount of level control depends on the size of the hall, the size of the orchestra, the ability of the singers, and the type of music. (Long, 2006) The following table shows the orchestra pit details:

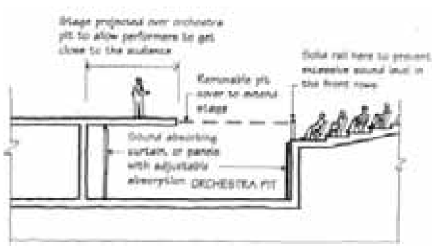
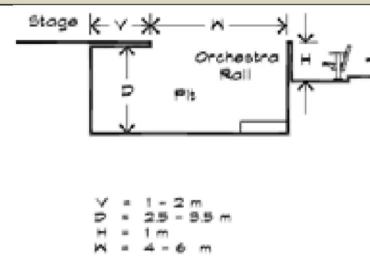
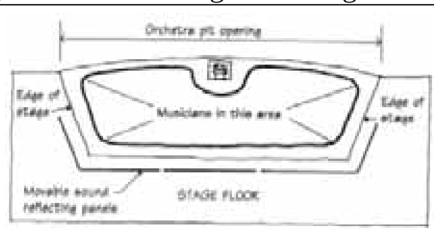
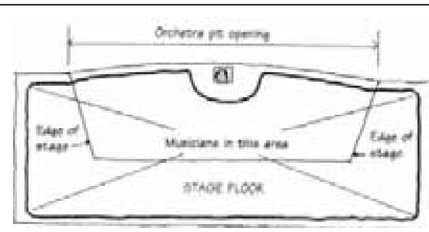
<table>
<tr><th colspan="2">Orchestra Pit Details</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>1.1- Section Through an archistra Pit</td><td>1.2- Typical Opera Hall Pit Dimensions</td></tr>
<tr><td colspan="2">Pits can be open or partially covered. The top of the orchestra rail is at the same height as the stage. Where the pit floor is on a lift, it can be raised to form an apron stage and act as a large freight elevator for sets and grand pianos. Open pits are located in front of the stage and have no stage overhang.</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>1.3- Plan of an archestra pit – Layout with a small number of musicians (less than 40 musicians)</td><td>1.4- Plan of an archestra pit – Layout with a large number of musicians (more than 100 musicians)</td></tr>
<tr><td colspan="2">The orchestra pit can be provided with removable sound absorbing panels, so that the conductor can adjust sound absorption in the pit according to the number of musicians.</td></tr>
</table>

TABLE 2.2-12: ARCHESTRA PIT DETAILS ILLUSTRATED BY (MADAN MEHTA, JAMES ALLISON JOHNSON, JORGE ROCAFORT, 1999) & (LONG, 2006)

2.2.6. SOUND INSULATION

The need to exclude unwanted sound from the interior of a performance space means that such buildings are more substantially constructed than other common building types. The degree of sound isolation needed in a specific building will vary depending on:

- The nature of the performance type (spaces for orchestral and choral music demand greater quietness than those designed exclusively for amplified music).
- The amount of noise in the zone around the building (noisy urban setting create more demanding isolation requirement than pastoral rural setting).
- Site constraints (tight sites may require that noise producing equipment rooms be closer to sensitive spaces that in more generous sites).

In developing proper isolating details, one must consider that sound may be either:

Air-borne: Sound is defeated through the use of massive walls and ceiling and special sound-isolation doors.

Structure-borne: Sound and vibration is defeated primarily through the use of massive, rigid structure, as well as separated and/or isolated structural systems.

Concert halls for orchestral and choral music in large urban centers have the most stringent isolation requirement. Isolation of such buildings typically require massive multiple masonry wall, double-slab roofs , acoustic-isolation joints, and other special construction to buffer the interior of the concert space from exterior noise.

Sound and vibration isolation are two related concerns. In a building with diverse uses or multiple performance spaces, one must consider isolation in two contexts. The first context is the isolation of the theaters from noise and vibration source which are external to the building. The second is the isolation of the theaters from each other and forms other activities in the building. (Joseph De Chiara, Michael J. Crosbie, 2001, p. 736)

2.2.7. ELECTROSTATICS

Sound reinforcement and reproduction systems have become extremely sophisticated in recent years. Specialist designers should be employed to ensure that the designs for a particular theater meet the needs of the performers and are integrated with the room acoustic design of the space.

The electro acoustic system has a variety of infrastructure requirements. In the house, a control room is typically required. This space is best located at the rear of orchestra level as close to the centerline as possible. The control room must be elevated above the last row of seats in the orchestra level to ensure that the operator has an unobstructed view of the stage. To hear an operable (sliding) acoustical window isolates the interior of house from conservation in the control room but can be opened if the operator wants to hear what is happening in the house. This space should be separate from control spaces provided for theatrical lighting or stage management purposes.

Sound engineers generally prefer to mix the sound for a show from a position in the house itself. An area of removable seats is usually provided for this purpose. This feature is generally called an in-house mix position. Power and audio wiring are routed to an electrical box at the in-house mix position so that sound equipment can be set at this location with minimal effort. Since the operator and the equipment will typically be taller than the surrounding seats, the location and the design of this area need to be carefully considered to eliminate sight-line problems for audience members behind. In some instances, it makes sense to depress the area of the in-house mix location. In others, the position can be located just below a vertical break (parterre) in the orchestra seating. Generally speaking, mix engineers prefer to be out from under any balcony overhang and as close to the center of the room as soon as possible. Sometimes as auxiliary in-house mix position is provided at the very rear of the orchestra level (in front of the control room) because some presenters do not like to loose seat in the center of the orchestra floor for this function.

In addition, the electro acoustics systems generally need an equipment rack room and audio equipment storage room. The former is generally positioned closet the stage on an upper level. The latter is generally backstage, ideally at stage level, and close to other crew and equipment storage spaces. (Joseph De Chiara, Michael J. Crosbie, 2001, p. 737)

2.3. LIGHTING AND SOUND IN THE AUDIO

Lighting and sound requirements should be studied as they have a have a significant impact on the design and detailing of the auditorium and must be considered at an early stage in the planning process. If appropriate, workable positions for rigging lighting and sound equipment are not considered with a design, theater technicians will have to make their own adaptations. These can be unsightly.

2.3.1. LIGHTING

The following table presents lighting position & requirements:

	Lighting Positions	Lighting requirements
Performance lighting	Auditorium at ceiling level, on side and rear walls, balcony fronts and at low level within the seating.	The lighting direction is towards the platform/stage with clear projection. Each position requires ease of access for technicians to change and adjust, with lighting bridges at ceiling level and ladder access to wall locations; follow spotlights require a location at the rear of the auditorium or from a lighting bridge at ceiling level with space for an operator. Performance lighting is an integral part of the staging of all types of production, except orchestral and choral music, and is subject to changes within a performance controlled by operatives at the rear of the auditorium. The tradition for orchestral and choral music is for the platform to be illuminated during the performance with a general and fixed level of lighting: however this may be changing with, say, follow spotlights as an increasingly common feature.
Auditorium lighting	circulation routes & seating areas for the audience; decorative lighting	Auditorium lighting is usually dimmed and out during the actual performance for all types of production except for classical and choral music, where the tradition is to dim the lights only.
Emergency lighting	circulation routes within the	Exit signs and emergency directions at points of egress in the auditorium.

	auditorium at ceiling level or/and at a low level at the gangways	Lighting of the auditorium at times of emergency.
Working lights	general illumination of the auditorium	For cleaning and maintenance as a separate system during times when the auditorium is not used for performance and rehearsals.
Blue lights:	Lighting bridges and entry points into the auditorium accessed by technicians	Requires lighting but at a low level with a blue light to avoid distraction to the audience. This covers ease of access required to service all luminaries.

TABLE 2.3-1: LIGHTING POSITION AND REQUIREMENTS ILLUSTRATED BY (APPLETON, 2008)

2.3.2. SOUND

The following table presents loudspeakers for the amplification of music, voices and special effects, position & requirements:

	Loudspeakers Positions	**Loudspeakers requirements**
Traditional position for proscenium stage	Over the platform or stage.	Along the setting line or above the proscenium opening
Traditional position for pop/ rock/ jazz concerts	At the sides of the platform or stage	Often touring groups provide their own equipments
Various positions within the auditorium	Supplement main loudspeakers and sound effects: On side and rear walls Auditorium Ceiling Balconies Under the floor.	The line from the speakers shouldn't be interrupted by any members of audience.

TABLE 2.3-2: LIGHTING POSITION AND REQUIREMENTS ILLUSTRATED BY (APPLETON, 2008)

2.4. VENTILATION AND AIR HANDLING

The experience of enjoying a performance is influenced by the quality of the ventilation in the auditorium, and the avoidance of draughts, stuffiness and noise of mechanical ventilation. Health needs include respiration while comfort needs include maintaining body heat, control of airborne contamination and removal of odors. There is also the cost of the ventilation and associated questions about heating which can contribute significantly to the running costs. (Appleton, 2008)

Air ventilation inside auditorium is affected by the following main elements:

- Size and shape (number of balconies in particular),
- Level of flexibility (different audience/performance relationships).
- The type of construction of the auditorium enclosure.
- External climate conditions.

2.4.1. NATURAL VENTILATION

Natural ventilation is more easily achieved with a small- or medium-scale auditorium, without large balconies or other overhangs. The inherit logic of a natural ventilation strategy is that it makes use of natural forces. Rising warm air has the potential to draw in cooler air from outside a building by what is termed the stack effect. While external wind pressures can override this internal effect, there are simple mechanisms for adjusting and compensating. (Strong, 2010) The following diagram shows the acoustic solution for natural ventilation.

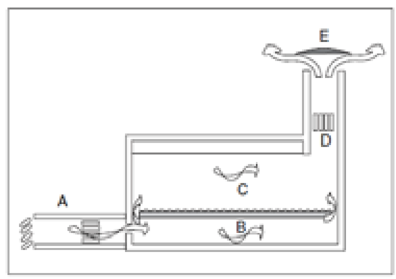


FIGURE 2.4-1: NATURAL VENTILATION IN AUDITORIUM DIAGRAM SHOWING THE METHOD OF NATURAL VENTILATION WHERE THE EXTERNAL NOISE LEVELS REQUIRE AN ACOUSTIC SOLUTION TO AVOID UNWELCOME TRANSFER OF NOISE INTO THE AUDITORIUM. (APPLETON, 2008)

2.4.2. MECHANICAL VENTILATION

- The mechanical ventilation in any auditorium is affected by the way air is distributed. In temperature conditions, heating is generally only required for warming up the auditorium prior audience arrival. The imperative during a performance is the supply of clean cool air. There are two primary models for air distributions. The following table presents the difference between such models:

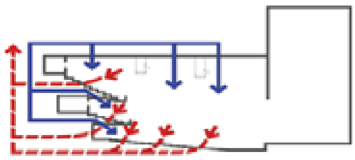
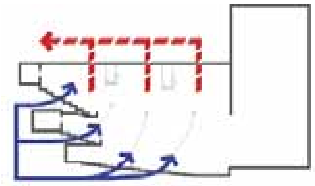
Cool air at high level	Cool air at low level
	
Cool air at high level mixes with the room air to give, on average, a comfortable condition throughout the space. Extraction is generally at low level and located to promote good circulation throughout the space.	Cool air at low level provides the cooled air at low level, adjacent to the audience members. This cooled air is then drawn upward as it warms and is extracted at high level.

TABLE 2.4-1: AIR DISTRIBUTION BY HIGH AND LOW LEVEL SUPPLY ILLUSTRATED BY (STRONG, 2010)

2.4.3. NOISE CONTROL FOR AIR VENTILATION

To minimize the amount of noise transmitted into critical spaces by the mechanical and other systems, following are some helpful guide-lines for programming or conceptual design work illustrated by (Joseph De Chiara, Michael J. Crosbie, 2001, p. 736)

- Employ ducts with large cross-sectional area and sound-absorptive lining.
- Use the lowest possible air velocity consistent with air-change requirement. The following velocity guidelines are useful for initial planning (these are maximum velocities, expressed in feet per minute)
- Trunk ducts 1,000
- Branch ducts 700
- Terminal ducts 400
- Slot speed at terminal 300
- Locate mechanical rooms remote from the theater. Long ducts runs are the easiest and cheapest means attenuating noise from HVAC systems.
- Do not route conduit pipes, or ducts in or through a noise-sensitive space unless they actually serve or supply the sensitive space.
- Seal around conduits, pipes, and ducts where they penetrate into sensitive areas to preserve the isolation characteristics of these assemblies.

3. CHAPTER (3): STAGE MACHINERY & TECHNOLOGY

The aim of studying the stage machinery and technology in this study is to figure out to what extend traditional theater stage became too complicated to achieve the physical scenery presentation on a theater stage. Up through theater history, as studied in chapter one, theater directors, producers and scenery designers invented many ways to imitate real sceneries captured from real life. But nowadays, however, theater experiments many changes in modern contemporary theater. Technology has affected the theater experiment vision and purpose just as giving it new tools for presenting sceneries in the nineteenth century.

In this Chapter, our study will start by presenting the main elements of platform and stage design for different types of products. Then, summarizing mechanical and technological achievement on theater stage. And finally, presenting a brief introduction for multimedia in theater stage to introduce the history of implementation of computer aided technology in theater until the introduction of Virtual Reality technology.

3.1. PLATFORM DESIGN

3.1.1. PLATFORM SPACE

Space must be provided for the musicians in a configuration where they can hear and be heard. The amount of floor space provided for the orchestra is a compromise between comfort and acoustics. This is not to say that acoustical excellence requires us to torture the musicians, but smaller stages generally yield better sound. (Long, 2006). The music components include orchestra

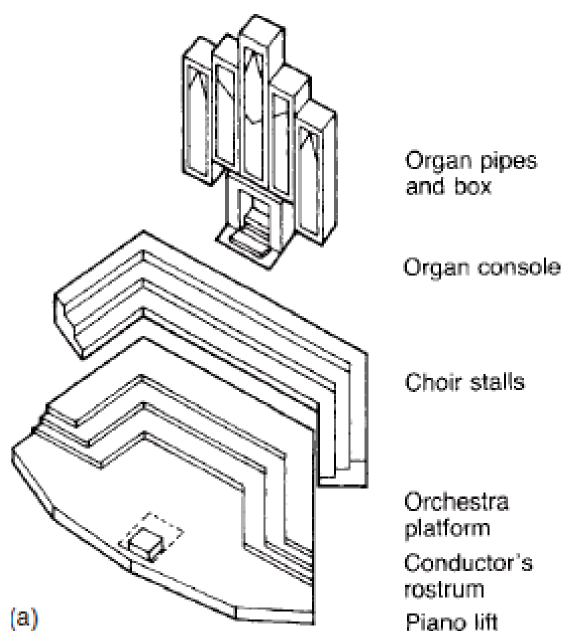


FIGURE 3.1-1: PLATFORM DESGIN MUSIC COMPONENTS (APPLETON, 2008)

platform, choir stalls and organ (**Figure 3.1-1**).

3.1.2. PLATFORM SIZE

The design of the platform relates to the size of the orchestra type:

Performance type	No. of musicians	Platform dimensions
Chamber Orchestra	40-50 musicians	6M deep, 9 M wide and 900 mm high.
symphony orchestra	80–120 musicians	12 M deep 12 M wide and 1000 mm high.
Choir & symphony orchestra	220 choir & 60 players	12 M deep 12 M wide and 1000 mm high.

TABLE 3.1-1: PLATFORM DIMENSIONS ACCORDING TO ORCHESTRA SIZE ILLUSTRATED BY (APPLETON, 2008)

The following table presents the area needed for individual musicians are:

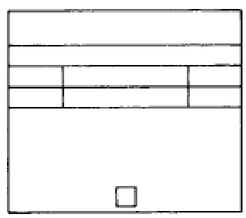
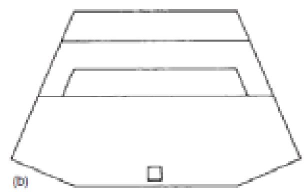
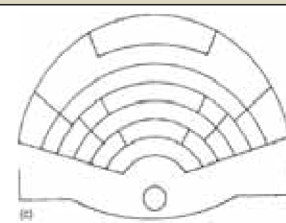
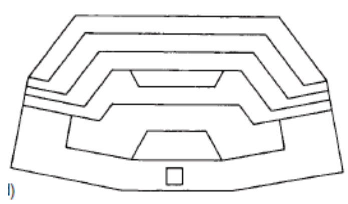
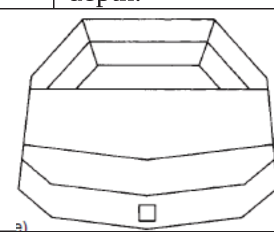
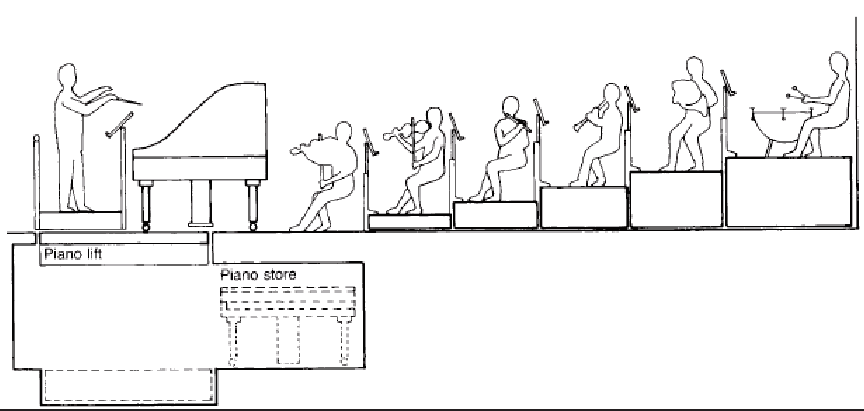
Performance type	Platform dimensions
Violin players and small wind instruments	1000 _ 600 mm
The horns and bassoons	1000 _ 800 mm
wood-wind and brass players including cellos and double basses	1200 mm
concert grand piano	2750 _ 1600mm
tiers	2000 mm
choir	0.38M2 minimum per singer in choir stalls with seats

TABLE 3.1-2: AREA NEEDED FOR INDIVIDUAL MUSICIANS ILLUSTRATED BY (APPLETON, 2008)

The longitudinal section can be flat and stepped traversal, rising from the conductor's rostrum. Risers should not exceed 450 mm because of the difficulty of carrying heavy instruments. The platform should be kept as small as possible. Size and shape affect tone, balance and homogeneity due to the variation in the delay with the location of different musicians on the platform. The height of the platform determines the focus for the sightlines. Recommended heights have been given. It should not, however, be less than 600 mm, or higher than 1.1 M to avoid a complete screening of the platform by those in the front rows of the audience. (Appleton, 2008)

3.1.3. PLATFORM SHAPE

The following table presents the different types of shapes for platform:

<table>
<tr><th colspan="6">Different Shapes of platforms</th></tr>
<tr><td colspan="2"></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td colspan="2">Rectangular plan</td><td colspan="2">Trapezoidal plan</td><td colspan="2">Wide and shallow plan</td></tr>
<tr><td colspan="2">With levels & conductor's rostrum,</td><td colspan="2">With angled side walls directed towards the audience.</td><td colspan="2">With rear raised levels focused towards conductor. Shape based on a rectangle, with a width twice the depth.</td></tr>
<tr><td colspan="3"></td><td colspan="3"></td></tr>
<tr><td colspan="3">Angular shape on plan</td><td colspan="3">Concentric curved levels on plan</td></tr>
<tr><td colspan="3">With rear raised levels and lifts at front to reduce depth of platform for smaller size of orchestras. Shape is based on a square.</td><td colspan="3">Focused on conductor: this layout ensures musicians are equidistant from conductor on three sides.</td></tr>
<tr><td colspan="6"></td></tr>
</table>

Section through platform, showing levels for musicians rising to rear
The section includes a piano lift at the front of the platform to lower piano, when not in use, down to a piano store below platform level. The levels may be formed by lifts and would be required to have lift machinery located below the platform level.

TABLE 3.1-3: DIFFERENT SHAPES OF PLATFORM (APPLETON, 2008)

3.2. STAGE DESIGN

The stage is easily defined as the part of the theater where the performance takes place. Its size, shape, arrangement, and equipment must therefore logically develop from the nature of the performances planned for the building and the resulting operational, visual, and acoustical criteria associated with each performance type. (Joseph De Chiara, Michael J. Crosbie, 2001, p. 737)

3.2.1. STAGE SPACE

Visually the stage is divided into two main spaces: the performing area and the working area (as shown in figure 3.1-1). The performing area is the area visible by the audience where the performance takes place by the actor. It can be subdivided into:

- **Acting area:** for the actor performance.
- **Scenery area:** where the scenery is placed facing the audience giving a space behind as passages for actors to go on and off stage and workmen to cross to the other side of the stage.
- **Orchestra pit:** A space for the orchestra adequate to the stage as some types of performances such as for opera, musical, dance and drama theater orchestra are placed outside the stage place to give room for the performance and to avoid visual blocking.

The working area is the invisible part of the stage by the audience. It supports the scenery change and sometimes the exiting of the performers. It also acts as a storage space for scenic elements, theatrical lighting, and all other equipments or features that support the performer. It is found in different spaces adjacent to the stage:

- **Side Stage:** The area to the left and the right of the performing area. Used as storage and performers' holding area.
- **Rear stage:** The area behind the performing area. Used for Scenery storage.
- **Unser stage:** The area where the stage machinery under the performing area works.
- **Stage Tower:** The volume above the proscenium opening where stage lighting, sound and scenery (when not used) are suspended over the performance area.
- The stage machinery and technology of these working areas will be studied later in details in the following two sections.

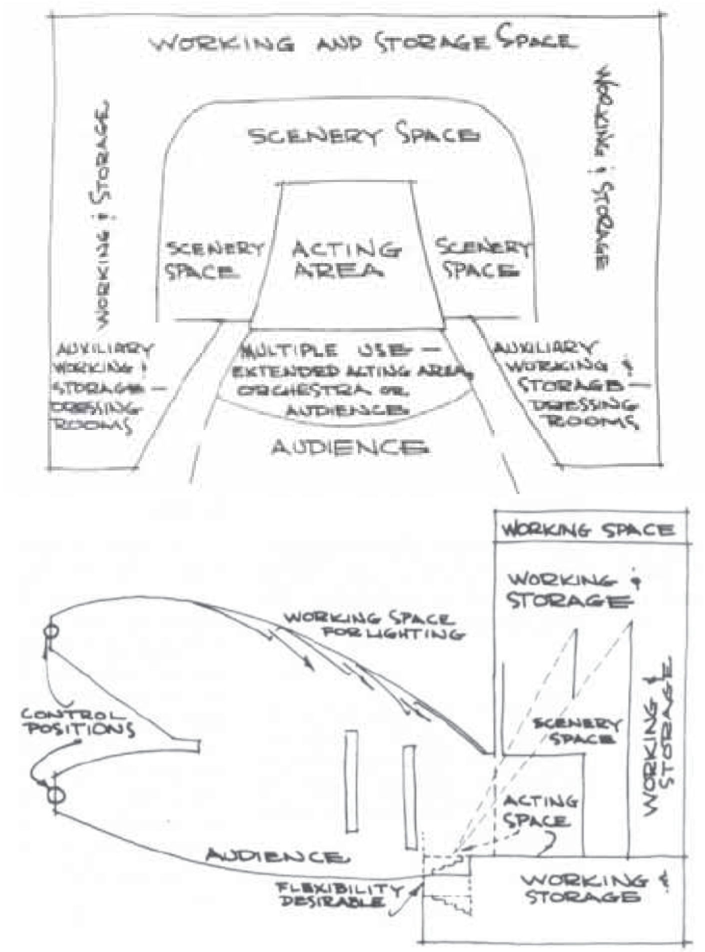


FIGURE 3.2-1: POSITION OF STAGE AREAS RELATIVE TO EACH OTHER, PLAN AND SECTION.(JOSEPH DE CHIARA, MICHAEL J. CROSBIE, 2001, P. 738)

3.2.2. STAGE SIZE

3.2.2.1. PERFORMING AREA & PROCENIUM OPENING

The proscenium structural opening is the reference for setting out the wings, galleries and stage depth. The dimensions of the opening are closely linked to the size and general design of the auditorium. The width needs to give adequate sightlines for the audience to the full playing area while avoiding acute sightlines into the wings. The height must also be adequate for the view from upper seating tiers. Too large a proscenium results in a need for wider wings, higher grid, and big events to fill the opening. Too small and contact between player and audience is cramped or lost. (Strong, 2010). The following is a table of performing area dimensions according to performing types:

Drama					**Dance**				

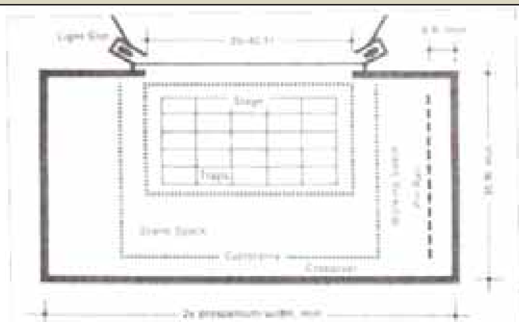
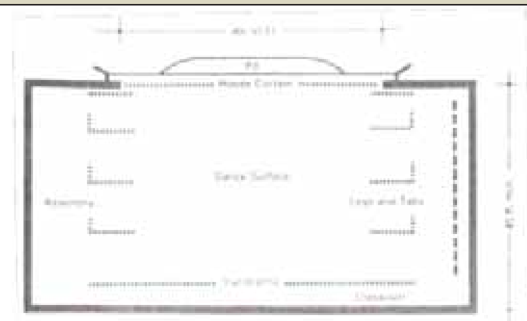

					

Figure 3.2-2: Typical Drama Stage					**Figure 3.2-3:** Typical Dance Stage				
Main Stage (ft)		Opening (ft)		Wings	Main Stage (ft)		Opening (ft)		Wings
Width	Deep	Width	High	Width	Width	Deep	Width	High	Width
35-40	20-25	35 -40	26	6 min	45-50	40	40-50	--	10-15
Music - Drama					**Opera**				

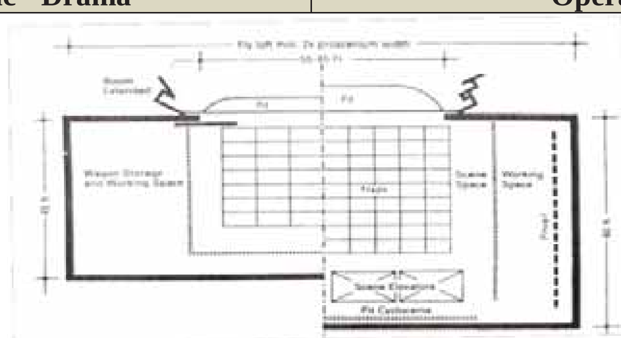



Figure 3.2-4: Typical stage for opera or music-drama									
Main Stage (ft)		Opening (ft)		Music.	Main Stage (ft)		Opening (ft)		Music.
Width	Deep	Width	High	No.	Width	Deep	Width	High	No.
50-60	50	50-60	35-50		50-65	50	50-60	30-50	

TABEL 3.2-1: RECOMANDED DIMENSIONS FOR STAGE ACCORDING TO PERFORMANCE TYPE (JOSEPH DE CHIARA, MICHAEL J. CROSBIE, 2001)

The following is a table for the dimensions of the proscenium opening height, stage width, depth and height according to auditorium scale with reference to German standards:

	Opening		Main Stage		
	Width	**Height**	**Width**	**High**	**Deep**
Studio Theater	6-12 m	4-6 m	12 m	8 m	8 m
Small Theater	6-15 m	5-8 m	15 m	10 m	10 m
Medium Theater	7-12 m	5-7 m	14 m	26 m	18 m
Large Theater	8-15 m	6-8 m	26 m	28 m	20 m
Grand Opera	10-18 m	6-10 m	30 m	30 m	25 m

TABEL 3.2-2: GERMAN STANDARS FOR STAGE DIMENSIONS (OGAWA, 2001, P. 47)

3.2.2.2. UNDER-STAGE

The under-stage area is the area beneath the whole area of the stage and used for the storage of sets on lifts. It requires a height of 7-10 m. Sometimes it is connected by the Orchestra pitch. In this case independent passages with fire- escape must be provided.

3.2.2.3. SIDE AND REAR STAGES

Planning for the side and rear Stage areas should be considered with the layout of any stage machinery to be installed in the project. The design of the side and the rear stages, being in close proximity to the main stage, must meet the need for the simultaneous use of those areas for the preparation and changing of scenery while a performance is in progress. One of the main factors that affect the size of the side and rear stages is the way the scenery is changed. Scenery may be moved to the side or rear of the performance area by:

- **Manually**: dismantling and stacking on the side and/or rear stages.
- **Casters or air pallets:** Moving large sections of the stage on trucks or wagons moving to either side and/or the rear.
- **Revolving stages:** two or more revolves which allow rapid changes of scenery.

There are additional rooms beside the main stage before the side and rear stages that should be acoustically isolated by movable sound barriers as sound doors. Also a depth of 2-3 m should be to the actual main stage to act as passages for movement. The optimum size of the side and rear stages is a function of the size of the main stage as shown in figure 3.1-5. The clear height should accommodate the highest scenery plus 1 M.

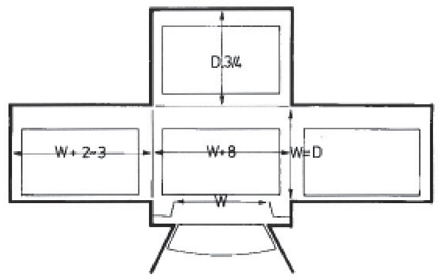


FIGURE 3.2-5: STAGE PLANNING ACCORDING TO ABIT (OGAWA, 2001, P. 48)

3.2.2.4. STAGE FLY TOWER

The fly tower height is determined according to the height of the grid system applied in the fly tower space volume. The grid is a framework of steel fixed above the stage floor and used to support the sets of lines used in the flying scenery. (Appleton, 2008, p. 149)

The height of the stage fly tower is determined generally as triple height the proscenium opening which is determined by the front row sightlines as **Figure 3.2-6**

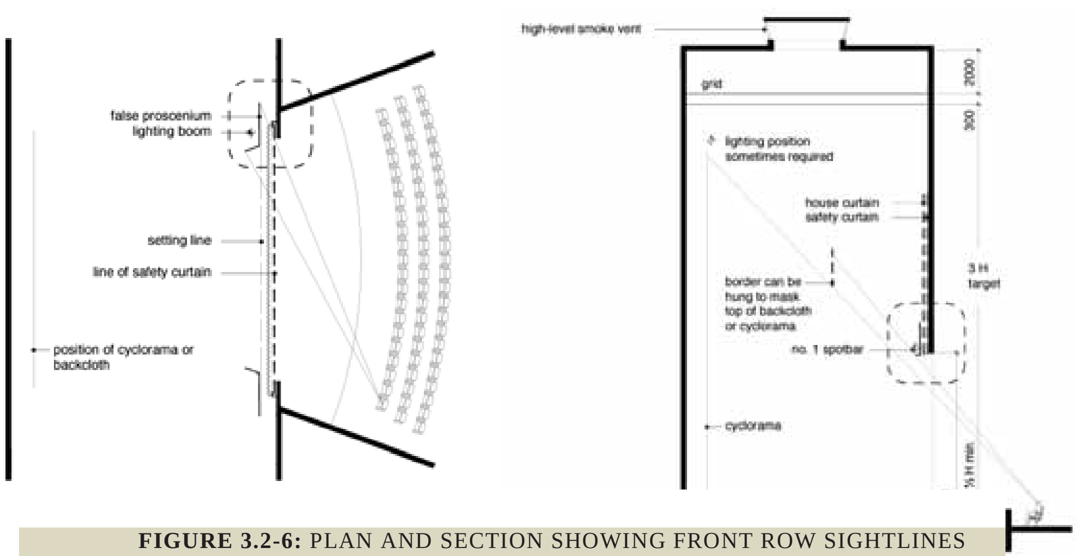


FIGURE 3.2-6: PLAN AND SECTION SHOWING FRONT ROW SIGHTLINES (STRONG, 2010)

3.3. STAGE MACHINERY & TECHNOLOGY

3.3.1. UNDER STAGE MACHINERY

Understage machinery is not a new idea. According to historian Allardyce Nicoll, even Greco-Roman theater utilized machines and scenery a lot more freely than one might think. Writing in the second AD, Pollux listed some 19 Theatrical devices including the Anapiemata which apparently raised the spirits mechanically from the depths. Theater Technicians have been building machines to raise the spirits ever since. (Strong, 2010)

The understage machinery can be simply used for the following purposes illustrated by (Strong, 2010):

- Facilitate rapid scene changing
- Produce spatula effects in front of an audience
- Aid manual handling when changing from one show to another
- Help to reconfigure the auditorium for different types of event.

3.3.1.1. TRAPS

The simplest type of understage machine is the hinged or sliding trap door. The following table presents the Stage trap details:

	Stage Traps Details
Basic functions	Enables an actor to make an entrance from below or to exit down stairs into understage area.
Different types	**II. Trap room**
	A room located under the stage. The stage floor over a trap room should be structured so that openings can easily be cut into floor to accommodate dramatic effects involving performers or scenery appearing from beneath the stage or disappearing into it.
	III. Full trap stage

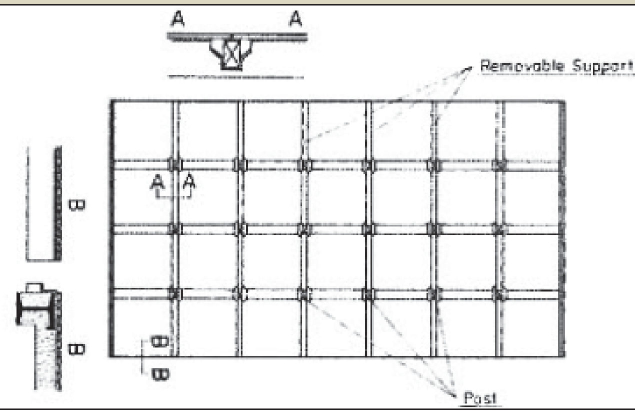
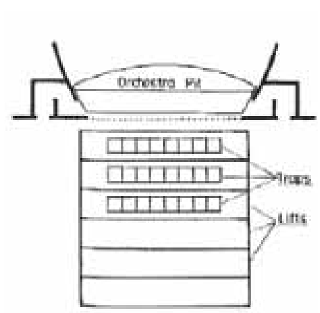
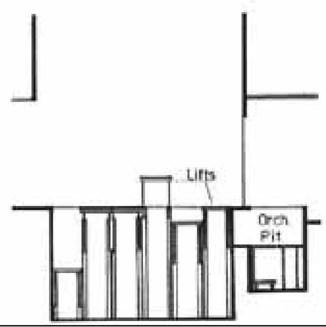
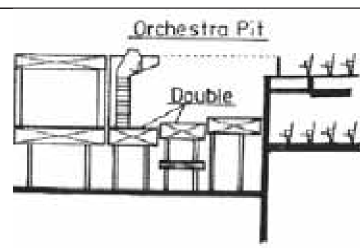
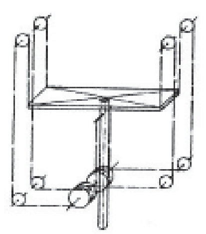
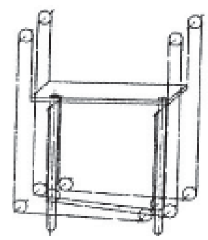
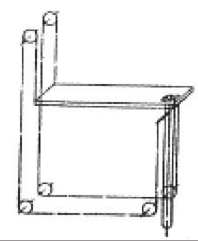
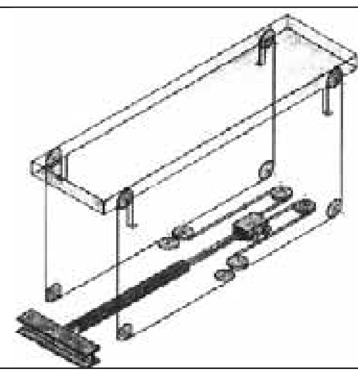
	Stage Traps Details
	
	It is a very workable system and provides good flexibility for an open or thrust stage, and arena theater. A practical trap stage generally uses structural beams arranged parallel to the curtain line to support the stage floor, with additional load bearing joists that are removable and equipped with proper fastening devices for stability and safely.
Size	The size of a trap area in a conventional proscenium theater can be determined by the opening of the proscenium plus 2 m.
General considerations	The trap panel shouldn't be too large as they will be extremely difficult to handle because of their bulk. The facing material used for a trap panel should be made of the same wood as the rest of the stage floor Some rigid fastening arrangement should be provided to fix the panels to the support structure of the stage. This will eliminate both the surface irregularity between panels and the problem of cracking noise between panels and supports.

TABLE 3.3-1: STAGE TRAP DETAILS ILLUSTRATED BY (OGAWA, 2001), (JOSEPH DE CHIARA, MICHAEL J. CROSBIE, 2001) & (STRONG, 2010)

3.3.1.2. STAGE LIFTS

Stage lifts are used to raise and lower larger items of scenery and groups of actors. They vary enormously in size and style, but may cover the entire stage area and travel deep down into the basement. More powerful lifts are capable of shifting tens of tons scenery and some will rise several meters above stage level to create instant raised acting platforms, often in modular form. (Strong, 2010). The following table presents the Stage Lifts details:

<table>
<tr><th></th><th colspan="2">Stage Lifts Details</th></tr>
<tr><td>Basic functions</td><td colspan="2">Make efficient scene changes possible. Also the room understage becomes an extra workspace.
It allows practitioners to utilize mechanical movement in staging to create scenic effects such as growing forests of trees, for sinking ships and for elevating heavenly choirs.
Technical work is made easier with a sectioned stage elevator, especially when divisions are parallel to the curtain line giving designers more freedom in the use of different stage levels.</td></tr>
<tr><td rowspan="9">Different types</td><td colspan="2">IV. Single Deck Stage Lift</td></tr>
<tr><td colspan="2">Stage elevators are generally constructed of single floor construction but some disadvantages were presented by such type when used such as:
A large opening remains at the stage level equivalent to the size of the stage elevator surface creating a safety hazard.
The balcony seats are able to see the whole and hear the noise coming from the basement.</td></tr>
<tr><td colspan="2">V. Double-Deck Stage Lift</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Stage lift layout</td><td>Stage lift Section</td></tr>
<tr><td colspan="2">The successful solution for a stage life is the double-deck lift stage where it is constructed of double floor level to close the produced opening by lifting the stage.</td></tr>
<tr><td colspan="2">VI. Double-Deck Orchesta Lift</td></tr>
<tr><td colspan="2">
</td></tr>
</table>

	Stage Lifts Details
	Double-Deck Orchesta Lift Section
	The sectioon nearest the apron of the stage which runs parallel to the curtain line, is made as double deck to provide room for musicians on the lower level when the upper deck is set at the stage level and provides an additional forestage acting area.
Size	The width of a lifted area can be determined by the opening of the stage plus 2 to 3 m. The height of the lift is maximum the proscenium opening height. The depth of each lift is from 2-4 m.
Mechanisms	**VII. Hydraulic System**
	  
	Different lifts equalized by hydraulic system to maintain level
	The mechanical construction of a small elevator consists of a vertical plunger installed in the middle of the elevator, with between two and four sets of guides to maintain a stable motion. Larger ones are built with two plungers and a stabilizing guide arrangement.
	VIII. Hydraulic Traction Drive
	
	Hydraulic wire traction drive
	A hydraulic plunger in mounted in the pit floor and a multi-purchase traction wire rope is arranged to drive stage lift.

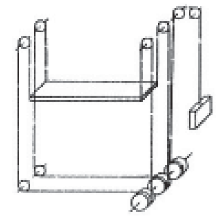
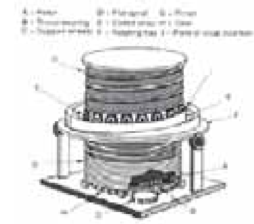
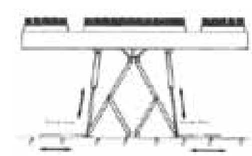
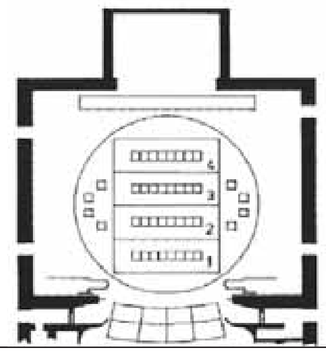
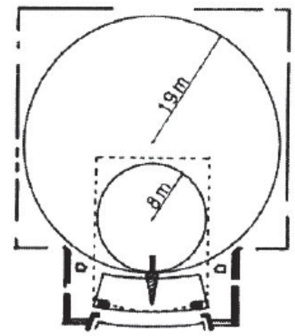
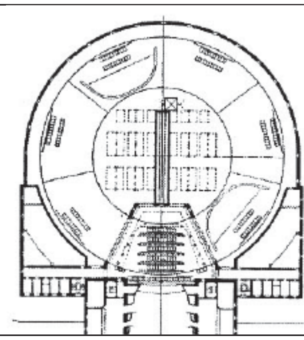
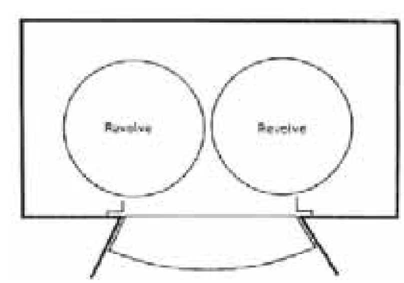
	Stage Lifts Details		
	IX. Electrical Motor System		
			
	Wire traction lift	Spiralift	Lambda Lift
	A simple lift developed for lifting the person from the basement to the stage by the means of counterweights balanced rope lines	The self locking and highly efficient (95-97%) spiralift does not require a deep machine pit for installation, or a caisson for the lifting column storage.	Lambda lift allows a minimum machine pit with self-locking mechanism. It is often specified for orchestra lifts and convertible seating raisers.
General considerations	Low operational noise and minimum vibration both in motion and at any stationary positions. A rigid grid guide arrangement to prevent instability, noise and vibration. Stable and constant performance regardless of the load applied. Specially locking devices at the stage level. Reliable upper and lower limit switches for the elevator. Variable speed control. The elevator must be flat with the rest of stage area.		

TABLE 3.3-2: STAGE LIFTS DETAILS ILLUSTRATED BY (OGAWA, 2001)

3.3.1.3. REVOLVES

Another popular scene-changing machine is the revolve. It is often said that some form of the revolving stage existed during the Greek-Roman period. It is considered a very old tool on theater stage. It has many shapes and types. This can be a simple circular platform either built on the top of, or recessed into, the stage floor. Two or more scene can be built on a revolve and rotated into view as the show proceeds, often in full view of the audience. They are particularly good for chases or for switching from an exterior to interior scene. (Strong, 2010)

	Stage Revolves Details	
Basic functions	Show different pictures to spectators by means of a circular plan divided into sections to accommodate more than one set, scene or locale by turning it around The rule is that the larger the diameter of the revolve, the greater the number of scenes that can be set up simultaneously.	
Different types & sizes	**X. Normal size revolve**	**XI. Large size revolve**
		
	Vienna Burg theater – normal size revolve	Frunkfort Opera House – Large size revolve
	Its diameter is from 2-4m larger than the stage opening. It gives chance for other facilities such as elevator or a tilting machine	Its diameter is twice as large as the stage opening. Another smaller revolver can be introduced to be shifted and replace the Orchestra pit to give a more room for stage.
	XII. Ring Revolve	**XIII. Dual Revolve**
		
	Ring revolve plan	Dual revolve by Izenour

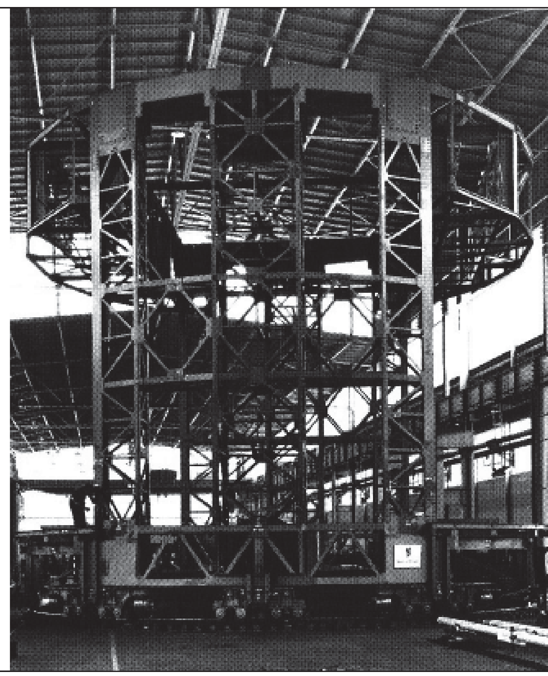
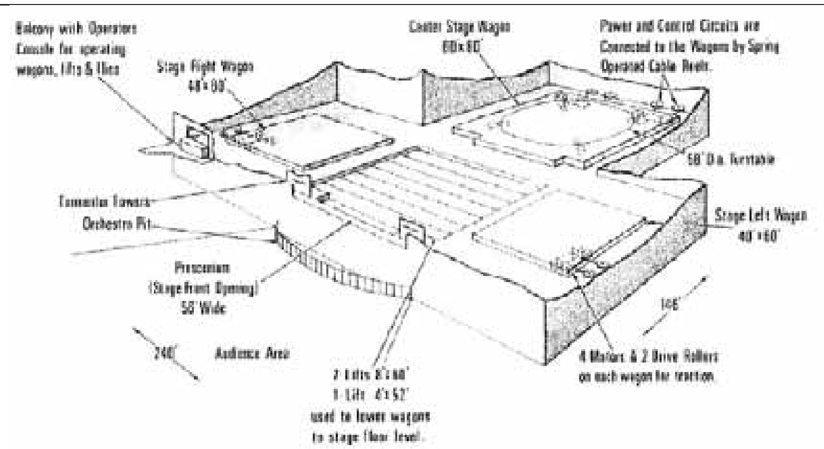
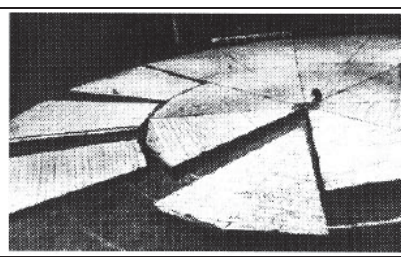
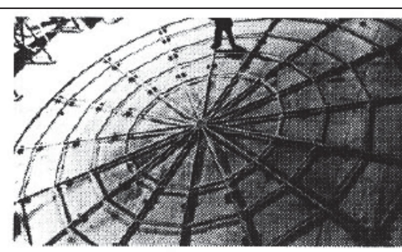
<table>
<tr><th></th><th colspan="2">Stage Revolves Details</th></tr>
<tr><td></td><td>Its diameters can be more than 11 m
The complexity of the ring revolve may provide challenging opportunities to theater architects and designers. It requires more complex engineering
Involve a sacrifice of much-needed room at stage level
The price of machinery is not within reach of most of contemporary building budget.</td><td>It can be used as a multi-purpose convertible-seating layout
It is sometimes incorporated in some practical scenes design.
The system's accepting as permanent stage machinery is debatable.</td></tr>
<tr><td rowspan="6">Mechanisms</td><td colspan="2">XIV. Disc Revolve</td></tr>
<tr><td colspan="2">The disc Revolve can obviously be incorporated with other stage machinery because it is flat profile.</td></tr>
<tr><td colspan="2">XV. Cylendrical Revolves</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">Cylendrical revolve- Drama theater at the Sydney Opera</td></tr>
<tr><td colspan="2">Cylindrical revolves are normally built as major stage machinery to dominate the stage. There height reaches 10-15m. The entire revolve is generally supported by wheels on a circular rail in the basement.</td></tr>
</table>

TABLE 3.3-3: STAGE REVOLVES DETAILS ILLUSTRATED BY (OGAWA, 2001)

3.3.1.4. WAGONS

Scene changes can take place at the stage level by rolling scenery on and off the stage from the side or rear. This can be done by building wheels into individual scenic elements or by constructing the scenery and props on top of big flat, wheeled platforms or wagons. (Strong, 2010) The following table shows Stage Wagon Details:

	Stage Wagons Details
Basic functions	Capable of carrying an entire three-dimensional standing set in one piece. Might incorporate a built-in revolve or may have trap doors that align with the traps in the stage or life floor
Different types	**XVI. Sliding Wagon stage**
	
	Metropolitian Opera House – Sliding Wagon Stage
	The wagon stage system is used with other stage machinery to provide flexibility and efficiency. It doesn't require a spacial arrangemet in floor. It rools on the floor by the means of a series of rubber or polyurethane tired wheels.
	XVII. Wagon stage with a built in Revolve
	 

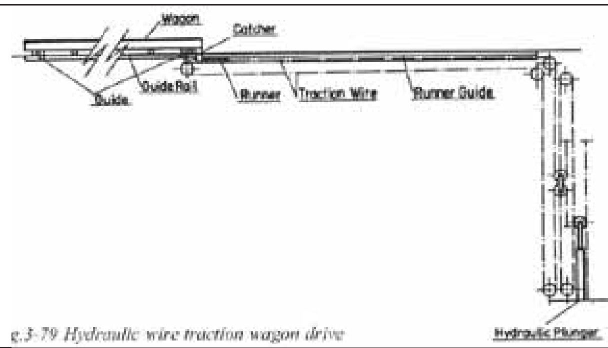
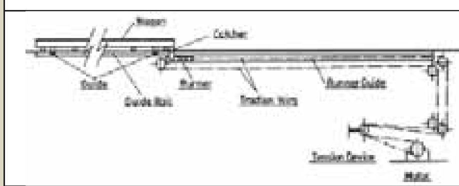
<table>
<tr><th></th><th colspan="2">Stage Wagons Details</th></tr>
<tr><td rowspan="2"></td><td>Portable Revolve</td><td>Sectioned portable revolve</td></tr>
<tr><td colspan="2">This type of portable turntable revolve is generally made of 24 sections. Each section can be slide partially as a wagon stage.</td></tr>
<tr><td>Size</td><td colspan="2">The optimum size of a wagon stage is based on the size of the main stage, both width and depth being more than the stage opening plus 2.
The main stage may be devided into six sectons. Parralel to curtain line.</td></tr>
<tr><td rowspan="9">Mechanisms</td><td colspan="2">VIII. Self –contained driving mechanism</td></tr>
<tr><td colspan="2">
</td></tr>
<tr><td colspan="2">Hydraulic wire tracion wagon drive</td></tr>
<tr><td>
</td><td></td></tr>
<tr><td>Self-propelling electronic wagon drive</td><td>Electric motor wire traction wagon drive</td></tr>
<tr><td colspan="2">Electric Motors are built in the wagon, which are normally 33-50cm high.</td></tr>
<tr><td colspan="2">XIX. Separate driver wagon</td></tr>
<tr><td colspan="2">Drive generally consists of both an automatic remote-controlled coupling from the main control station and a manual coupling arrangement done by the crew.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td>General consideration</td><td colspan="2">The decisive factors in planning for a wagon stage:
The strength of the floor.
Good guide system.
The number of wheels to distribute the gross weight.</td></tr>
</table>

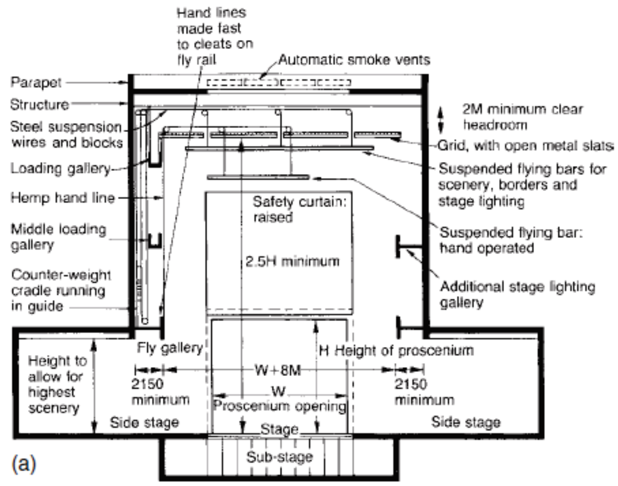
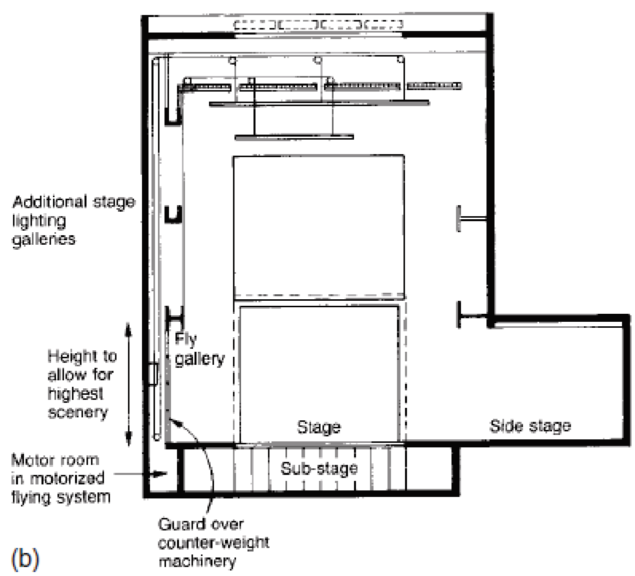
TABLE 3.3-4: STAGE WAGONS DETAILS ILLUSTRATED BY (OGAWA, 2001) & (STRONG, 2010)

3.3.2. FLY TOWER MACHINERY:

3.3.2.1. GRID SYSTEMS

The grid is the maintenance and access deck for the stage suspension systems. It may also carry equipment loads. The following table shows Grid system details:

	Grid System Details
Basic functions	Provide a secure and reliable place for the installation of the rigging system, machinery and driving units.
Different types	**XX. The grid**
	
	The desgin of the grid depends on future suspected other systems that will be suspended by the grid such as fly systems, scenaries and lighting.
	XXI. The grid system with double-purchase flying system and side stages

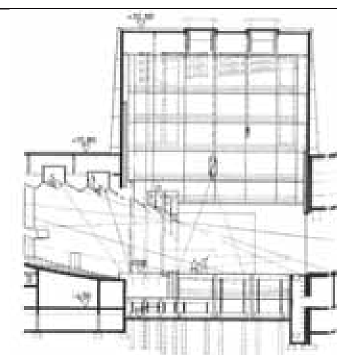
<table>
<tr><th></th><th>Grid System Details</th></tr>
<tr><td rowspan="3"></td><td>
</td></tr>
<tr><td>XII. The grid system with a single-purchase flying system</td></tr>
<tr><td>
</td></tr>
<tr><td>Size</td><td>The height of the gird can be 2.5 times the procenium opening , extra height is a production bonus and three times the procenum openning should be the target.
It should be noted that the end seats of front rows are usually the worst case.
The minmum width of the grid should be the proscenium width plus an over lap 2m, from both side with a further 2m on each side for counter weights and flys.</td></tr>
<tr><td>Structure</td><td>The construction of the grid consists of two main elements:
Steel beam construction to support the total weight of the grid structure and the weight of machine and scenery that will be added.
The flooring arrangement of the grid.</td></tr>
</table>

	Grid System Details
General consideration	It must not only support the weight of such hardware, but also that of the scenery and lighting installation necessary for normal production It must provide a safe place for service and maintenance with easy access for technicians, flexible platform for the utilization of new scenic developments, and to meet any unexpected requirements in production activities such as the dropping of additional spotlights to suspend pieces of scenery.

TABLE 3.3-5: GRID SYSTEMS DETAILS ILLUSTRATED BY (OGAWA, 2001), (APPLETON, 2008) & (STRONG, 2010)

3.3.2.2. **GALLERIES**

Due to the great height of fly tower and the complexity of the stage machinery in such tower there is a great need to galleries to be able to access different levels in this enormous height. The following table shows Galleries details:

	Gallery System Details
Basic functions	Provide a work and service area for the fly system, connecting corridors to various locations including the lighting bridges and extra lighting positions.
Different types	 Gallery layout (five galleries in karlsruhe city theater)
	XIII. Fly Gallery
	It is the first gallery above the stage floor perpendicular to the curtain line built along the sides of the fly system guide rail.
	XIV. Loading gallery

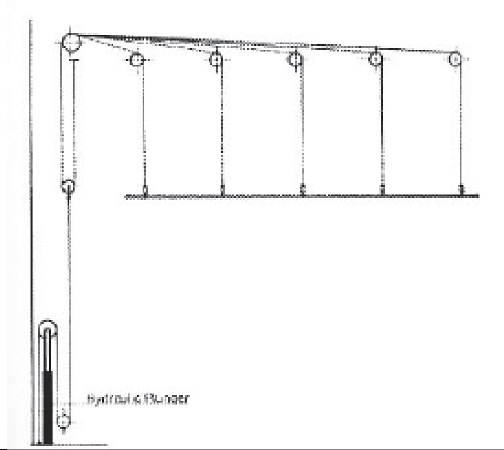
	Gallery System Details
	It is the top gallery used by the fly crew to load and unload counterweights to balance the weight on the scenery battens. It is considered the most frequently used work areas in theater.
	XV. Other galleries
	They are from 1 to 3 pairs located between the fly and loading galleries. They provide greater convenience in technical work.
Size	The standard gallery width is from 0.8 to 2 m
Structure	There are two main types of gallery construction: Reinforced concrete construction Simple steel frame construction (better solution for multiple gallery system)
General consideration	Gallery safety rails are at height 1.1 m above the gallery floor. Gallery floor material should be non-flammable.

TABLE 3.3-6: GALLERY SYSTEMS DETAILS ILLUSTRATED BY (OGAWA, 2001)

3.3.2.3. FLYING SYSTEMS

The flying system is considered one of the most complicated components in the stage tower that took several developments from the 16th century until now. The main purpose of such tool is to overcome one of the most important natural physical parameter onstage which is gravity. This concept will be shifted a little as will be studied later in the following chapter. The introduction of digital and multimedia technologies on theater stage had offered alternative forms for theater illusion and digital scenery changes that could possibly overcome such parameter.

At first in the 16th century, flying systems consisted of two sets of large wooden drums, one on the grid and the other on the gallery. In the 17th century hydraulic power and multiple pulley system were used which eventually led to the concept of the centralized remote controlled flying system of modern theater technology. Later, electrically powered scenery battens using electrical winches and complex spotline systems with synchronization devices were used. (Ogawa, 2001). All such forms are still used in modern theaters in order to achieve high accuracy and safety in changing the sceneries and moving heavy objects and equipment into the stage tower. The following table presents some details about each system and also the advantages and disadvantage of each:

	Fly System Details
Basic functions	It suspends moving objects and moves loads overhead into the stage tower with high safety degrees and installations.
Different types	 Hemp fly system
	XVI. Hemp or Manual fly system
	Direct haul theater suspensions either have a single hemp (manila rope) carring a small piece of decoration, like a chandelier or a number of ropes, attached to alluminium pipe to which the scnery is tied by the help of pulleys placed on the grid and the galleries. Advantage: It can be used for simple spotline and as suplemented rigging rid in addition to the permenanat flying system It can easily be set utilizing available space on the grid according to the needs of an ambitious scenic design. Disadvantage: Needs frequent adjustment, as the lines stretch irregularly because the load of the enviroment. Needs high number of man power for weights over 1KN
	

Fly System Details

XVII. Hydraulic fly system

The typical modern hydraullic flying system consists of a hydraulic cylinder (plunger) installed vertically along the sidewall of the fly tower, combination blocks for steel cable, loft sheaves, collect sheaves, and scenery batten.

Adventage:

Acurate motion and relatively quiet operation.

A constant ascending-descending speed.

Additional hydraulic functions such as safety break.

Disadvantage:

High expenses for the installations.

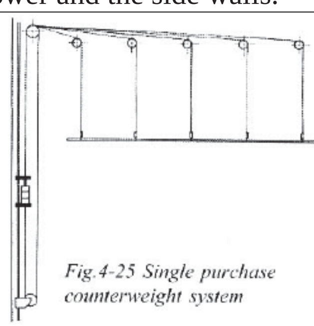
Incresed construction costs because of the necessary reinforcement of the fly tower.

High maintenance costs.

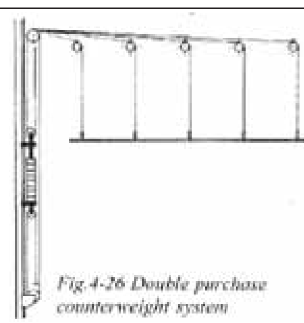
The wall frame of a single purchase counterweight installation

XVIII. Counterweight systems

Scenery is hung and balanced against a set of weights suspended on wire ropess which pass over pully blocks above the grid at the head of the flytower and the side walls.



Single purchase counterweight



Double purchase counterweight

	Fly System Details	
	The travel distance is equal to the height of the grid above the stage which is required for the guides a continuous vertical wall running higher than the grid. The operation can be from the stage level. It is more accurate system as there is less friction to overcome. The operation at stage level benefits the operator, especially in small theaters, who may have other duties during a performance.	The distance travelled by the counter weights is halved in relation to the distance of the suspension. Allows the operation to occur from a gallery above stage level. An extra loading gallery is necessary between the flying gallery and grid. Requires less width of flytower and releases the stage area.
	 The winch motor room	
	XIX. Powered flying system	
	Powered assistance	Direct lift
	Counterweight cradles operated by an electrical motor.	The suspension wire ropes are wounded directly onto a drum rotated by an electrical motor.

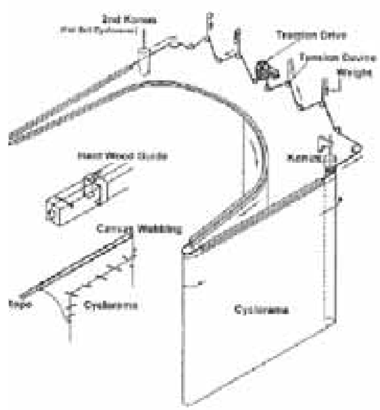
TABLE 3.3-7: FLY SYSTEM DETAILS ILLUSTRATED BY (APPLETON, 2008), (OGAWA, 2001) & (STRONG, 2010)

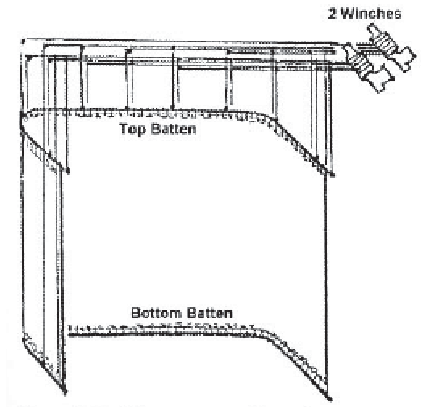
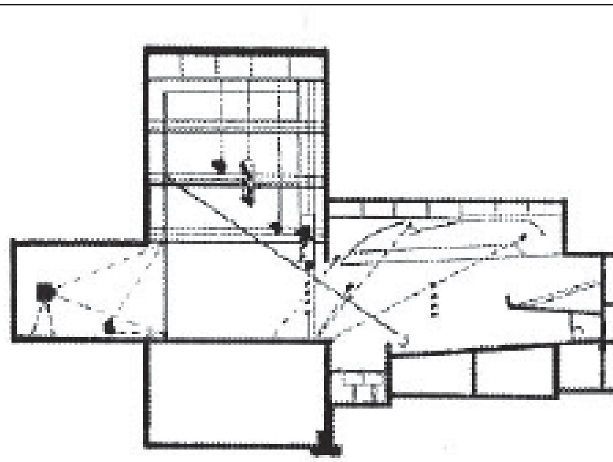
3.3.2.4. CYCLORAMA

It is one of the key items in stage settings as it is considered the infinitive medium for creation. It has a great role in introducing projection sceneries in modern theaters. It took different forms and shapes through theatre history.

In the vista stage during the Renaissance period it took the shape of painted backgrounds at the end of the rows of vista wings. And in Italy in the 18th century, it took the shape of a dome to envelope the stage but it wasn't that practical for opera houses because it interfered with most of the fly systems and gave many restrictions on the stage floor layout. In the 19th century it was developed to take the shape of 360 degree-wide painted landscape in a cylindrical building in an exhibition. This was developed in Paris by another innovation called ' Cineorama' to show still and moving images by projection (it will be studied in more details in chapter five). (Ogawa, 2001)

The modern cyclorama is not a dome-type design, but rather a wrap-around, gigantic 'rolling type' or simpler 'batten hang type'. The in place curved cyclorama introduces serious restrictions in staging and scenic design. The following table presents some details for the Cyclorama:

	Cyclorama Details
Basic functions	It is a plain, curved, stretched cloth or rigid structure used as a background to a setting to give an illusion of great depth.
Different types	
	XXX. Rolling type
	Consists of curved curtain tracks fixed under the grid with a tracking wire or rope to pull the cyclorama curtain, and a reversed-cone shaped rope drum, to which the cyclorama curtain is rolled when not in use.

<table>
<tr><th></th><th>Cyclorama Details</th></tr>
<tr><td rowspan="3"></td><td>
</td></tr>
<tr><td>XXI. Battern hang type</td></tr>
<tr><td>The cyclorama curtain is hung from a curved batten located at the back of the stage with the exact shape of the cyclorama.
When two sets of curved cyclorama battens are installed, one can be used for the normal solid cylorama curtain, while the other (the front batten) may be used to hang an auxillary theatrical scrim to provide modern means of achieving the mysterious fortuny effect.</td></tr>
<tr><td>Size</td><td>The height of the cyclorama should cover the sightline of the first row in the auditorium.</td></tr>
<tr><td rowspan="2">Projection types</td><td>XXII. Rear projection (Popular German Method)</td></tr>
<tr><td></td></tr>
</table>

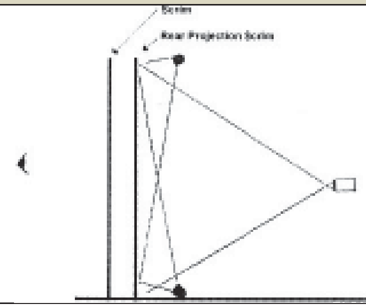
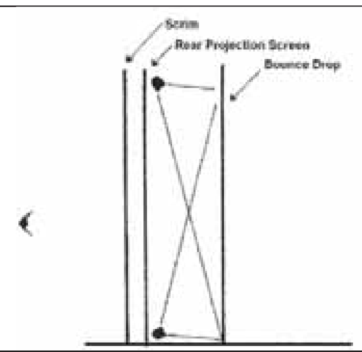
	Cyclorama Details
	
	Opera Folie back lighting with diffuser black scrim
	Rear projection screens needs rear spaces that should be calculated carefuly.
	XIII. Bounced Cyclorama (American Method)
	
	Bounce lighting cyclorama method
	It is a popular method for Broadway productions where there is no room for rear projection equipment. Lighting strip lights are placed between Opera Folie and a white bounce drop. In the back lighting method, black diffuser method can be added in front of the frontal Opera Folie. The rear projected screen can be replaced by translucent painted drops to create multidimensional image and depth.

TABLE 3.3-8: CYCLORAMA DETAILS ILLUSTRATED BY (APPLETON, 2008), (OGAWA, 2001) & (STRONG, 2010)

3.4. CONCLUSION

The stage area is the main focus point in the design of any traditional theater. As studied before in chapter one, it returned to be a huge transmitter to passive receivers since the 17^{th} century until the end of the twentieth century. This huge transmitter was developed into many forms and shapes to achieve its approach which is the complete attention to the performance. During this period this approach was only achieved by physical imitation to reality on the theater stage. The great competition between the cinema industries and theatrical production has resulted in the great desire of implementing the theater illusion on the stage platform. To achieve such illusion, the backstage area turned to be a busy factory with very complicated machinery and technology.

The introduction of such complicated machinery and technology added more boundaries between the audience and the actor. Audiences should sit quiet in the dark zone completely isolated from the busy backstage zone. Entrances of audience should be entirely separated from the entrances of the crew cast. The only shared visual zone between both entities is the bright stage zone but every entity has its own visual sightline for such zone. So the audiences missed the main happening on the stage platform which is the creation process of such creative illusion.

Due to the high complicity of stage machinery, many concerns were aroused regarding it. First, it took additive volume around the stage that was more than triple its volume. These spaces were located behind, in both sides, above and under the stage. It was completely wrapped around except from the common side between the stage and the auditorium. This kind of wrapping will be substituted by other suggested forms in the next chapter by the introduction of multimedia theater.

Another concern about such complicity is the unsustainable use of such machinery. The idea of using physical presentation on stage, such as hanged painted sceneries and the process of scenic changes by sliding it into the stage sides or hanging it up to the fly tower, added inflexibility in the quantity and given options for the setting of the stage. The stage setting here was subjected to the maximum number of scenic battens in the flytower, the capability of the flying systems, the number of sliding wagons and its layout on stage and the trap grid options for removing the scenic objects from stage. Sometimes the introduction of a creative scenic setting always lead to high costly modifications. This kind of unsustainable usage of stage will be substituted also by other tools in the next chapter.

UNIT TWO: VIRTUAL REALITY

4. CHAPTER (4): INTRODUCTION OF MULTIMEDIA TO THEATER STAGE

Throughout the history of traditional theater, the main element on stage was the actor. The actor was the core when the performance was performed outdoor and the actor was surrounded by the audience using his voice and body as main elements, then adding some elements to help to send the message such as musical instruments. Due to theater development, stage was created to focus on the actor space and then moving from outdoors to indoor to protect the actors elements from the weather and to have the chance to act in dark times. By the creation of Stage, theater illusion was born. (Tannenbaum, 2000) The implementation of stage machinery is to achieve higher quality of production assisting the main element (the actor).

By the end of the 20th Century, technological inputs became very effective in the theater production and sometimes it occupied the priority level in some plays rather than the actor. New approaches in theater production have been taken as removing the boundaries between the actor and the audience, emerging them in one space and in one experience. Sometimes roles are changed and audience start to be actors by introducing interactive multimedia on stage.

It is important to identify multimedia before studying its implementation in theater production. A specific definition was given by Tannenbaum in an article about the history of multimedia in human communication for multimedia which is: **an interactive computer-mediated presentation that includes at least two of the following elements: text, sound, still graphic images, motion graphics, and animation.** (Tannenbaum, 2000) In this definition he connected computer–mediated presentation with at least one of the main elements of theater scenography. Many modern presentations include mixtures of two or more media and may in some descriptions be termed multimedia, for example, a poetry reading accompanied by music, a theater play with photographic slides projected as part of the stage set (Tannenbaum, 2000).

The main purpose of a theatrical production is to produce a reaction, a feeling, a sense in the audience by communication between the actor and the audience. Multimedia and cinema are very powerful communication tools but differ than successful live theater in the way the actor responds live to the audience reaction. It is important to be aware of the difference between them in implementing Multimedia in theater production without losing the interaction channel between the actor and the audience. (Tannenbaum, 2000). The main purpose of implementing Multimedia in theatre production is to enrich the immersion feeling of the audience into the theatrical experience and not to lose it.

Due to financial and sustainability issues, some modern theater has evolved to rely much less on physical illusion (for example, minimalist scenery) and more on creating the illusion in the mind of the audience. To the same approach some multimedia presentations may prove effective in transmitting some messages, as well as being more cost-effective. (Tannenbaum, 2000). So multimedia for some producers is a sustainable and reusable material on stage rather than wooden sets scenery, costume, masks and other theatrical elements that maybe used for only one play. Another approach for using multimedia on stage is to send messages that can hardly be sent by physical sets. It opens a further creative approach in front of stage designers. And the third approach is to add interactivity to theater experience and change passive audience into active ones. All these approaches will be discussed later while presenting multimedia theatrical productions.

In this chapter, the components and implementation of Multimedia technology in different types of theaters will be studied. Also a brief analysis will be presented for the effect of implementing the Multimedia in the auditorium interior through presenting different types of theaters as examples.

4.1. MAIN COMPONENTS OF MULTIMEDIA ON STAGE

4.1.1. VIDEO PRODUCTION EQUIPMENT

According to Strong, 2010, the Video Production is mainly composed of three main elements:

Capture: Recording/ grabbing images from transmission live or at a later date. (Strong, 2010)

Media Production: Creating/manipulating/ editing video images in a studio to create film or scenic video.

Presentation: Playback of images/scenic video to support production

The following table a brief description of each element and the Architectural considerations:

	Description	Architectural Considerations
Capture	Capture system is composed of Cameras and camcorders, lenses, lights, cabling, dollies, etc.	The location of the cameras should be considered in the design of the auditorium and located carefully through the layout of the auditorium.
Media Production	Images and videos from still cameras and images created from graphics, all can be animated and composited to create media files may then replayed on a media server	Spaces required are video recording studio and video edit suite (12 m2 to 15 m2).
Presentation	There are types of Video presentation: The presentation of films to an audience in the traditional sense (35 mm film or Digital film presentation) The use of video within the set design of a show as a graphic, illustrative element.	Installation of 35mm projector with the usual specification of a long play system should be considered such as a tower or cake stand. Scenic projection types and location will be discussed later.

TABLE 4.1-1: DESCRIPTION AND ARCHITECTURAL CONSIDERATIONS FOR VIDEO PRODUCTION ELEMENTS ILLUSTRATED BY (MALON, 2006) & (STRONG, 2010)

FIGURE 4.1-1: ILLUSTRATING THE USE OF VIDEO IN IVE THEATER ' PETER PAN' PRODUCTION BY (STRONG, 2010)

4.1.2. SCENIC PROJECTORS

Type of projectors:

There are two well known projector type in theatrical production, DLP (Digital Light Processing) & LCD (Liquid Crystal Display). They are compared in regards to Lumens (brightness), Contrast Ratio, Lenses, installation, etc.

Location of Projectors:

The following table presents the different locations of projectors in theater and the architectural considerations of each location:

	Architectural Considerations
Control room on the center line	The room should be equipped with a glass projection window containing the associated noise. Ideal placing for a projector.
Auditorium ceiling	This has the disadvantage of being inaccessible and potentially noisy.
Balcony front	For small projectors mainly Special pockets should be used for larger units. The disadvantage is loosing prime seat location.

	Architectural Considerations
Rear projectors	The most ideal projection Tie lines at the rear of the theater and a sufficient depth to allow an image the width of the proscenium. The maximum wide lens available is 1:0.8 where 1 = width and 0.8 = throw. So proscenium opening of 10m requires 8m projection depth.

TABLE 4.1-2: ARCHITECTURAL CONSIDERATIONS FOR DIFFERENT LOCATIONS OF PROJECTORS BY (STRONG, 2010)

4.1.3. SCREENS AND SURFACES

Material: Many interesting materials such as gauzes, scrims, filled cloths, plastics, foils and painted surfaces are currently used for effects. (Strong, 2010)

Location: Front and rear-projection screens. Front screens are often white and will reflect projected light into the audience whereas rear projection screens are pale through to dark grey and transmit light through a screen to the audience. (Strong, 2010)

Kinetic Scenic elements: Some stage machinery and technology may be used for kinetic Scenic elements such as: Turntables, tracks, traps, costumes, robotics, animatronics, environmental "wraparound" designs such as "virtual caves", etc. (Malon, 2006)

4.1.4. SOUND EQUIPMENTS

Samplers, mixers, processors, microphones (wired and wireless), acoustic and electronic instruments, amplifiers, speakers, etc.

4.1.5. VIDEO CONTROL ROOM

The video control room is a room where the operator controls the video sense. It should have a desk surface for vision mixer or digital playback from video server with a series of video monitors. The video control position requires a good view of the stage and in proscenium house a reasonable vertical sightline to the rear of the stage. (Strong, 2010)

4.2. MULTIMEDIA PRESENTATION ON STAGE

4.2.1. OPERA & DRAMA THEATER

Joseph Svoboda’s scenography is considered the first to blend live theatre with projections and film techniques and become known internationally as **the godfather of modern scenography**. (Eagan, 2010) In “Laterna Magika”, his famous play in 1958, he created a unique cross-disciplinary art form by conjoining film and theater. His projection scenes composed of wide elasticized strips that allow the actors to enter and disappear through it as in **Figure 4.2-1** (Eagan, 2010).

FIGURE 4.2-1: LATERNA MAGIKA PRODUCTION BY (LATERNA MAGIKA, 2002)

From a political point of view, he aroused contemporary issues live in his plays. In “Intolleranza” (1965), he replaced the live chorus on stage by real images of strikers projected on placards held by on stage. And by using a TV channel, he connected people real life in streets with his plays on stage. So by this interaction between inside and outside the theater, he transferred public people into artists. In another play he transferred the audience themselves into actors by projecting negative images projected fed from live cameras placed inside the theater. The idea of the negative images is to convert the color of white people to black once and vice versa. It was a political issue at that time where still there was discrimination between white and black. (Vogiatzaki-Krukowski, 2011)

His theater "Laterna Magika" was a famous experimental theater in Prague known as the Aquarium. Designed by the Czech architect, Karel Prager, it was largely state-funded. It was a huge cube-shaped building, clad on the exterior in square frosted-glass tiles, as seen in **Figure 4.2-2** and was intended as a showcase for contemporary and *avant guard* theatre productions. Its location was significant - virtually next-door to the National Theatre, home to both the Czech National Opera and Ballet. (Eagan, 2010).

FIGURE 4.2-2: Laterna Magika, Prague. Designed by Karel Prager BY (EAGAN, 2010)

George Coates is considered one of the pioneers in using multimedia technology in his theatre productions to create artificial scenography and spatial environments, in effect replacing conventional wooden sets with videated or virtual sets composed of projected light. In 1987, Opera Actual Sho, the stage was transformed into a series of arresting environmental spaces and architectural structures. Actors appear to lean out of the windows of a skyscraper, to emerge from a railroad tunnel, and to balance on the wooden joists and beams of a vast shell frame work of a building under construction. . (Dixon, 2008)

In 1991 (Virtual Sho), he used a thirty-foot by sixty-foot perforated aluminum screen on stage to project computer sets and images. The actors worked behind it, but through lighting effects was visually rendered to appear within the 3D environments. The audience viewed the show through polarized glasses. One of the interesting scenes was that the actors seemed to be floating in midair inside a giant birdcage (Dixon, 2008). The use of Media technology gave the chance to create live illusion and visually stopped gravity effect on the actors that couldn't be done in traditional theatre except by using flying cables.

The Builders Association is another leader company in the multimedia theatre. It presents the postmodern theatrical spectacle in contrast with Coat's visceral immersive theatrical images. It creates worlds onstage that reflect the contemporary culture which surrounds us. One of the leading performances for the 21st Century theatre is "Alladeen, 2003". It is an example of experimental digital theatre with the stylish look and acting finesse of a West End or Broadway production. By using a screen with the height and width of the stage, the first scene is projected with a very interesting and creative way by dropping blocks one by one as the computer Tetris game as in **Figure 4.2-3**. (Dixon, 2008) So digital means didn't only introduce artificial scenes in an easy way but also gave an opportunity to presenting scenes in a very creative ways that can hardly be achieved by traditional means.

FIGURE 4.2-3: ALADDEN PERFORMANCE BY (THE BUILDERS ASSOCIATION, 2003)

Robert Leapge and his Company Ex Machina, founded in 1994, presented also a good potential in Multimedia theatre. He had a great history in installing new mechanical and technological tools in theatre productions. He used relatively few computer-generated effects to ignite his visual spectacles, preferring the use of conventional video projection in conjunction with kinetic screens, mirrors, and ingenious mechanical sets. (Dixon, 2008)

One of the most ambitious of his works is "Der Ring des Nibelungen" known by the "Ring" that is played now in the Metropolitan Opera. The setting of such performance will be studied as a case study compared to the traditional setting of the original performance of Wagner on the Bayreuth stage.

4.2.2. MUSIC THEATER

Multimedia is considered a main element in the Music Theater, where pop and rock music is always a leading in using high tech technology in their concerts. Projections and light effects are very essential in live concerts on stage. According to Appleton, The following requirements are needed to achieve a music stage:

- Metal structure along the line of the stage edge forming a 'proscenium' opening to receive stage lighting, framing the performance;
- A lighting grid over the stage to receive stage lighting;
- Levels formed on stage, with rostra;
- A backcloth or curtain at the rear of the stage;
- Masking at the side of the stage;
- Side stages for musical instruments, and performers entry and assembly;
- Sound relay positions at the side of the stage;
- Video screen(s) (Figure 4.2-4) performance sound, lighting and power outlets: temporary cable access with cable link to control rooms, relay towers, etc.

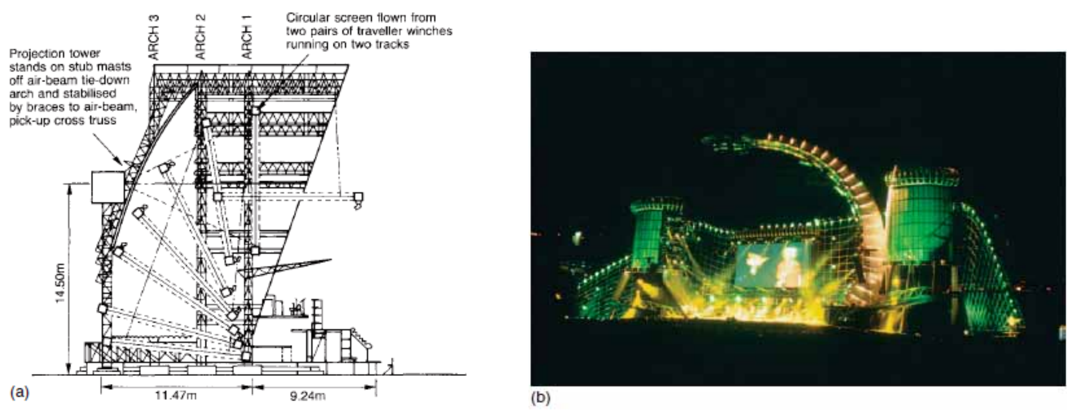


FIGURE 4.2-4: A) CROSS-SECTION THROUGH THE STAGE SHOWING THE CANOPY AND MOBILE SCREEN FOR THE PINK FLOYD TOUR. (B) VIDEO SCREEN AS ON INTEGRAL PART OF THE SETTING OF A ROCK CONCERT. THE ROLLING STONES TOUR BY (APPLETON, 2008)

4.2.3. DANCE THEATER

The Aldwych Theater in London is now presenting a classical play called "Dirty Dancing". It was first presented at the Neue Flora Theater in Hamburg. It is considered a good example of the digital dance theater. The theater is one of Europe's largest, with a capacity of over 2,000, and its stage accommodates an enormous production that includes LED walls, Pani Projections and over 150 automated lights. Other production elements include a 29 m rear projection screen, a curved LED wall which splits four panels built into the set and two full-sized radio controlled cars. The set itself includes a 12 meter outer revolve and an inner revolve which splits into three sections as **Figure 4.2-5**. The show is a unique mélange of theater play, dance and music. (DIRTY DANCING THE MUSICAL, 2011)

Through a personal experience by visiting the Aldwych Theater, the use of digital technology in such a classical play was very impressive. The original story contained many scenes in different locations and different times of the day. To overcome such difficulty, a screen behind the actors suggested the changing locations rather than using traditional backdrops or movable wooden settings. The only mechanical element used is the revolving stage which smoothly revolved rised and fell to create new settings. Visual effects were projected into the revolving stage to present different scene as a hotel pool, golf land and other locations. One of the magical scenes in such a play was projecting the lake water on a transparent screen in front of the actors that let the audience believe that the actors are immersed in water. Overall, however, the film is slickly recreated on stage. (Love, 2010)

FIGURE 4.2-5: DIRTY DANCING: THE CLASSIC STORY ON STAGE - SET DESIGN BY STEPHEN BRIMSON LEWIS BY (HUDSON)

Another impressive example of applying Multimedia in a dancing theater is the Turkish play "*Fire of Anatolia*". It is a unique project that is delivered from the concept of Anatolia's ancient mythological and cultural history. The aim is to introduce the fire that arises from the ancient mosaic of love, culture, history and peace of Anatolia spanning thousands of years as in **Figure 4.2-6**. It is a huge scale production up to (up to 120 dancers) includes a synthesis of hundreds of folk dance figures and music from different regions in that vast area. (YILDIZ P. , 2007)

FIGURE 4.2-6: THE STAGE PRESENTING THE FIRE OK ANATOLLIA BY (YILDIZ P. , 2007)

The set design of the stage was implemented by artificial intelligence technology. The purpose of using such technology is to synchronize all the real and virtual changes on stage to be achieved. The play consists of many historical and cultural dances that been gathered from every part and history of Turkey. So the stage is supported by slide show on the white screen in the back of the stage that presented different scenes according to the dance and historical event presented by the dancers. (YILDIZ P. , 2007)

Stage management through organizing between the dance and the slide show is very important. As an example, when Hittite drummers appear on the screen; drummers in original costume take the stage in the performance. Another one is connected with establishing peace. When two commanders are seen shaking hands in the archaeological piece on the white screen, two groups in blacks and whites give up warring on stage and two commanders are shaking hands loyal to the original story. (YILDIZ P. , 2007)

According to Yildiz the advantages of implementing of artificial intelligence on stage are having the possibility of quick changes of the sets, the interactivity of spatial organizations and the possibility of the unlimited creative and imaginary aspects through using virtual sets. (YILDIZ P. , 2007)

4.3. PROTOTYPE DESIGN FOR UTOPIAN MULTIMEDIA THEATER

During the last century, theater stage has seen technological revolution in the field of light and sound effects and equipments which was booming in many theatrical productions at that time. By the beginning of the 20th Century, the design of theater stage has taken a new path by integrating many disciplines to reach high-tech approach in light and sound installations. But by the beginning of the 21st Century, the field of implementing multimedia on stage occupied the first level in many contemporary theatrical productions on traditional stages that were not designed for such approach but modified for that purpose. Theater design is supposed to shift into another new path through the coming 20 years by implementing new technology of interactive multimedia stages.

Multimedia theater is a field that is still under development. It is hard to find a theater that can typically present an ideal Multimedia Theater. As said before, most theater stages were just modified to present multimedia productions in opera, drama, music and dance theaters, but still the original design doesn't integrate the optimum design requirements for experiencing more creative developments of such technology. A proposal for an ideal Multimedia Theater was given by a research and professional producing/presenting unit called "Multimedia Performance Studio" of the Department of Art and Visual Technology (AVT), College of Visual and Performing Arts, Georse Mason University. The aim of such project is to develop and extend technologies for performance while maintaining a critical eye toward these same technologies for performance art, Music Theater, dance and theater design, indoor and outdoor multimedia installations, and other performance and exhibition forms for the 21st Century. (Kirby Malone & Gail Scott White, 2006)

Kirby Malone, Gail Scott and other researchers in the Multimedia Performance Studio have designed a utopian structure, the Diorama Theater, and complied variations on a (100 ft. x 100 ft. floor plan) design that synthesizes the traditional, flexible "black box," with other experimental conceptions:

"White box" (or virtual Cave) with 360° projection screens

"Green box" for use (with green-screen capabilities) as a soundstage for motion-capture and film and video shoots. . (Kirby Malone & Gail Scott White, 2006)

The main concept of such theater is distributing the projector in the second floor almost anywhere in the room by using wrap-around catwalk/deck as seen in **Figure 4.3-1**.

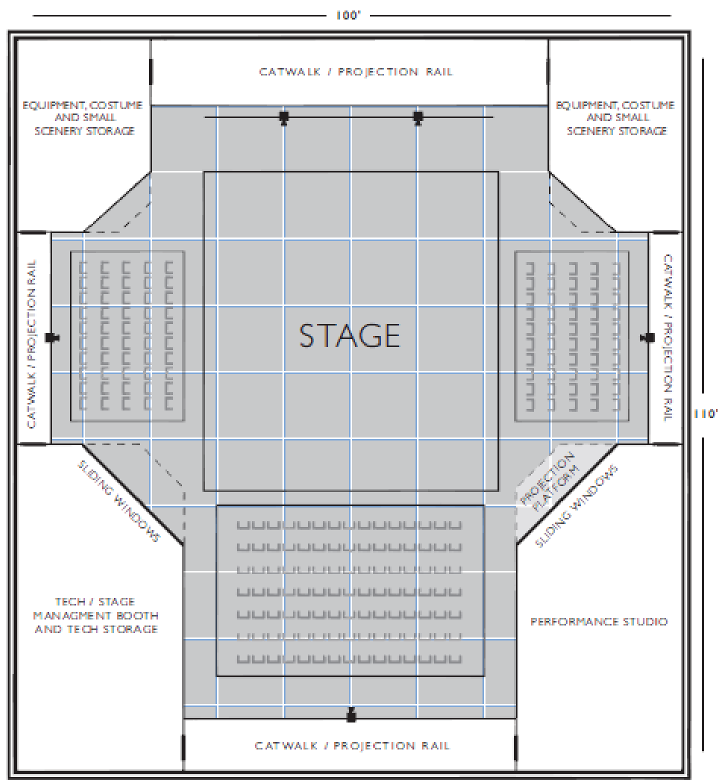


FIGURE 4.3-1: SECOND FLOOR PLAN OF DIORAMA THEATER ILLUSTRATING THE PROPOSED TECH CATWALKS AND DEACKS BY (KIRBY MALONE & GAIL SCOTT WHITE, 2006)

Another important feature of this ideal Multimedia Theater is that it almost contains most of the components needed for such technology. The stage conceptual design can easily be implemented in designing any theater building from scratch. The relation between the audience and the actor can easily be controlled through the arrangement of the seating, the screens and the projectors according to the type of theatrical production performed on stage. This theater can be arranged in (at least) seven configurations that will be briefly discussed below.

4.3.1. FAMILIAR STAGE ARRANGMNETS

In this conceptual theater stage design, audience seating can be arranged as familiar arrangement of theater stages studied before in chapter one (thrust, end stage, arena and stadium). By studying these plans it can be analyzed how the arrangement of different types of theater stages can easily be achieved through the clever orientation and zoning of the spaces needed for the multimedia presentation on stage.

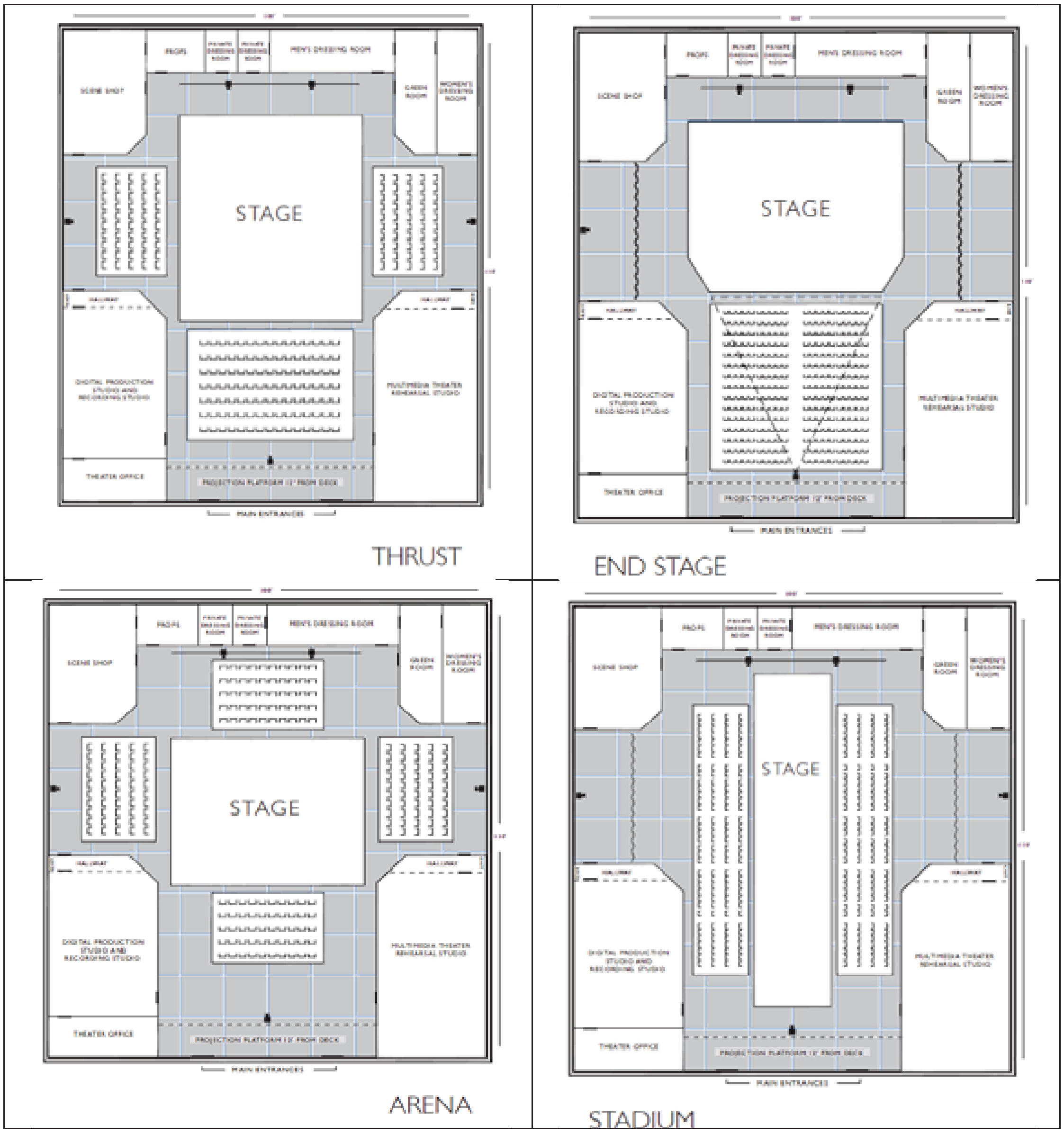


FIGURE 4.3-2: DIFFERENT ARRANGEMENTS FOR THE UTAPIAN MULTIMEDIA STAGE BY (KIRBY MALONE & GAIL SCOTT WHITE, 2006)

4.3.2. DIORAMA THEATER

The Diorama Theater is the first unconventional alignment proposed by Multimedia Performance Studio. The main features of such Theater can be summarized as follows:

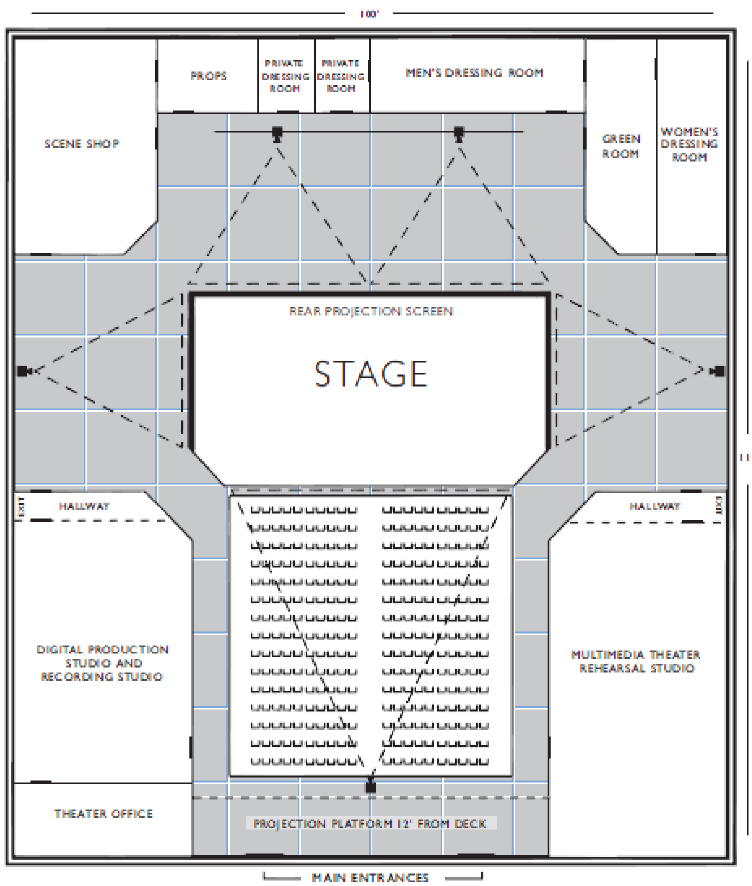


FIGURE 4.3-3: DIORAMA THEATER CONFIGURATION BY (KIRBY MALONE & GAIL SCOTT WHITE, 2006)

Seating alignment: The stage is surrounded by the audience from one side only which makes the relationship between the audience and the actor as traditional proscenium theater were Drama and Opera Performances can be achieved. All the seating faces the screen with no side aisles or wings.

Screen Location: Screens are enveloping the stage from three sides like a room with three walls and the forth wall is removed for the audience to watch the scene. The platform works as a projection screen too where 3d screens can easily be projected on 3 walls and floor.

Projections location: A projector is located over the entrance in the opposite side of the back screen. It is a platform projector. Other platform projectors are located on both sides of the stage in the second floor at angle 45 degree see **Figure 4.3-1**. There are also 2 rear projectors used as rear projection for the back screen of the stage. The two side screens perpendicular to the audience also have 2 rear projections.

4.3.3. CAVE THEATER

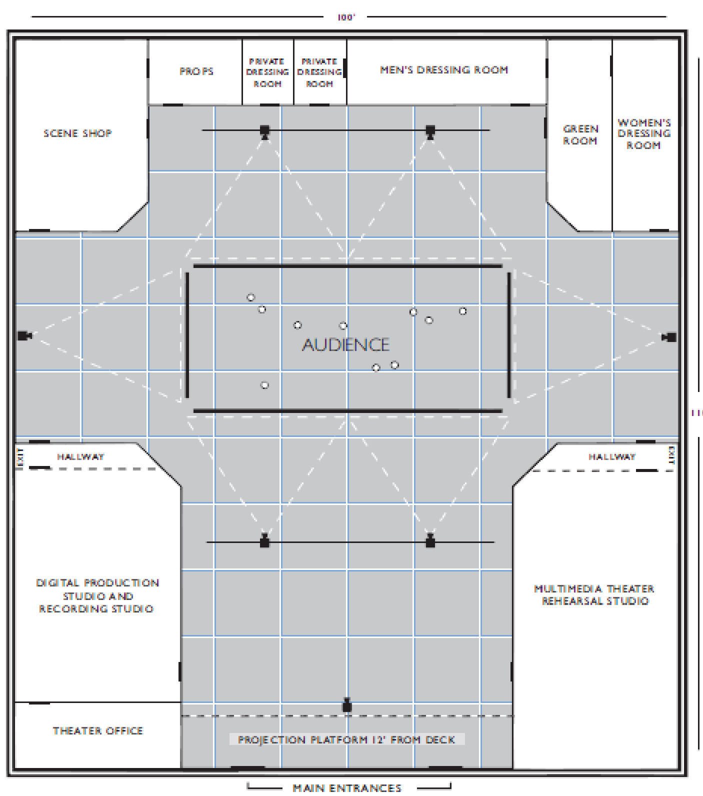


FIGURE 4.3-4: CAVE CONFIGURATION BY (KIRBY MALONE & GAIL SCOTT WHITE, 2006)

Another unfamiliar theater is the CAVE Theater; it is completely surrounded by screens. The Auditorium and the stage is one space. Audience isn't seated in isolated place like traditional theaters but they are moving freely over the stage and maybe interacting with the performance itself. This type of arrangement can be used in exhibitions and museums. For projection locations it is the same as Diorama Theater but added to them 2 rear projectors in front of the entrance to project on the fourth added screen.

4.3.4. CINEMA OR LECTURE THEATER

The final arrangement is for Cinema or Lecture Theater that can easily be achieved by adding a cinema screen at the end of the stage. The film projection is achieved from front projection not rear projection as other types. The stage is demolished as there is no live performance and in the case of lecture use, the stage is used by only one person, the lecturer. This gives more room for the audience seating.

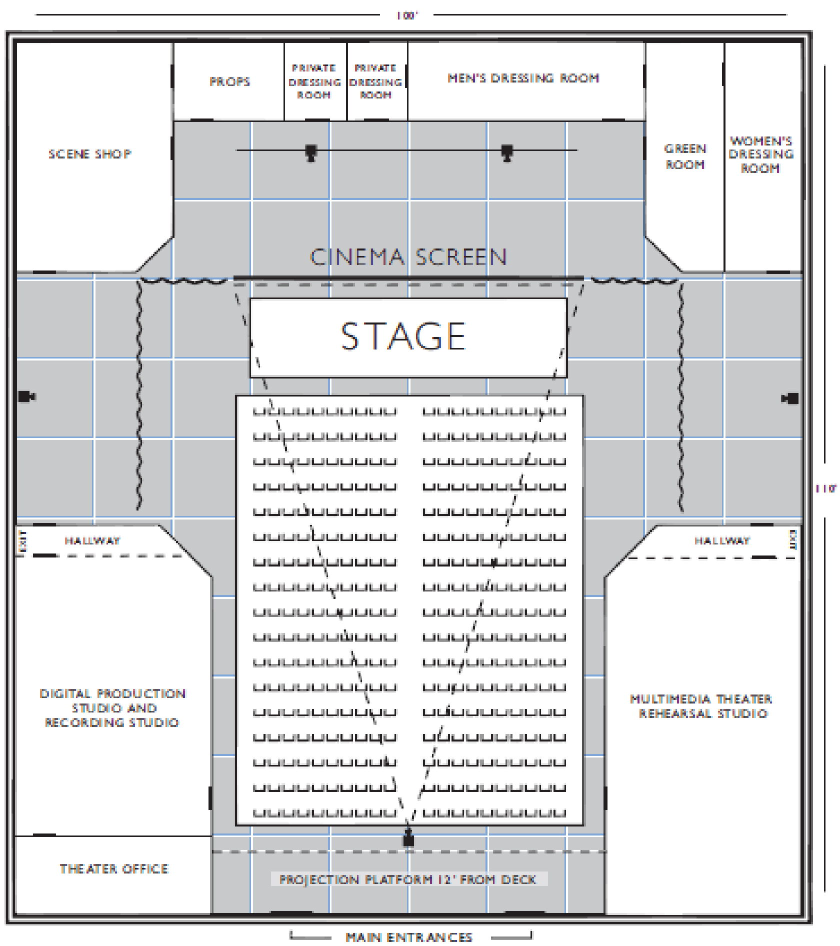


FIGURE 4.3-5: CINEMA OR LECTURE ARRANGEMENT BY (KIRBY MALONE & GAIL SCOTT WHITE, 2006)

4.4. MULTIMEDIA AFFECTION ON THEATER INTERIOR

One of the pioneers in studying the effect of implementing multimedia on theater interior is **Pelin Yildiz.** She is working at the Department of Interior Architecture and Environmental Design, Hacettepe University, Beytepe Campus, Ankara, Turkey. Specified papers were published for her studying such issue that worth to be presented in this study. She analyzed and compared local (Turkish) and international examples to verify the idea of implementing Multimedia on theater stage and its affect of theater interior. The following will be a brief presentation of her ideas, analyzed examples, applications, and conclusions.

4.4.1. MULTIMEDIA INTERACTIVE THEATER

Interactivity is achieved in theater through two different approaches. The first is between the audience and the actor and the second is between the spatial organization elements on stage which leads us to the term "multimedia interactive theater ". According to Yildiz, "The multimedia interactive theater is the high-tech approach of set design in relation with the concept computational intelligence. Computational intelligence is the supplier of all the technological advances in artistic disciplines as well as other fields." (Yildiz, 2007). The reasons of implementing computational intelligence on stage can be summarized according to (Lovell, 2000) as follows:

- Having the ability to manipulate the media in response to performers at a rate, and in a way, that cannot be fully pre-programmed.
- Having the expert knowledge to translate higher level and complexity for creating and controlling effects into programming by using several controller devices (sound, lights, and sensing).
- Posing a set of fruitful design/direction questions, rather than merely a question pertaining to the ‘legitimacy’ of the computer’s function.
- Building a bridge between the different art forms, music, visual arts, dance, and theater.
- Introducing emergent phenomenon that influence the processes through which a work is created by providing options that might not otherwise enter the designer’s mind.

One of the keys of successful multimedia production is the synchronization between the different elements in stage design. The visual and audio effects, the costumes, the scenic projections, the stage machinery… etc. all should act as one organization where changes should be updated by the live performance on stage. Errors in such synchronization lead to high disappointing image in the theatrical production which can be controlled by using artificial or computational intelligence.

4.4.1.1. STAGE INTELLIGANCE

The intelligent stage [10] is an application for implementing computational intelligence on stage. It is a mediated performance space that responds to the actions of performers as they move. The main objective of such technology is to turn the theatrical stage into computer's body where the electronic media are the limbs, cameras and microphones used as sensors are the eyes and ears, a speech generation program is the mouth, and the CPU(s) and internal programming are the brains that are used to interact with the physical world. (Lovell, 2000). In order to achieve such approach, three kinds of abilities are required for computer intelligence as follows:

Perception: can be measured, as a level of understanding about what is happening in the environment. The computer accomplishes this through abstractly created and stored representations of sensed information. Sensing occurs through analysis of video images, spoken text, and user interface interactions.

Reasoning: is the computer making decisions about what responses are necessary or appropriate for given contextual and sensed information.

Dexterity: is the computer's ability to respond to, and carry out, abstract decisions using electronic media and to interact with artists. (Lovell, 2000)

[10]The technology of the Intelligent Stage developed by a research being explored at the Institute for Studies in the Arts (ISA) at Arizona State University is in the area of the use of computer intelligence in the arts.

With these abilities, the computer should be able to become a new kind of participant (as a performer, technician, or assistant) within the performance of a theatrical work or an interactive art piece. (Lovell, 2000)

The current Intelligent Stage is not really 'intelligent' as it lacks the above-mentioned qualities. It integrates only two qualities as follows:

Sensing the environment: The primary sensing occurs through a program called **EYES** that analyzes video activity to understand what is happening on stage. In **Figure 4.4-1**, three color-sensitive sensors are looking for movement in three different camera perspectives, viewed as red for camera 1, green for camera 2, and blue for camera 3. The yellow, magenta, and yellow show the direction of movement.

Responding according to predefined procedures created for each production: Responses occur through the manipulations of electronic media: lights, sound, visuals, robotics, etc. (Lovell, 2000)

. This algorithmic knowledge is lost each time a new show is created which makes the whole system still uneasy to use. It is still under development and research.

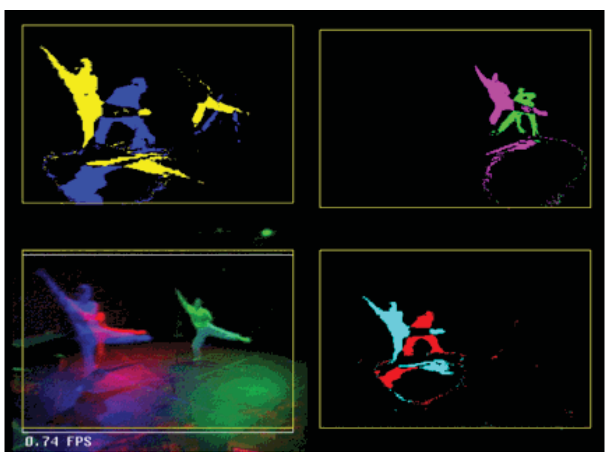


FIGURE 4.4-1: ROBB LOVELL DEMONSTRATES MOTION SENSING IN A VIEW OF THE EYES SENSING SYSTEM. (LOVELL, 2000)

This application has been used in a performance called *Time in the Eye of the Needle*. The following are some innovative features for such performance that illustrate the use of Intelligent Stage:

In Scene 1, a woman dances a solo where two interactive musical effects are possible as in **Figure 4.4-2**. One interactive element consists of two locations on stage where she is able to access some background sounds of birds. Another consists of a sensor an overhead camera (inset) that looks at a floor projection of water; when the dancer enters the floor projection the computer responds with bamboo chimes.

In scene 3, four women dance a quartet, but stay within the same vicinity of each other as in **Figure 4.4-4**. Three projections of tombstones, two upstage and one stage left, "watch" the dancers as they move, turning stage left and right.

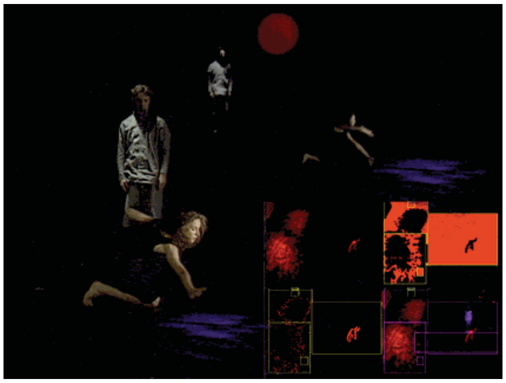


FIGURE 4.4-2: SCENE 1 IN *TIME IN THE EYE OF THE NEEDLE* PERFORMANCE BY (LOVELL, 2000)

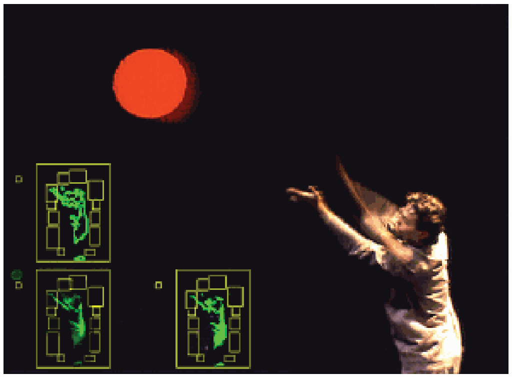


FIGURE 4.4-3: SCENE 2 IN *TIME IN THE EYE OF THE NEEDLE* PERFORMANCE BY (LOVELL, 2000)

FIGURE 4.4-4: SCENE 3 IN *TIME IN THE EYE OF THE NEEDLE* PERFORMANCE BY (LOVELL, 2000)

Lovell predicted that In the future, these kinds of effects will be accomplished through more intelligent computers in what will become traditionally defined processes. Computer Intelligence, video based sensing, and speech understanding will become mechanisms used by performers and designers, and will find their place as tools of the trade. (Lovell, 2000)

4.4.1.2. DESIGN PARAMETERS FOR INTERACTIVE THEATERS

The multimedia interactive theater design can't be achieved by conventional design approaches anymore such as task analysis, where the designer expects all the tasks the user will need to accomplish and take within a specific context. But in interactive multimedia, which deals with fun and entertainment experience, other techniques should be taken in consideration rather than traditional ones. New technologies for implementing interactive multimedia are still in developing stage. It will need imaginative effort in technology and text to have to have a new method in interactive multimedia implementation. Theater has been through the same phase before while implementing motion pictures on stage one hundred years ago as will be studied in the next chapter. (YILDIZ P. , 2006)

In order to design an interior for an interactive multimedia on stage, the designer should respect the introduction of interactivity on stage. This introduction will lead to two main affections in theater design. First is the implementation of physical ways by which the users will interact and second is introducing interactive prototypes for the domain narrative on stage.

Implementing physical ways for interaction always leads to the change of the architectural interface of the design. As an example, using a touch screen requires an increase in the size of on-screen elements as the active areas need to accommodate the size of a finger rather than the narrow tip of a cursor controlled by a mouse. (YILDIZ P. , 2006) So designers should choose the best physical instrument (input advice) for interaction and study its integration in the interior design (as an example, integrating joystick to audience seats).

Another important issue is the change of the storytelling procedures. The narrative structure in an interactive multimedia which responds to multi changes and inputs from different disciplines, stage or auditorium; stage elements such as video, projection sound or text and audience inputs can't be a linear structure any more as used to be in a traditional theater experience. Filming industries in cinema have gone through interactive multimedia since the first of this century. As shown in **Figure 4.4-5**, industries that were once independent bodies (print, film, and computer), have become integrated into a cohesive media network. (Hilf, 1996). Theater drama is going through the same phase which will lead to look for efficient, alternative methods of communicating the multidimensional appeal of drama. (Yildiz, 2007)

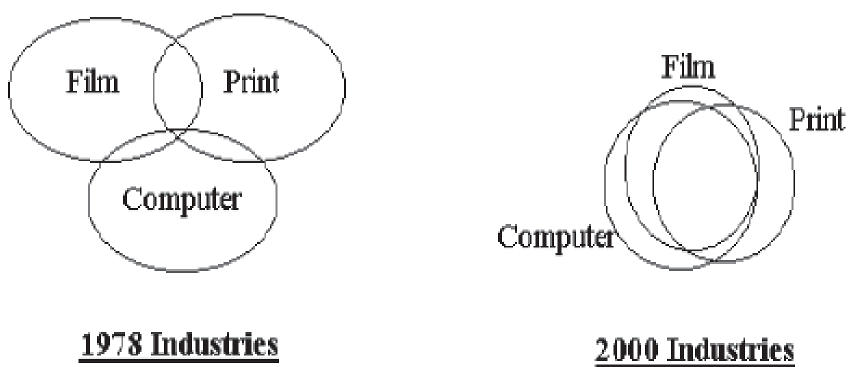
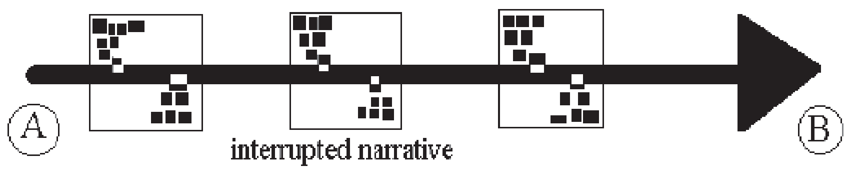
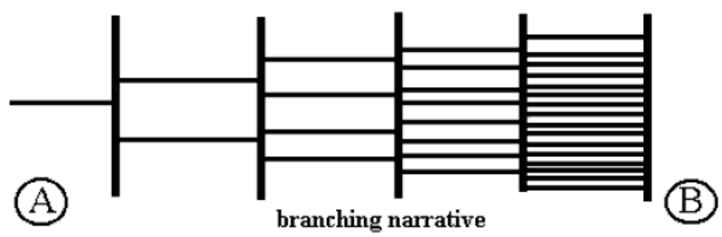
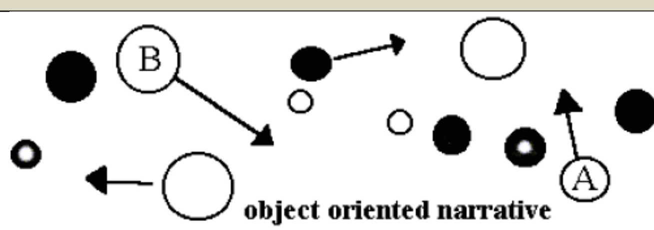


FIGURE 4.4-5: THE OLD AND THE CURRENT FILMING INDUSTRIES BY (HILF, 1996)

In Cinema industry, at first audience should watch a film with only one expected end. But recently many successful innovative films changes their story structure according to the audience votes which lead the audience to be a participant and not only a passive observer. This introduces new narrative interactive prototypes that can be studied to take into consideration while designing an interactive multimedia theater. The following table shows briefly the types of interactive narrative structures presented by Hilf:

Interactive narrative structures
Interrupted narrative

It is the structure of the video game "story" "Interruptions" occur during the story in the form of problems, discovery, tests, probing or examination. These interruptions are both controlled and responsive, thereby changing the next step on the narrative line according to the user's actions. The various elements in the large squares represent possible user actions, while the smaller squares breaching the narrative line represent the action taken.
Branching narrative

It is a revolution of the interrupted narrative structure. It builds different narrative paths once the linear structure is changed. The mathematics of the branching narrative brings up a considerable problem. For example, if the above pattern were followed for a feature film, over twenty-eight variations would have to be offered from the original. This raises issues of storage capacity, cost factors and hardware capability.
Object-oriented narrative


Interactive narrative structures
Object-oriented structures in interactive entertainment are derived from design techniques used in computer programming. It is a method in which a system is modeled as a collection of cooperating objects and individual objects are treated as instances of a class within a class hierarchy. Utilizing independent objects within a specified "hierarchy or environment, offers the advantages of a changeable and fluctuating story within a designed setting. Currently, this structure has only appeared on the Internet, but it is the direction of the interactive narrative media of the future.

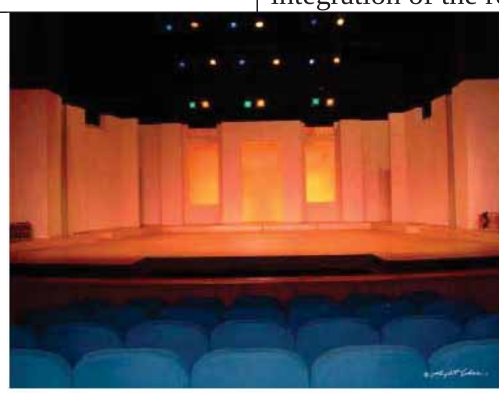
TABLE 4.4-1: TYPE OF INTERACTIVE NARRATIVE STRUCTURES BY (HILF, 1996) & (YILDIZ, 2007)

4.4.2. SUSTAINABILITY IN AUDITORIUM INTERIOR BY MULTIMEDIA

As studied in chapter one, theaters in the Baroque period was known by its highly decorative features, sometimes the auditorium interior was more dominate in the theater experience than the performance on stage. The interior was unsustainable, inflexible and not reusable but in contrary it controls and leads the stage design into limited options. And in the Machine age, more complicated interiors where introduced to the auditorium design. In the beginning of the last century, the modern interior and its simplicity took the lead in the design of many auditoriums that sometimes it was criticized by its poor look and others were described by their high functionality and its harmonization with the new auditorium interior aspects on keeping the focus on the performance stage.

It is supposed that in future, applying multimedia in theater stage will have its own reflections on the design of the interior of the auditorium. A fourth dimension will be given to the interior organization of the auditorium which is time. A synchronization process will be achieved between the multimedia reflections and the auditorium interior. (YILDIZ P. , 2006) The interior design will not be solid and inflexible as used to be in the past, but it will be variable according to the stage performance. The separation between the stage design and the auditorium interior will disappear to achieve high immersion feeling for audience.

Example of sustainable and reusable usage of auditorium and stage presented by Yildiz are the Taksim Auditorium & AKM Auditorium while presenting different plays on the same stage. The following images presents different scenes of the stage and the auditorium while and after the scene.

<table>
<tr><th colspan="2">Taksim Auditorium with the play "Don Kişot"</th></tr>
<tr><td></td><td></td></tr>
<tr><td>The Stage during the performance by virtual means</td><td>The actors also are adapted to the virtual feature of the play by costumes and the interactivity of the space is supplied by the integration of the reel and the virtual.</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">The photo of the Taksim Auditorium without the performance</td></tr>
<tr><th colspan="2">AKM Auditorium with different plays</th></tr>
<tr><td></td><td></td></tr>
<tr><td>The play with a multidimensional space approach again supplied by multimedia database.
The stage is variable accordingly to the reflections through the surfaces of the set by virtual atmosphere.</td><td>Another play in the same auditorium by no reel decoration but supplied by virtual artifacts.
The effects of lighting and multimedia activity is the resonance of a stage by reflected images rather than reel donations</td></tr>
</table>

The photo of the auditorium of *AKM Theater* without the performance

FIGURE 4.4-6: PHOTOS FOR TAKSIM AND AKM AUDITORIUM WITH AND WITHOUT PERFORMANCE BY (YILDIZ, 2007)

By analyzing these samples similarities between the two samples illustrated by Yilidiz are as follow:

- The aesthetical approach of multimedia by live performance activity,
- The virtual effects of stage supplied by multimedia with the lighting, acoustics, the reflected images on the screen, the synchronization of systems in set designing,
- The multidisciplinary artistic team work, etc. The spatial expressions in the reel with virtual artifacts are the contemporary solutions to architectural aspects by variable explorations.

And on studying the interior design of both Auditoriums it seems that plain surfaces without any decorations are the main feature of the spaces. The interior depends mainly on the performance on stage. The reflection visual effects of multimedia on stage is the dominate element in the space with high synchronization between all the reel and virtual images. The space is optimally used, flexible and reusable according to the performance on stage. The balance between virtual and reel should be taken into consideration so as not to result in a synthetic image that is not realistic and may depress the audience. (Yildiz, 2007)

One of the main tools that should be taken into consideration in designing theater spaces in future is the implementing of artificial intelligence in order to enlarge the capacity of the efficiency of the usage. HCI (Human-Computer Interaction) under the basis of spatial organizations can open new directions for designers especially in performance areas in order to achieve the virtual reality in stage design. Multimedia is an important medium in HCI adapted to space designing. So designers should be aware of the facilities of computational intelligence in order to reach more efficient and creative spaces. (Yildiz, 2007)

4.4.3. SUSTAINABILITY IN FLEXIBLE STAGES BY MULTIMEDIA

In flexible theaters stages, Multimedia has a great role in changing the whole interior according to the status of the stage usability. The multiuse theater is the Century Theater. The stage and the auditorium are flexible to be used for different kinds of performances (music, drama, dance and lecturer purposes etc.). Every use should reflect its own atmosphere over the stage and the auditorium. Mechanical methods are used to simply change the stage size and shape, the audience seating and arrangement, the acoustics of the room according to the kind of speech or music in the performance…. etc. But the interior design cannot be easily changed according to the stage usage. The interior organization should have flexible and variable properties for the audience which depends on some elements illustrated by Yildiz as follows:

- Architectural spatial form,
- The flexible and modular donations and elements used for audience seating and stage design,
- The multimedia affection integrated with spatial meanings,
- The quality and the affection of computational intelligence regarding the organization of the whole function as a performance or any activity etc. (YILDIZ P. , 2006)

The sample given for such case by Yildiz is the auditorium of high-tech performance areas having flexible functions and usage ability "*The Istanbul Convention & Exhibition Centre (ICEC)"*. The auditorium of the center is the largest auditorium facility in Turkey with its multidimensional interior organization and high-tech computational intelligence adapted in stage designing and orienting. (YILDIZ P. , 2006)

The stage has different impressions when it is in use with some live performance activity or some different functional requirements. When it is during the activity the atmosphere created captures a virtual ambience and space cumulated around the computational intelligence with the integration of man-machine systems. The synchronization of the scenic requirements is the artificial usage of the technical output with a systematic process. (YILDIZ P. , 2006)

<table>
<tr><th colspan="2">ICEC Center Auditorium</th></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">The Auditorium view</td></tr>
<tr><td colspan="2">The Auditorium has a capacity of 2,000 people seating. The ICEC Complex was also designed to be multidimensional as the speedy usage of the space also to reach the sustainable meaning.</td></tr>
<tr><td colspan="2">I. The different functional usages of the interior based on multimedia affection</td></tr>
<tr><td></td><td></td></tr>
<tr><td>The stage with a musical performance activity.</td><td>The stage with multimedia facilities having a function of presentation during the performance.</td></tr>
</table>

	
The Stage with the function of a contest.	The Stage with presentation facility.
The virtual atmosphere is created by a system synchronization based on color and lighting on the stage also added with music. The synthesis of the desired stage is the product of a whole technical data.	The stage is fully affected under the great reflection of the presenter. This forms the whole stage without any donations and scenic elements. The reflection time on the screen, the acoustics, the lighting and the color is all synchronized to be as one. And the timing property of each of them follows the other as the continuity arises.

II. Elements that supply flexible usage of the interior

The systematically synchronized performance abilities reflecting the image of virtual reality,
The multimedia concerning computational intelligence as the whole system is controlled and directed by technical data which is processing continuously as the performance goes on and on. The maintenance of the programming issue is a coordinating facility before the show starts. The computational coordination is being prepared before all types of functionalities.
The cyclorama and back stage is the most flexible property of the stage as it changes all the atmosphere of the virtual image of the interior

III. Results & Conclusions

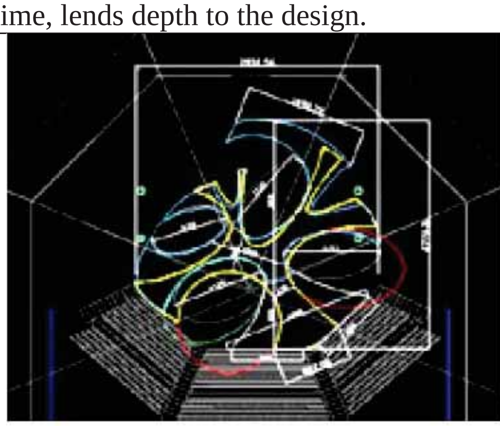
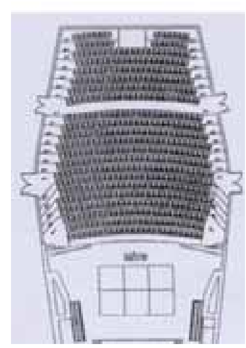
Multimedia is a tool to maintain the systematic synchronization of the stage design of the auditoriums having the capacity to interact the interior with the computational hardware with timing processes in good sequence.
The flexibility of the auditorium interior depends not only the flexibility of the set design decoration or seating capacity but also the variability of the stage by visual means as the changing durations of the color, lighting, the cyclorama, the effects concerning background etc. in conjunction with each other.
The synchronization is the sustainable meaning of any auditorium interior as it is a high-tech reflection of the newly invented with systematic point of view and organization. The contemporary value of the product is the success of the optimal programming ability of the computers dedicated to act as one.

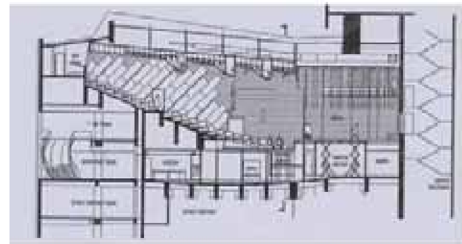
TABLE 4.4-2: THE ICEC COMPLES AUDITURIOM AS AN EXAMPLE OF FLEXIBALE STAGE ILLUSTRATED BY (YILDIZ P. , 2006)

The sustainability of the auditorium indicates the full capacity of the usage of the space all the time with functional requirements. The efficiency supplied by less effort of human-interaction but more with computational programming ability is the reason of the newly invented technological developments in auditorium facilities. (YILDIZ P. , 2006)

4.4.4. THEATER STAGE VS CONCERT STAGE

Yildiz analyzed 2 different Turkish stages to study the affection of Multimedia stage on the auditorium interior. The first presents the theater stage (**Akün Theater in Ankara**) and the other presents the Concert Stage (**Eurovision Song Contest 2004 in Turkey**). The following table presents the comparative analysis between the two examples illustrated by Yilidz:

<table>
<tr><th>Eurovision Song Contest 2004</th><th colspan="2">Akün Theater in Ankara</th></tr>
<tr><th colspan="3">Description</th></tr>
<tr><td>It is a stage design for a competition between 36 stars from various cultures.
The stage design looks like the ‘Hagia Sofia’ (Church of the Divine Wisdom) where the center of the stage is the focus attention: a dome consisting of "minarets of light" frames this structure and, at the same time, lends depth to the design.</td><td colspan="2">It is a multidimensional theater hall that used to be a cinema hall. The interior was completely changed.
The interior carries a function of creating a different atmosphere inside from the outer in order to display a virtual interior.</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>The conceptual framework of the stage.</td><td>The plan with 444 seats</td><td>The plan with 544 seats</td></tr>
</table>

Eurovision Song Contest 2004	**Akün Theater in Ankara**
	
The virtual creation of the stage.	Side view for the theater stage
Interior aspects	
The interior organization finds its real meaning and ambiance during the performance only. The multidimensional digital technical organization declines the reusable space by no time loss and efficiency of manpower but by the help of the digital reflections which is the data of the multimedia structure.	The interior organization has been designed to compensate 4 different spatial characters. The multimedia surrounds the interior atmosphere by the help of the technical disciplines adapted to create a visual effect in the real and dominant architecture.
	 
The interior view without the performance	
	
The interior view with the performance	The Interior view of the theater without the performance
Similarities	

Eurovision Song Contest 2004	**Akün Theater in Ankara**
Both theater and concert hall interiors are places that are reusable and multidimensional. In fact different disciplines come together to create a virtual and relaxing atmosphere. The multimedia affection creates the main structure of both of the auditoriums.	
Differences	
The spatial characters are different in the two samples. 'the Akün Theater' as an interior, is noted for its dominant and more realistic interior while the 'Stage of the Eurovision 2004' is somehow more dominant with its multimedia aspect of the virtually based system. The interior is noted not for its visual features but for the features it gains while a performance is active. This is the main difference of the two places. The multidimensional interior synchronizes the reusability by different conjunctions. In the theater interior multimedia effectiveness is hardly to be recognized by virtual means but in the concert hall this situation is a complex and more technical activity where multimedia is optimal by different parameters. Te concert stage is much more activated by multimedia creators than the theater stage. The optimal criterion in system performance is more dynamic and virtual in concert stage as the meaning of the auditorium is variable in other words the stage has two meanings, during the performance and after the performance. Multimedia effectiveness is hardly to be recognized in theater stage by virtual means. In the theater interior the visual recognition of the inner atmosphere doesn't change that much.	
Conclusion	
The usage of multimedia concerning auditorium interiors should be adapted to studies related with optimization criteria.	

TABLE 4.4-3: COMAPRISON BETWEEN THE MULTIMEDIA AFFECTION ON A THEATER STAGE AND A CONCERT STAGE ILLUSTRATED BY (YILDIZ P. , 2006)

4.5. CONCLUSION

In the last century, theater stages have gone through many complex shapes and machinery for achieving illusionary scenery settings. The fly tower, stage aisles and stage basement became busy places with different equipments and machinery. The backstage have changed to a small factory for producing performance settings with a great loss of material and human effort. Large scale theater productions depended mainly on high consumption of time, money and effort.

The introduction of multimedia on theater stage affected the whole theater experience. It gave powerful tool to theater stage to open a new channel of connection between the actor and the audience in modern theater. Messages are sent to audience not only by realistic images but also with non-realistic ones. The theater has changed from being a tool of imitating the real life inside a box into a communication method to the audience to discuss futuristic issues and dreams, to discuss unrealistic matters that lead to more creativity and innovation. The new theater space should consider the new generation of audience that is no more restricted by the reel around him, but he started to put his own hypotheses and then act as if they are his own virtual reality. In some modern interactive multimedia theater, the audience has changed from being a passive observer into a participant and sometimes an actor on the stage.

Multimedia wasn't restricted only to modern and experimental theaters but also Classical drama theaters gained a new variety of scenery settings. Wooden painted sceneries that used to be stored in the fly towers have been changed to digital back screens on stage. The stage platform was given new properties and flexibility. Complicated sceneries such as lake, golf, forests and others are easily achieved on stage without the need of immersing a tree or even water in the middle of the stage as it used to be in the Baroque period. Another factor has been easily introduced to the theater stage, the weather. Snowy, rainy or even windy weathers, as those in Shakespeare novels, were easily presented on stage by multimedia affections.

The main concern in using multimedia on stage is the balance between reel and virtual so as not to have a disappointing image on stage. Also the synchronization between different elements on stage and multimedia as all should have one reference in space and time. Also the relation between the auditorium and stage should be well studied as multimedia has a great reflection on auditorium design and interior.

5. CHAPTER (5): VR APPLICATIONS IN THEATRICAL FIELD

According to Mark Reaney, "***Theater is the original virtual reality machine.***" He described the theatrical experience as visiting imaginary, interactive and immersive worlds. He also noted other similarities between theater and computers:"*Both offer fleeting, metaphysical experiences. Both create fictive worlds in which intangible concepts can be given perceptible form."* So due to such similarities, it worse to consider Computer-based VR is going to be a strong ally for the theater production in future. (Reaney, 1995). As for Dixon, He considered:" *The conjunction of VR (Virtual reality) technologies with theater and performance appears to be a marriage made in heaven.*" He noted that VR technology can enrich the theater experience by ideal technological medium with four main fundamentals elements: ***"visual spectacle***", "***imaginary worlds"*** and "***transformative spaces"***, and ***"audience immersion"***. (Dixon, 2006)

In fact, the enhancing of Virtual Reality technology in theater space is still under development although its extraordinary potentials. (Dixon, 2006) But still there are remarkable applications that can be studied with this newly invention in different theatrical fields. The criteria of choosing such applications will be through a notable taxonomy presented by Schrum of digital performance as in **Figure 4.5-1**. In this taxonomy, Schrum presented a continuum for digital theater starting from one end by the traditional theater that doesn't enhance any digital technology and the other end by a futuristic form of interactive holographic theater space that is totally virtual.

Due to the objective of this study, which is studying the effect of implementing Virtual Reality in theater spaces architecture and interior, the theaters that will be concerned in such taxonomy is the real physical theaters. So the last two types; "**Computer mediated performance"** and **"Interactive Holographic Theater"** are not going to be studied in the next presented applications and case studies. Also the third type **"Digitally Assisted Theater"** will be excluded as it doesn't enhance Virtual Reality Technology.

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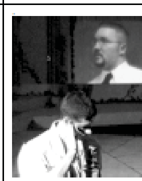
TRADITIONAL	DIGITALLY - AIDED THEATRE	DIGITALLY ASSISTED THEATRE	MULTIMEDIA THEATRE	DIGITALLY ENHANCED THEATRE	CYBER-ADAPTED THEATRE	COMPUTER-MEDIATED PERFORMANCE Performance happens through the computer screen. Interactivity limited to preprogrammed responses. Responses may not influence or be perceived by performers		"INTERACTIVE HOLOGRAPHIC THEATRE"
Production methods that do not include any digital technology.	Production methods include technology, but for pre-production; includes computer-aided design for sets and lights, digital audio production, electronic communication Example: Studio Z's Monologue Show (1995): distant playwrights communicate with directors and actors; event is staged live.	Technical elements are designed with or supplied by digital technology and are noticeably part of the performance Includes computerized light board, digital sound elements (designed, recorded, and played back), projections; these could be done by analog methods but work better with digital. Example: A 15-minute sunrise light cue.	Use of technology (though not necessarily digital) as part of the performance, in service to the play/production Example: In *Medea*, a reporter does a lead-in to a video clip of Jason speaking. (Performed at Pitt-Greensburg, March 2006.)	Technical elements are designed with or supplied by digital technology and are part of the performance; Effects are produced live or "rendered in real time" (Dixon, 385) rather than canned, pre-recorded, or preset; Suggests interaction between technicians, actors and/or the technology. Example: ieVR's *The Adding Machine* (1995; (Image from the Digital Performance Archive.)	Plays about cyberspace subjects; performed in Real Life (RL)	**RL-ADAPTED PERFORMANCE** Plays about Real Life (RL); performed in cyberspace *Example:* *The Perm*, by Zayante Hegel, directed by Phorkyad Acropolis, (performed in Second Life July 13 and 14, 2007).	**CYBERSPACE PERFORMANCE** Plays created and set in cyberspace; performed in cyberspace Examples: *NetSeduction* by Stephen Schrum, (performed in ATHEMOO in 1996), *Gestus*, conceived by Stephen Schrum (to be performed in Second Life, August 2007.)	Full immersion in a virtual world Full interaction with characters and objects The use of the quotation marks indicates that it is something we don't yet have….
						Note the change in nomenclature from "theatre" to "performance" as we move to computer-mediation. As we traditionally define theatre, the interaction between an actor and an audience, what we present online is not theatre, although it may be performance. However, if the virtual performance created by the interaction between performer and the audience can be made "real" (given the imagination and wiling suspension of the spectator), perhaps we need to expand out traditional definition of theatre, and can then create theatre (more than simply performance) in online and cyberspace venues.		
								

FIGURE 4.5-1: SCHRUM'S TAXONOMY OF DIGITAT PERFORMANCE (DIXON, 2007)

The rest five theaters are concerned in this study. The **"Traditional Theater"** has been studied in details in the first three chapters and will be considered a comparative base for the chosen case studies later. The history and development of **"Multimedia Theater"** was presented in the last chapter and a suggested prototype was studied.

In this chapter, the study will be focused in presenting different applications of enhancing Virtual Reality technology in three different theater types presented in such taxonomy as follows:

- **"Digitally-Aided Theater":** Different applications of implementing Virtual Reality will be studied in different theatrical fields. Virtual reality can be implemented in the theater production through different phases and industries. In this study, two applications will be studied through applying virtual reality in **"theater education"** and "**stage planning and design"**.
- "**Digitally-Enhanced Theater**": it will be divided into 2 fields. The first one is Enhancing of Virtual reality technology on theater stage in a **traditional performance**. Applications will be given to different types of theater stages. The second one is the free untraditional stages that can be created by enhancing virtual Reality. An application will be given for enhancing Virtual Reality in **non-traditional performance** on a free stage space.
- "**Cyber-Adapted Theater"**: This theater type is considered a development of film theater stages. Applications will be given concerning the enhancing of virtual reality as a main scenographic tool that transfers the whole space into cyber space.

In the next chapter two case studies will be studied concerning "**Digitally-Enhanced Theater**" and "**Cyber-Adapted Theater**". The first Case study presents the enhancing of Virtual reality technology on theater stage in a **traditional performance** with comparison to the original one in a "**Traditional Theater**". The Second case study is for presenting the "**Cyber Adapted Theater".** This case study is a comparison between three degrees of enveloping of the stage to the audience which presents a negative feature for the "**Traditional Theater**" as it was classified in the first chapter into three degrees of envelopment from the auditorium to the stage.

Before studying the applications of virtual reality in different theatrical fields a brief introduction will be presented for introducing virtual reality.

5.1. BRIEF INTRODUCTION TO VIRTUAL REALITY

In the beginning of the 21st Century, a new shift has been taken into the theatrical experience. A new technology approach was introduced into many industries giving more possibilities than those that have been given by applying conventional computer technologies. In the last chapter, the effect of introducing multimedia on stage on the theatrical space was studied mainly in terms of replacing complexity of stage machinery and technology into more practical and flexible stages. The introduction of virtual reality in the theatrical experience didn't only have its input on stage but also in different theatrical fields as will be studied in details later in this chapter.

5.1.1. MULTIMEDIA VS VIRTUAL REALITY

According to Nadja Masura's PHD thesis in "Digital Theater", virtual reality can be considered a subset of Digital Theater (another term for Multimedia Theater). She defined Digital Theater as "*a term can relate to performances which utilize a large range of technologies and their multiple uses, including but not limited to: digital video, digital projection, animated sets and characters, virtual reality ….. and many other forms of digital media interplay*." (Masura, 2007). The main reason of choosing virtual reality in this study as a main element on theater stage is its different potentials compared to Multimedia and sometimes other conventional means in the theatrical production within different approaches. These approaches can be categorized as follows:

5.1.1.1. MODELING POTENTIAL

Recently, virtual reality became a very creative tool specially in modeling field. It gives higher options for the user to examine the model than physical prototypes. In theater field, it is used to examine the stage scenes, lighting affects and even acoustics quality as will be shown later in this study. The following table describes the difference between using VR and other means for modeling:

	Realism	Interactivity	Marginal Cost
Handmade physical prototype	Very high	Very low	Very high
Machine-made physical prototype	Very high	Low	High
Computer-aided design	Low	High	Low
Animation/ multimedia	Low	Low	Low
Virtual reality	High	High	Low

TABLE 5.1-1: CHARACTERISTICS OF VR AND OTHER TECHNOLOGIES (TIM WATTS, G.M. PETER SWANN, NARESH R. PANDIT, 1998, P. 3)

VR also provides the user with special capabilities that can hardly be achieved by any other means. According to Tim Watts & G.M. peter Swann, It offers special characteristics to the modeling experience that will briefly highlighted in table below:

	VR modeling characteristics
Capacity to Experiment	VR enables greater experimentation with new products, services and processes prior to large-scale commitment.
Involving all	VR makes it easier to involve different groups of staff in the innovative process.
Capturing Ideas	Because it can be used interactively, VR can be used to capture ideas generated during the innovation process.
Data Visualization	VR technology can improve the way we handle information because of its capacity to increase information absorption by presenting it in a more intuitive fashion.
Facilitating Communication	VR has the potential to promote easy comprehension and therefore to facilitate better communication across functional and professional boundaries.

TABLE 5.1-2: MODELING CHARACTERISTICS OF VR ILLUSTRATED BY (TIM WATTS, G.M. PETER SWANN, NARESH R. PANDIT, 1998)

5.1.1.2. **STEREOSCOPIC VISION**

VR technology depends on presenting a stereoscopic vision rather than a monoscopic one as in other conventional computer and multimedia tools. (Morad, 2003). This potential is very essential on theater stage and the history of its development will be studied later. The need for such vision is to present more realistic scenes on stage especially for traditional and classical performances. This stereoscopic image still has its own limitation as it can't be presented except through wearing special kinds of glasses or head mounted displays that sometimes disappoint the audience in his theatrical experience.

5.1.1.3. **REAL TIME RENDERING**

According to the "Proposed Taxonomy of Digital Performance" by Schrum 2007, one of the main factors that differentiate between "Multimedia Theater" and "Digitally Enhanced Theater" is that stage effects are produced in the second live or “rendered in real time” rather than canned, pre-recorded, or preset in the first one. Also he suggested another factor is adding the interaction between technicians, actors and/or the technology. The implementation of VR technology on theater stage added another main potential which is the real time rendering live on the stage during the performance which is considered a main difference between Multimedia and VR.

5.1.1.4. **THE INTERFACE OF INTERACTIVE MULTIMEDIA AND VIRTUAL REAITY**

Another potential of using VR technology in theater is the disappearance of its interface into the context as presented by the continuum of interface by Hedberg and Alexander as seen in **Figure 5.1-1**. This continuum shows the point where a complete shift exists in the interface between VR and Interactive Multimedia (IMM) (Morad, 2003). As studied in the last chapter, the main display screens onstage in the multimedia theater were the cyclorama and the movable digital scenic projections screens. The cyclorama, as example, took many forms according to the kind of performance on stage but in the end it is still controlled by the backstage input. In contract, as going to be studied later, implementation of VR in many theatrical applications led the output generated data to be manipulated by the user directly (by voice commands as example) which doesn't need a high specified awareness by the user for the technical application interface.

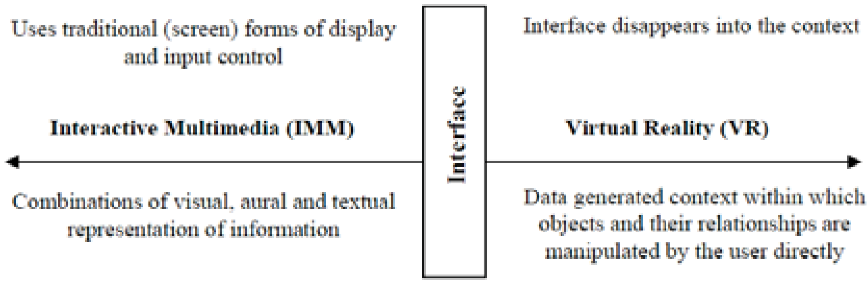


FIGURE 5.1-1: THE RELATIONSHIP OF INTERFACE BETWEEN VR AND IMM BY (MORAD, 2003)

5.1.2. DEFINITION & MIAN CHARACTARISTICS

The term Virtual Reality is considered a very recent term. It was first coined by Jaron Lanier, CEO of VPL, in 1989. Before 1989, different terms as virtual worlds, virtual cockpits, and virtual workstations were used to describe specific projects. By this term, all the virtual projects were brought under a single rubric. (Krueger, 1991, p. xiii)(Steuer, 1992). Since then, there are different points of view in defining such term. In this study, two points of view will be discussed; according to the **technological hardware aspects** and **human experience**.

In the 90's, it was defined at first according to the technological hardware used at that time. In 1992, Coates states that virtual reality is "**an electronic simulation of environments experienced via head-mounted eye goggles and wired clothing enabling the end user to interact in realistic three-dimensional situations**" (Coates, 1992), and Greenbaum defines VR as "**an alternate world filled with computer-generated images that respond to human movements. These simulated environments are usually visited with the aid of an expensive data suit which features stereophonic video goggles and fiber-optic data gloves**" (Greenbaum, 1992) (Steuer, 1992), both quotations thus stressing on the revolutionary **technological hardware** aspects of VR. (Morad, 2003).

But today, Virtual Reality isn't achieved mostly without head- mounted displays, by using large projection screens or desk-top PC's. Similarly, gloves can be replaced with much simpler trackballs or joysticks. Therefore describing Virtual reality in terms of the devices it uses is not an adequate definition. (Grigore Burdea, Philippe Coiffet, 2004)

Through the last 2 decades, definitions were given to virtual reality term due to human experience rather than the devices used. The concepts of **immersion, presence, and interaction** are important in understanding the physical and psychological experience of users in VR.(Francisco Rebelo, Emília Duarte, Paulo Noriega, Marcelo M. Soares, 2011)It is important to understand the definition of each term in order to study the link between them and the definition of virtual reality.

> **Immersion:** “The feeling of presence, of "being there", surrounded by space and capable of interacting with all available objects” (INTUITION Virtual Reality, 2005)
>
> **Presence:** "The sense of being in an environment." (Steuer, 1992)**.**
>
> **Interactivity:** "The extent to which users can participate in modifying the form and content of a mediated environment in real time." (Steuer, 1992)

In this study, a more general definition presented by Unabridged will be taken into consideration to avoid any elimination for vital features of virtual reality. So Virtual Reality is defined as: *"**A realistic simulation of an environment, including three-dimensional graphics, by a computer system using interactive software and hardware.**"* (virtual reality. (n.d.). , 2011). This will lead the introduction of Virtual Reality in the next section in terms of its components; hardware and software components.

5.1.2.1. **MAIN CHARACTERISTICS OF VIRTUAL REALITY (I'S OF VR)**

It is important to understand the main characteristics of Virtual Reality to differ it from any other kind of media. In 1993, Burdea introduced the three I's of Virtual Reality. Virtual reality is an integrated trio of **Immersion-Interaction-Imagination** as shown in **Figure 5.1-2**. (Grigore Burdea, Philippe Coiffet, 2004).While M. Heim stated that the there "I's", **Immersion**, **Interactivity** and **Information Intensity**. (Heim, 1998), (Furht, 2008) But Sherman and Judkins described the most significant characteristics for virtual reality by what is known as “VR five ‘I’s”: **Intensive**, **Interactive**, **Immersive**, **Illustrative** and **Intuitive**. (Barrie Sherman, Phillip Judkins, 1992), (Morad, 2003)

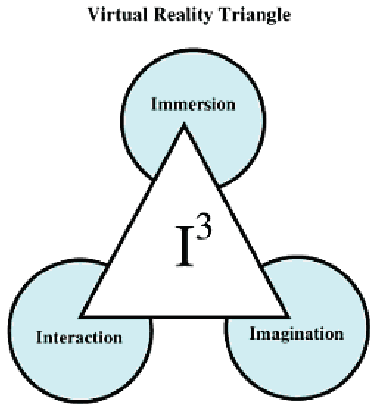


FIGURE 5.1-2: THETHREE I'S OF VIRTUAL REALITY (GRIGORE BURDEA, PHILIPPE COIFFET, 2004)

The following table is to summarize the I's of virtual reality with simple description of each characteristic:

	I's of VR description
Immersion	Immersion comes from devises that isolate the senses sufficiency to make a person feel transported to another place.
Interactivity	Interactivity comes from the computer's lighting ability to change the screen's point of view as fast as the human organism can alter his or her physical position and perspective.
Intensive	In virtual reality, the user should be concentrating on multiple, vital information, to which the user will respond.
Illustrative	Virtual reality should offer information in a clear, descriptive and (hopefully) illuminating way.
Intuitive	Virtual information should be **easily perceived**. Virtual tools should be used in a “human” way.
Imagination	The extent, to which a simulation performs well, depends very much on the human imagination. It also refers to the mind capacity to perceive non exist things.

TABLE 5.1-3: THE DESCRIPTION OF VR I'S ILLUSTRATED BY (GRIGORE BURDEA, PHILIPPE COIFFET, 2004) (WILLIAM R. SHERMAN, ALAN B. CRAIG, 2003) (MORAD, 2003) & (FURHT, 2008)

5.1.2.2. THE REALITY-VIRTUALITY CONTINUUM

In 1994, Kishino and Milgram represented "A Taxonomy of Mixed Reality Visual Displays" They noted that:" Mixed Reality (MR) visual displays is a subset of Virtual Reality that involves the merging of real and virtual worlds somewhere along the “virtuality continuum” as in **Figure 5.1-3** which connects completely real environments to completely virtual ones." (Kishino, F. & Milgram, P., 1994). In this continuum, one goes from reality alone to augmented reality (See See-Through) to Augmented Virtuality (displaying real objects in a computer-generated world) to pure VR.

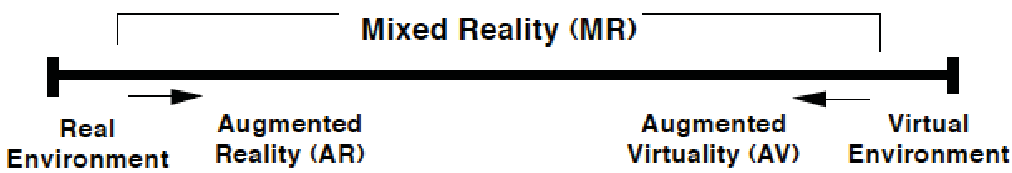


FIGURE 5.1-3: REPRESENTING VR ON THE REALITY-VIRTUALITY CONTINUUM BY (KISHINO, F. & MILGRAM, P., 1994)

Mixed reality will be implemented in many theatrical applications studied in the next two chapters such as stage planning before the performance and as a main senographic tool on stage. It is important to study such continuum and understand the difference between each of its terms illustrated by (INTUITION Virtual Reality, 2005):

- **Reality (IRL)** The meat world, with real persons, in realtime.
- **Augmented Reality (AR):** "This is a twist on VR, with the use of transparent displays (see See-Through) worn as glasses on which data can be projected. This allows someone to repair a real piece of equipment, for example, and have the needed VR data displayed on the glasses while walking about in the real world."
- **Augmented Virtuality (AV):** "This is similar to Augmented Reality. With augmented virtuality, most of the imagery is computer-generated. For example, you might see something real, perhaps even yourself, projected into an imaginary environment."
- **Virtual Reality (VR):** "An immersive, interactive simulation of realistic or imaginary environments. With VR, a human operator can perceive and interact with numerical data in a virtual world by means of computerized systems"
- **Mixed Reality (MR):** "A continuum defined as a combination of the real environment (as perceived by humans) and a virtual environment (created by computer)."

5.1.3. HISTORY OF VIRTUAL REALITY IN PERFORMANCE

The history of virtual reality in performance can be divided into three main phases. First is the history of creating Stereoscopic images on stage, second is studying the roots of VR starting from the Sensorama until developing full Virtual Reality system and finally giving a brief history to show how artists were interested in presenting new interactive image presentations by using virtual reality.

5.1.3.1. HISTORY OF CREATING STEREOSCOPIC IMAGE ON STAGE

The "illusion" on theater stage has taken further steps in the first of the 20th Century. It started by the invention of the stereoscope in 1838 by Charles Wheatstone where a binocular image is received through looking into two eyeglasses to give a combination of two images from different point of view for each eye. Also modern painters had this desire "*to be in the picture*" by creating ‘‘the illusion of a single continuous canvas’’. Between 1915 and 1917, Claude Monet painted a complete panoramic view of Monet’s water lily lake which led its audience to feel "submerged" in a lake which developed later into 360 degree image. (Grau, 2003)

In the first of 18th century the desire to "be in the picture" appeared on the traditional theater stage. In 1915, the futurist Prampolini in his manifesto on Futurist scenography called for a new vision for theater stage to remove the boundaries between the audience and the image space. He called for the immediate and radical removal of all static, painted scenery and its replacement by dynamic electromechanical scenic architecture of luminous plastic elements in motion. And in 1924, he called for "polydimensional Futurist stage" by giving the traditional box shape stage a "spherical expansion". (Grau, 2003) This conception shared resonances with Walter Gropius’ vision of a Synthetic Total Theater, an unrealized project designed for Erwin Piscator in 1926 to coordinate complex arrangements of projections and light sequences. (Darroch, 2008) That was achieved by twelve surrounding screens placed between columns so the audiences are surrounded with light performance as seen in **Figure 5.1-4**. Also the seating can be transformed into three arrangements; the center section rotates for deep stage, proscenium stage, and center stage configurations. (Kram, 1998)

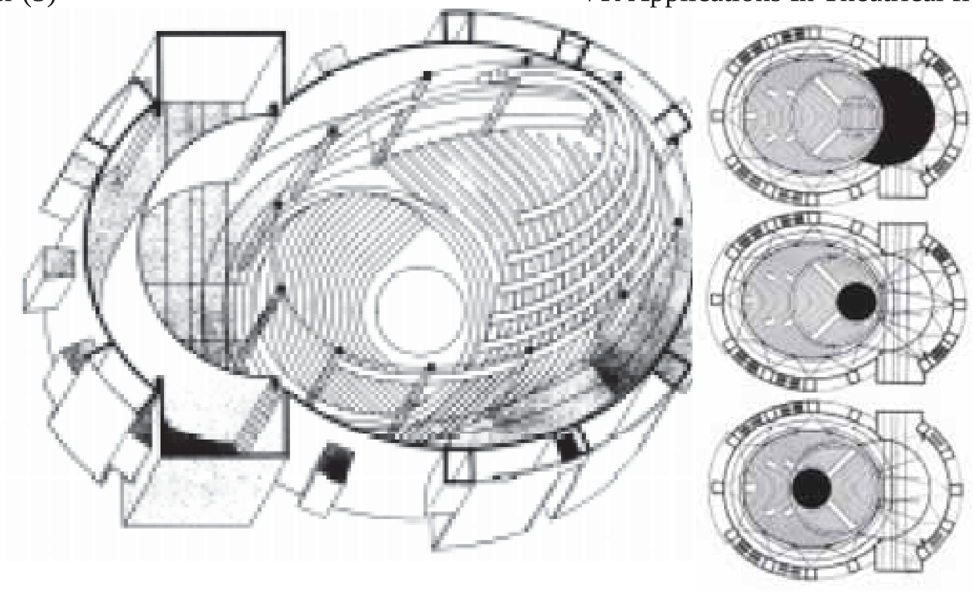


FIGURE 5.1-4: THE TOTAL THEATER BY WALTER GROPIUS. RIGHT: VIEW FROM TOP. LEFT: DIFFERENT STAGE ARRANGEMENTS

In the beginning of the 20th century the spectroscopic image entered the cinema industries having a great influence in the development of film theater spaces. It was first presented in 1900 World Exhibition in Paris, the Cine´orama, a hybrid medium where ten 70mm films were projected simultaneously to form a connected 360 degree image. And in the New York "Futurama", in 1939 World’s Fair, visitors sat in darkened cabins, arranged in a circle and hanging several meters above the stereotyped image of urbanity city model as in **Figure 5.1-5**.

FIGURE 5.1-5: FUTURAMA, 1939 WORLD’S FAIR, NEW YORK BY (GRAU, 2003)

The introduction of 3D films to the United States was presented by *Teleview* in 1912, where the audiences wear colored glasses to watch colorful light projections. Since then there were many trials for expanding the Silver Screen in the United States. One of the leading trials is Fred Waller’s Cinerama, with its 180 degree screen. Compared to the 360 degree panorama, the Cinerama presented a step backward in immersion although it is commercially successful at that time. (Grau, 2003)

The Cinerama works by three cameras, shooting from slightly different angles, were used to film each scene in a Cinerama movie. The film was then synchronized and projected onto three large screens that curved inward, wrapping around the audience's peripheral visual field. (Packer, 1999) Cinerama occupies a paradigmatic place within successful 3-D entertainment cinema of the 1950s and 1960s. (Grau, 2003) Cinerama's today technology proved too costly to be embraced by most commercial theaters, but the theory of visual immersion became an important VR element.

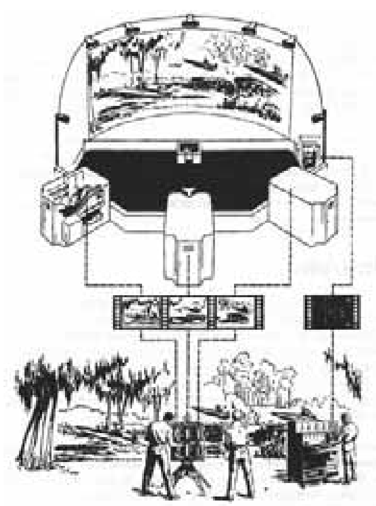


FIGURE 5.1-6: ILLUSTRATION TO SHOW HOW CINERAMA WORKS BY (PACKER, 1999)

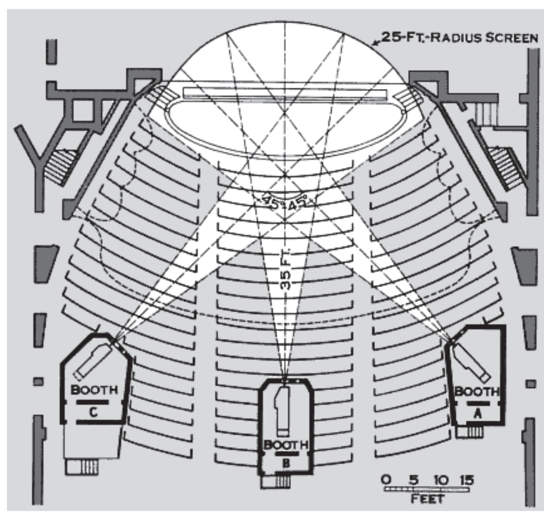


Figure 5.1-7: This illustration describes the projector configuration for theaters equipped to display Cinerama™ FILMS BY (WIKIPEDIA, 2006)

5.1.3.2. THE BEGINNING OF VIRTUAL REALITY

Being excited by the idea of Cinerama, in 1962 Morton Heilig invented “Sensorama” which he called "Experience Theater." It was a multisensory vehicle simulator. The system allowed users to sit in front of a screen where they could choose from different rides prerecorded using motorcycles, bicycles, and even a helicopter. It used wide field of view optics to view 3D photographic slides and had stereo sound, as well as smells and wind generators. The system had almost no interactivity; the user was a passive observer. (Gutiérrez, M.A., Vexo, F., and Thalmann, D., 2008)

At the beginning, the introduction of Virtual Realty Technology in industrial life was for modeling, planning and practicing purposes. The main issue is to substitute expensive simulators or models for trainees or designers by creating virtual worlds that a user can easily travel into it and discover. This trip was first produced by Ivan Sutherland in 1963 with HMD (Head mounted display) by inserting 2 displays in front of each eye which let the user travel into the virtual world using his sight and hearing senses as if he was in a dream. This HMD was developed to produce the correct image for the virtual world whenever the users rotate his head. At that time the weight of the HMD was too much to bear without some additional support.

The GROPE project in 1967 was the first prototype of a force-feedback system between virtual objects (the molecules) by adding a haptic interface for molecular forces. (Mario Arturo Gutiérrez Alonso, Frédéric Vexo, Daniel Thalmann, 2008). The next development in 1984 was by Jaron Lanier. He added the touching sense for the real physical user by inventing a Data Glove that can highly track the hand movements and interpret it inside the virtual world. This led the user feel more immersed and can interact by any abject inside the virtual world he is looking at.

Jaron Lanier also invented the data suit later in 1991 as a full body version of the data glove. Adapted DataSuits soon allowed for fully sensory and tactile effects, with wearers able to transmit and receive ‘telecaresses’. (Dixon, 2006) This invention was a lead in the history of virtual reality in theatrical performance, especially after the ability of introducing multi-user system in the same virtual world. A group of dancers in different physical worlds, for example, can now practice together inside one virtual world without being in the same physical place.

The first Real and complete VR system included input and output devices, tracking system and VR software was the Virtual Interface Environment Workstation (VIEW) in 1985 by Scott Fisher. The VIEW system consisted of a wide-angle stereoscopic display unit, glove-like devices for multiple degrees-of freedom tactile input, speech-recognition technology, gesture-tracking devices, 3D audio, speech synthesis, computer graphics, and video image generation equipment. (Mario Arturo Gutiérrez Alonso, Frédéric Vexo, Daniel Thalmann, 2008).

Another form of complete virtual reality system is developing the CAVE (cave automatic virtual environment) by Daniel Sandin and Thomas DiFanti in the 1990's. It uses immersive projections onto three walls and the floor of a small space, which dispenses with the need for HMDs, although stereoscopic glasses are worn. Users commonly operate a mouse ‘wand’ to manipulate the environment, and a ‘head tracker’ detects the user’s changing spatial position and angle of point of view, prompting the software to display realistically changing perspectives. (Dixon, 2006)

Largely because of cost, relatively few art and performance projects have taken advantage of the rich potentials the environment affords, with notable exceptions (Dixon, 2006) ConFIGURING the CAVE (1996, Jeffrey Shaw will be given as an example later.

5.1.3.3. THE INTRODUCTION OF VIRTUAL REALITY IN ART

The idea of discovering and experimenting new imaginary and virtual artistic worlds excited many futurist artists in the last 2 decades. There are many notable VR experiences using VR installations that led later to the entrance of virtual reality in theater performance. See (Appendix B: The history of VR in ART)

5.1.4. COMPANENTS OF VIRTUAL REALITY

Hardware and **Software** is the main components of any virtual reality experience. It is important to study the hardware components to understand the physical demands needed to be achieved in the physical built environment of the VR system. Software components will briefly studied later in to order to follow up how a VR system works.

5.1.4.1. HARDWARE COMPONENTS

The Hardware components in any VR system can be simply divided into input and output devices as shown in **Figure 5.1-8**. The Input devices are divided into tracking systems, where the user's position is tracked by the system to update the data received by the user in real time according to his new position and also other interactive input devices where the user gives his input to interact in real-time. The output devices are the displays (visual, aural and haptic). These are the channels where the user receives the VR experience according to the degree of immersion needed.

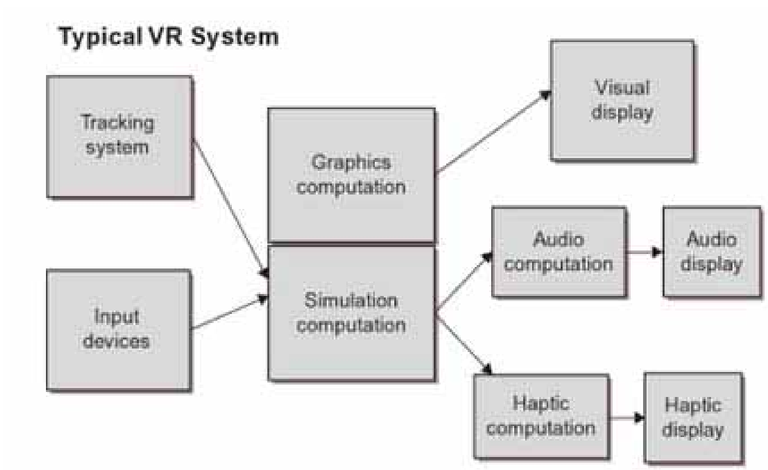


FIGURE 5.1-8: DIAGRAM ILLUSTRATES HOW THE VARIOUS COMPONENTES ARE INTEGRATED IN A TYPICAL VR SYSTEM (ALAN B. CRAIG, WILLIAM R. SHERMAN, JEFFREY D. WILL, 2009)

IV. Input devices

They are used to interact with the virtual environment and objects within the virtual environment. Examples are joystick (wand), instrumented glove, keyboard, voice recognition etc.

V. Tracking System

The tracking devices are the main components for the VR systems. They interact with the system's processing unit. This relays to the system the orientation of the user's point of view. In systems which let a user to roam around within a physical space, the locality of the person can be detected with the help of trackers, along with his direction and speed. (Virtual Reality Tracking Systems, 2009). They are categorized into Electromagnetic, Mechanical, Ultrasonic, Optical, Video metric, Internal and Muscular tracking systems. See also Appendix C: Brief description for different types of Body tracking systems

VI. Visual Displays

The visual display portion of a virtual reality display generally has the most influence on the overall design on the virtual reality system. This influence is due to the visual system being the predominate means of communication for most people. It also tends to dominate how a VR system is defined; including which display paradigm is implemented. (Alan B. Craig, William R. Sherman, Jeffrey D. Will, 2009)

- According to Alan B. Craig, William R. Sherman & Jeffrey D. Will, the main visual displays of virtual reality are categorized to:
- Stationary displays: (Monitor-based /Fish tank) & (Projected-Based/Large screens).
- Head-based displays.
- Hand-based displays.

Also See Appendix D: Brief description for Visual displays.

VII. Aural Displays

Virtual worlds are often represented as 3D environments, so it is important that the sound in that space also have a 3D character. In the real world, we are surrounded by sounds on all sides, and those sounds aid us in understanding the nature of the environment we are in. (William R. Sherman, Alan B. Craig, 2003)

FIGURE 5.1-9: EXAMPLE OF LOUDSPEAKERS IN VR SYSTEM BY (MARIO ARTURO GUTIÉRREZ ALONSO, FRÉDÉRIC VEXO, DANIEL THALMANN, 2008)

The Aural displays are mainly divided into two types, **Stationary aural display (speakers)** (see **Figure 5.1-9**) and **Head-based aural display (headphones)**. Choosing the proper aural display for the VR system is according to aural presentation properties. The following table is a brief comparison between both aural displays to understand the difference between them:

		Stationary Aural Displays / Speakers	**Head-based Aural Displays/ Headphones**
Aural Presentation Properties	Number of display channels	Stereophonic sound should be provided to the Speakers relative to the user position. (Tracking system should be connected to the user)	Stereophonic headphones can be used to provide different information for each ear.
	Sound stage	Does not require sound processing to create a world-referenced sound stage (i.e., one that remains stable to the virtual world)	Require sound processing to create a world-referenced sound stage
	Localization	More difficult to implement spatialized 3D sound fields	Easier to implement spatialized 3D sound fields
	Masking	Doesn't mask real-world noise	Masks real-world noise
	Amplification	Needs more powerful amplifiers. Multiple amplifiers are used for large number of speakers	Needs less powerful amplifier

TABLE 5.1-4: COMPARISON BETWEEN LOUDSPEAKERS AND HEADPHONES AURAL DISPLAYS ILLUSTRATED BY (WILLIAM R. SHERMAN, ALAN B. CRAIG, 2003)

VIII. HAPTIC DISPLAYS

Haptic displays relate to the sense of touch. However, not all of the haptic sensations come via the skin. Some of what is called “haptic display” is related to the muscular and skeletal systems. Therefore, haptic displays are generally discussed in the two component terms according to . (Alan B. Craig, William R. Sherman, Jeffrey D. Will, 2009):

- **“Tactile”** (input through the skin).
- **“Proprioceptic”** (input through the muscular and skeletal systems).

The Haptic displays are not spread used in VR experiences. They are used in very special VR application where the need of feeling the force especially on fingers is needed such as in surgery training. Another feature about haptic displays that some of them are already used as input devices such as the Data glove where it is used interactive input device and in the same time transfer force to the user's hand to feel the objects in the virtual world.

According to (William R. Sherman, Alan B. Craig, 2003), they categorized Haptic displays into 4 categories which are described briefly below:

- **Tactile displays** provide information to the user in response to touching, grasping, feeling surface textures, or sensing the temperature of an object.
- **End-effector displays** (including locomotive displays) provide a means to simulate grasping and probing objects. These displays provide resistance and pressure to achieve these effects.
- **Robotically operated shape displays** use robots to present physical objects to the user's fingertips or to a fingertip surrogate. These displays provide information about shape, texture, and location to the user.
- **3D Hardcopy** is the automated creation of physical models based on computer models, which provides a haptic and visual representation of an object. Since the model is a static object, it functions only as an output system.

5.1.4.2. SOFTWARE COMPONENTS

A variety of software components must be integrated to enable cogent VR experiences. Such software ranges from low-level libraries for simulating events, rendering display imagery, interfacing with I/O devices, and creating and altering object descriptions, to completely encapsulated “turnkey” systems that allow one to begin running an immersive experience with no programming effort. (Alan B. Craig, William R. Sherman, Jeffrey D. Will, 2009)

5.2. DIGITALLY-AIDED THEATER: VR IN THEATER PRE-PRODUCTION

5.2.1. THEATER EDUCATION

"In the field of theater studies, there is a range of software- and online-based projects that offer a unique opportunity to experience new forms of theater, entertainment and culture through an amalgamation of virtual reality, installation and performance. Some of them aim to provide new user-friendly ways of accessing media databases of our cultural heritage and build upon traditional research and teaching methods. Others employ VR techniques to expand the definition of traditional performance space, sometimes suggesting certain ways and contexts to replace the embodied sites with virtual ones, in order to introduce learners to the spatial and mechanical aspects of theatrical space. These projects aim to evoke new associations, meanings and values that could fundamentally reshape the conventional construction of theatrical and art venues." (Kuksa, 2008)

In this section, applications of implementing virtual reality in theater education will be divided into 2 main categories, first the reconstruction of theater heritage and second studying theatrical elements on stage. There are many online applications for both, but in this study one application is chosen with reference to its popularity and success in the field of theater studies.

5.2.1.1. RECONSTRUCTION OF HERITAGE THEATERS RECONSTRUCTION

The main objective of using VR modeling in theater history education is to provide the students with great variety of scholarly materials, and in the same time offer them an interactive exploration in a virtual environment. In this case, students will have alternative choices in the way they confront such historical data rather than those offered by conventional means of education. It also gives the students an opportunity to interpret many destroyed and lost theaters in a very feasible way. (Kuksa, 2008)

One of the applications that had a great popularity in the theater education field is the THEATRON project which will be studied later in details. It is important to note here that this application was applied in this study in understanding the history of the main millstones in European theater development. The theaters that was studied are the Greek Epidaurus amphitheater, Globe Shakespeare Theater in London, , Odeon of Agrippa at Athens in Greece, Teatro Olimpico in Vicenza, Sabbioneta Theater, Theatro Farnese, Theatro Alla Scalla in Italy and Festspielhaus Bayreuth in Germany. It gave another layer for analyzing such theaters in a deeper content by visiting them virtual and having the chance to explore many of the gathered historical data about such theaters.

I. The Development of Scenic Spectacle

It is a site devoted to the Study of Renaissance & Baroque Theatrical Spectacle. This website contains computer models and animations of theatrical scenic spectacle of the 16th, 17th, and 18th centuries. Besides providing excellent visual illustrations of theatrical machinery, the site also explains the computer modeling process and has scholarly references for researchers and students who want to find more information. (Mohler, 2005) Applying it in this study, it helped in studying some complicated machinery and scenic changes used in these periods and understand how it developed until the end of the 18th century. It was also used in sketching out the machinery used in the Festspielhaus Bayreuth Theater presenting the "Traditional Theater" in the first case study presented in the next chapter.

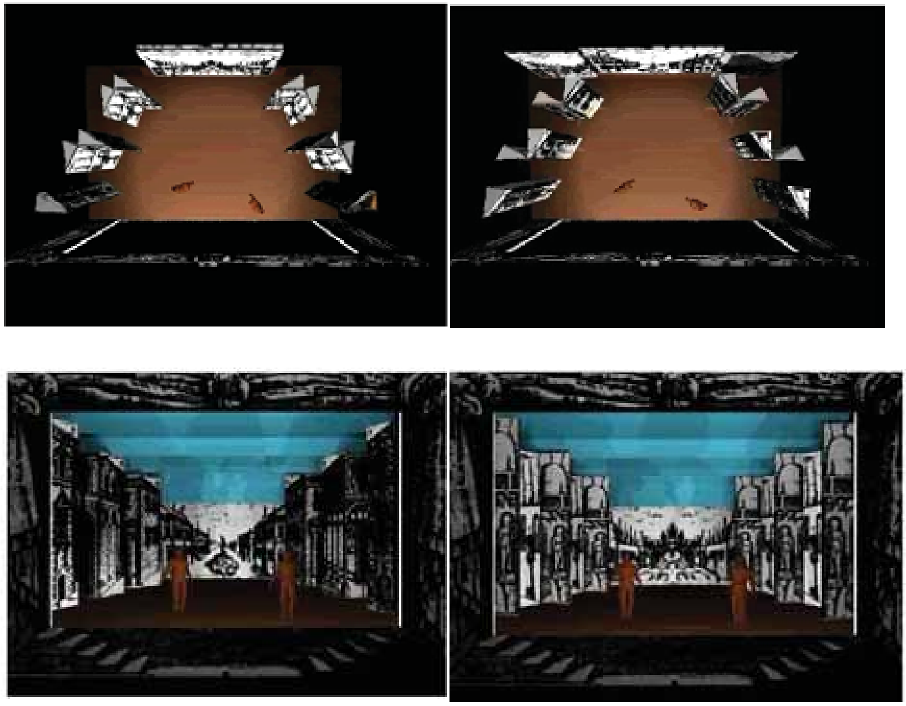


FIGURE 5.2-1: SCENIC CHANGES IN THE 18TH CENTURY FOR FURTTENBACH'S PERIACTOI ABOVE: PLAN VIEW BOTTOM : ELEVATION VIEW BY (MOHLER, 2005)

II. Evaluation and Revival of the Acoustical heritage of ancient Theaters and Odea (ERATO)

Heritage theaters don't have only impressive architectures but also have high standards of acoustical qualities that are applied now in modern theaters such as concerts, operas and other kinds of cultural performances. In this project the concept of acoustical heritage is used in order to emphasize the importance of the acoustic qualities. The ancient theaters in this project are divided into three main categories: the Greek large open-air theaters, the Greek smaller odea and the Roman amphitheaters with the audience surrounding an oval arena. The main objectives of this research are identification, virtual restoration and revival of the acoustical heritage in selected examples of the theater and the roofed odeum in a 3D virtual environment. (ERATO, 2006)

The models of the theaters are built according to the ruins of these theaters and the known state of how they were originally built, after a possible reconstruction and with the temporary stages and scenery often applied when these spaces are used as performance venues today as in **Figure 5.2-2**. Also the musical instruments that will be tested are from the Hellenistic and Roman period and music samples are recorded. A presentation of virtual performances with high degree of realism on the selected theaters produces audible sound demonstrations to form the audio in 3D virtual realizations. (ERATO, 2006)

FIGURE 5.2-2: ABOVE: PHOTOS FROM THE THREE SELECTED THEATERS, BELOW: VIEW FROM THE ACOUSTIC COMPUTER MODELS, RECONSTRUCTED FOR THE ROMAN PERIOD. LEFT: JERASH, MIDDLE: ASPENDOS, RIGHT: SIRACUSA.BY (INCO-MED, 2006)

5.2.1.2. STUDYING THEATRICAL ELEMENTS ON STAGE

Online VLE's concerning theatrical studies are not only concerned by teaching the architectural forms of theater spaces. They were also involved in studying the design of different theatrical elements on stage, giving the chance for different disciplines to study and cooperate together in one virtual environment. It gives innovative channels for students to create complete virtual performances and study all the factors that affect such performance on stage. It provides the users with great digital library to help him in creating his own performance. There many applications for such category online. The following is a quick presentation for some of these applications.

I. Open stages

OpenStages is an interactive 3-D computer model of any theater or performance space into which are placed the systems usually associated with performance; lights, sound, fly bars, revolves and trucks etc. It is possible to hang cloths on bars, position flats, floor cloths, rostrums and revolves on stage. There are basic scenic elements as well as building blocks of basic geometric shapes that can be resized and used as scenery. From a library it is possible to pull in custom made pieces of scenery. Period and modern actors can be costumed and blocked into scenes. All these elements can then be lit and manipulated in real time just as it would be possible with real scenery in a real theatrical space as in **Figure 5.2-3** .

FIGURE 5.2-3: EXAMPLE FOR THE OPENSTAGES, A MODEL OF THE 1978 PRODUCTION OF SHAKESPEARE'S TAMING OF THE SHREW BY THE RSC AT STRATFORD-UPON-AVON (DYER)

OpenStages' primary use is as a teaching tool for all theater disciplines. It is recognized that this technology will eventually be used by professionals. It is not a lighting design program or a scene design program, but it can be used to help these and all other stage disciplines. Its strength is that it uses all the stage disciplines and looks at individual disciplines in relation to all the parts that go to make up a stage event. It is collaborative and forces the user to appreciate the contributions of all. (Dyer)

II. Virtual Theater Project

The virtual theater interface was constructed around a virtual stage - a simulated 3D space which allows the user not only to enter and explore the environment but also to interact with its content by controlling lighting, movement, and design elements built into it. In effect, the interface enables a range of different virtual performances to be mounted under the interactive control of the user. The project involved the construction of a detailed simulation of the Department's Roy Bowen Theater, a 250-seat thrust stage located in Drake Union. The simulation enables users to:

- View the stage from various positions in the house (seats) to get a range of different sightlines.
- Have standard furniture pieces (chairs, tables, boxes) placed on the stage for blocking, directing, and design purposes.
- Manipulate representations of actors.
- Alter backdrop and lighting arrangements to accommodate different design concepts.

The system offers two distinct benefits. As a new interactive tool, it offers undergraduates, graduate students and faculty an exciting medium for experimental projects and research that situates the theater department at a leading edge of theater technology. As a pedagogical tool allowing students to take part in directing/design experiments that are impossible under existing arrangements. (The Virtual Theatre Project, 2004)

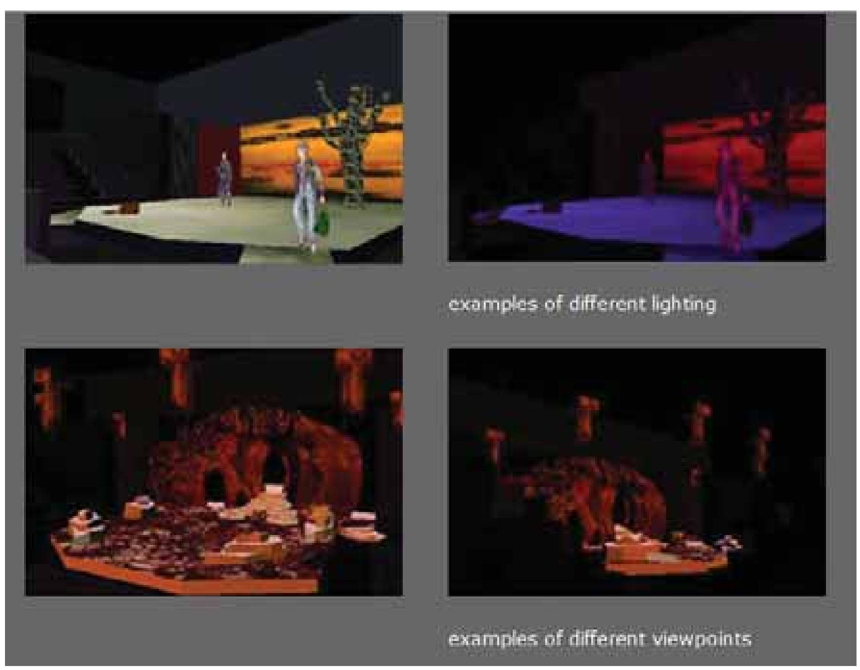


FIGURE 5.2-4: DIFFERENT EXAMPLES OF THEVIRTUAL THEATER PROJECT BY (THE VIRTUAL THEATRE PROJECT, 2004)

5.2.1.3. APPLICATION (1): THEATRON PROJECT BY RICHARD BEACHAM (1998) & THEATRON 3 BY KVL (2007-2009)

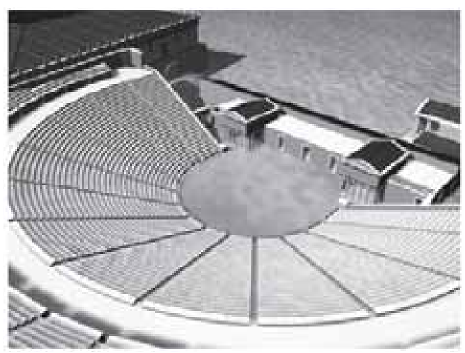
The THEATRON is considered one of the first examples of employing VR technologies in theater education. The abbreviation THEATRON decodes as 'Theater History in Europe: Architectural and Textual Resources Online'. It has been through 2 main phases. The first phase is in 1998. It was conceived by Professor Richard Beacham of the School of Theater Studies at the University of Warwick, and Dr Peter Eversmann of the Department of Theater Studies at the University of Amsterdam. It was known by **The THEATRON project** where it emerged as a specific computer-generated tool that made it possible to discover, investigate and analyze visual dimensions of theater history by 3D interactive models of historic European performance spaces. (Kuksa, 2008)

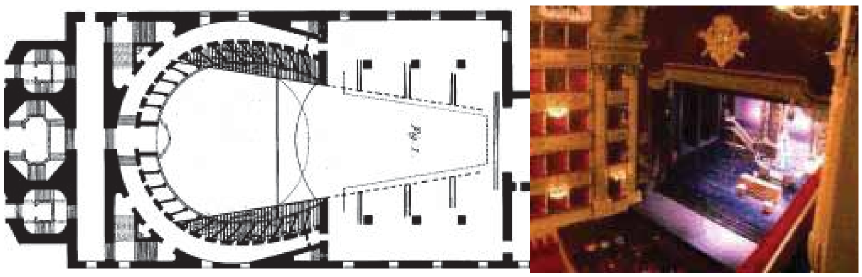
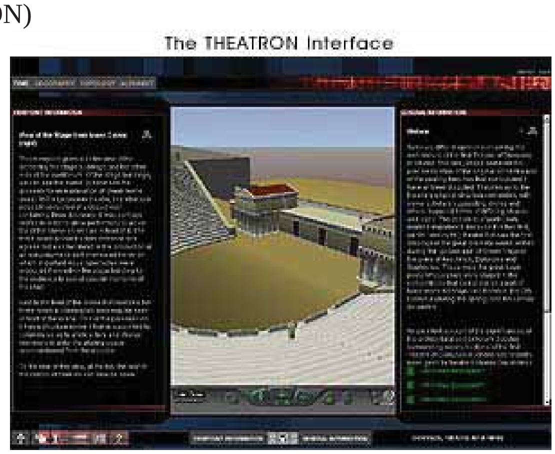
The second phase was undertaken between 2007 and 2009, by King's Visualisation lab within the Centre for Computing in the Humanities (CCH) at King's College London. It is known by **THEATRON3** which added the sense of immersion by enabling the multi-user to interact indie these virtual environments Second Life[11] see **Figure 5.2-10** . Also to enables users to create live performances through using a director tool where it host interactive tools, scenarios and tutorials, customizable actors, props, sound effects, lighting and scenic technologies, streaming video. (Theatron3, 2009)

The following table presents a description of the **THEATRON project** application:

	THEATRON project

[11] ***"Second Life*** is an online virtual world developed by Linden Lab. It was launched on June 23, 2003. A number of free client programs, or Viewers enable Second Life users, called Residents, to interact with each other through avatars. Residents can explore the world (known as the grid), meet other residents, socialize, participate in individual and group activities, and create and trade virtual property and services with one another." (Second Life)

	THEATRON project
Objectives & goals	Establishing new teaching techniques in theater education. Enabling users to experience ‘virtually’ the evolution of the European theater. Providing a well grounded understanding of the elements of architectural space and also time in 3D. Enabling students to examine particular theatrical spaces and to assess what impact they might have had on contemporary performances and audiences as a range of historic navigable models of theater buildings, ranging from the antique to the nineteenth century, was developed. (Kuksa, 2008)
Application framework	Identify and target the theaters that would be modeled Gather architectural and other background details on these theaters Model the theaters in 3D Studio Max Map textures to the models via comprehensive rendering Transform the architectural CAD models into VRML Implement an attractive and intuitive interface for the finished product. (Seamus Ross, Martin Donnelly and Milena Dobreva, 2003)
Operating systems and installation	It is a Fish Tank (screen based) VR application type where the user access to the project through the internet. There he can explore historical theaters along with all the theatrical and practical aspects of sightlines, facilities, access, egress and even the acoustics within the space. Computer-reconstructed ancient theaters also give a clear magnificent picture for ancient theaters just as our recent arenas and auditoria rather than the lost spaces and the existing ruins of these theaters as **Error! Reference source not found.** . (Dixon, 2008)  **FIGURE 5.2-5:** AN EXAMPLE OF VIEW ANGLE OF RICHARD BEACHAM’S DETAILED VR RECONSTRUCTION OF THE THEATER OF DIONYSUS. (DIXON, 2008)

	THEATRON project
Innovation features	THEATRON project allows the student to explore the virtual reality model of a performance site; users are able to 'experience' elements of the theater, such as space, acoustics, sightlines and the relationship between these, which are difficult to convey using conventional teaching materials. (THEATRON) As example Studying Baroque Theater in 2D diagrams shows the bad sightlines seats as shown in **Figure 5.2-6** but on the other hands 3D view from the same seats that they have a good communication with the actors on the forestage regardless the poor sightline. (Eversmann)  **FIGURE 5.2-6:** ILLUSTRATION SHOWS THE 2D DIAGRAM OF THEATER OF SS. GIOVANNI E PAOLO, VENICE, ITALY AND A 3D VIEW IN THE LEFT (EVERSMANN)
	User has access to a wide variety of related multimedia assets and narrative text accessible from the model and information panels. These include photographs, computer animations and 360 degree panoramas. Some of the theater sites also have audio reconstructions, enabling the user to hear what the audience would have heard from different parts of the theater. (THEATRON)  **FIGURE 5.2-7:** THEATRON INTERFACE BY (THEATRON)

THEATRON project

The freedom to explore: Navigation of the virtual space may be conducted using keyboard or mouse giving the user a full six degrees of freedom. To aid users in their exploration, each virtual environment includes a number of preset viewpoints placed at areas of interest and marked by scaled figures that serve as additional visual navigation cues see **Figure 5.2-8**. (THEATRON)

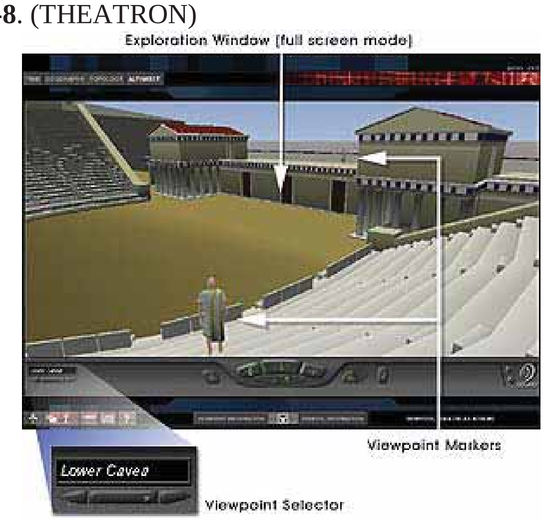


FIGURE 5.2-8: ILLUSTRATION SHOWS THE MARKED VIEWPOINTS THAT AID TH USER THROUGH HIS EXPLORATTION BY (THEATRON)

A personal virtual tour guide: THEATRON links each viewpoint within the virtual space to textual narrative contained in a side window that may be shown or hidden at will by the user. The narrative provides the theater explorer with a personal 'virtual tour guide' explaining not only that which can be seen, but the concepts, history, cultural relevance and other fundamental factors behind the selected viewpoints as in Figure 5.2-9. (THEATRON)

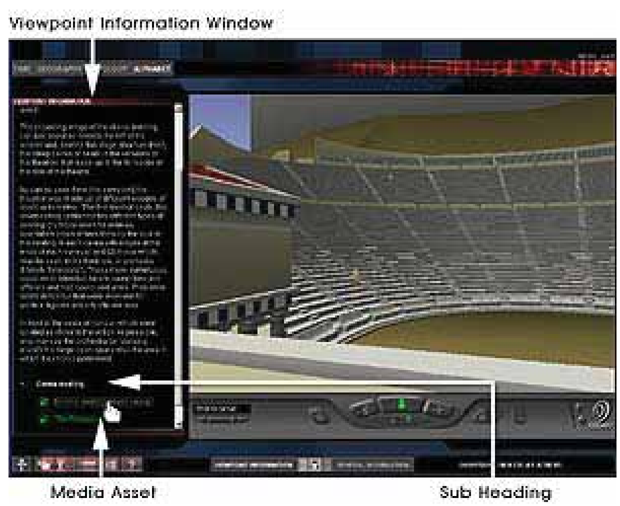


FIGURE 5.2-9: ILLUSTRATION TO SHOW HOW INFORMATION IS GIVEN FOR EVERY VIEWPORT CHOSEN BY THE USER (THEATRON)

	THEATRON project
Advantage	Walking through such virtual theaters structure, students will come as close to experiencing the dimensions of a lost early stage as possible without actually being there. (Ravelhofer, 2002) Students can access these virtual worlds wherever they are, at home or schools, as long as they can get on the internet, which allows the process of learning no longer bounded by time or place, and the education purpose accompanying by the virtual tools is easier to achieve. (Childs, 2009)
Disadvantage	In some historical projects the colors follow common sense rather than a historical source. The surfaces are too clean, as if cribbed from standard CAD templates (such as wood), and the contrasts too strong. (Ravelhofer, 2002) Light sources aren't considered relative to the historical period of the theater as example (the Tudor Hall at Whitehall). In 1635, this space was dimly lit by torches and candles. The bright lighting in this application suggests spotlights mounted between the wings or even a daylight parameter. (Ravelhofer, 2002)

TABLE 5.2-1: DESCIPTION OF THEATRON PROJECT APLICATION

The following table presents a description of the **THEATRON3 project** application:

	THEATRON 3
Objectives & goals	Transforming the THEATRON project content and additional content since created by KVL, into an extensive, content-rich range of research-based virtual environments in Second Life. Generating highly innovative, interactive teaching and learning resources designed to take full advantage of the pedagogical potential of the environment. Developing new educational activities and implementing partner institutions across a wide range of Higher Education subject areas - including scenography, creative writing, and theater design in addition to the performing arts - to take advantage of the social, collaborative and interactive aspects of this shared virtual environment. (Theatron3, 2009)
Application framework	Build of the theaters were new theaters were built in this phase Develop of inworld tools. Three tools were developed to support the activities within THEATRON. These were the Director’s tool, the audience Heads Up Display (HUD) and the Explorer HUD. Integrate web-based booking system which allows users to register with THEATRON and book THEATRON Island for a particular period, select a theater to be razzed for the start of the session, and list the other users who will be present during the session. (Childs, 2009)

	THEATRON 3
Operating systems and installation	 **FIGURE 5.2-10:** THE ORIGINAL THEATRON ENVIRONMENT IN 'FULL SCREEN MODE BY (THEATRON3, 2009) It is still (Screen Based) Fish tank VR application depends essentially on VRML but with more tools that enables multi users to interact with each other in the Second Life. **Input tools** are still the traditional known tools keyboard and mouse to control avatars chosen by the users in the Second life. **Output Display** is the PC Monitor. There isn't any tracking systems needed or goggles. The experience overall is a non-immersive one, as it does not depend on stereoscopic vision. (Childs, 2009)
Innovation features	**Explorer HUD:** The Explorer HUD was created to enable users to access the THEATRON information, and to do so in a geographically-specific context, i.e. depending on where the avatar is located, different content, specific to that location, is presented.
	The Director's Tool: The Director's Tool allows sequencing of events by controlling actors' HUDs and objects inworld. Actors can select one of three different HUDs which does one of the following: simply provide cue for the actor to perform certain actions or speak lines of text; automate some aspects of the performance; or automate all aspects of the performance. The Director's Tool then sends out information to the actors' HUDs. The difficulty with the director's tool was automating the avatars.
	The audience HUD: The audience HUD also communicates with the Director's Tool. From the Tool the Director can direct the audience viewpoint to particular positions, so that the audience can be given preferred directions from which to view the performance. The HUD also enables audience responses, such as cheering, clapping, booing, throwing an apple, etc. Audience members can select a gender which will then provide a gender-specific sound for each response.
Advantage	Transforming all the THRATON project content and additional content since created by KVL, into an extensive, content-rich range of research-based virtual environments in Second Life. Generating highly innovative, interactive teaching and learning resources designed to take full advantage of the pedagogical potential of the environment. (Theatron3, 2009)

	THEATRON 3
Disadvantage	If the student does not engage the embodiment, which not everyone will so easily immerse into the virtual world, then their learning experience will suffer. (Joff, 2009) This resembles what already happened in such study as studying the theaters in The THEATRON project was more easier than the THEATRON 3 as it took much time to get use to move the virtual avatar smoothly. Maybe the THEATRON3 will be more helpful in the digital presentation of such study. Some students may see these immersive virtual worlds as more like a computer game rather than an educational tool. (Theatron 3 - Educational undertakings in Second Life , 2009) The virtual theaters are impractical since they were empty and limited to real life performance. This is the opposite in the meaning of the purpose of the theater; the kind of distraction can contribute to an engaging experience. (Childs, 2009) The foundation of this application is largely relied on the technical requirements of the computer and appropriate skills of the user. This means it can become very difficult to master. (Childs, 2009)

TABLE 5.2-2: A DESCRIPTION OF THE THEATRON3 PROJECT APPLICATION

5.2.2. STAGE PLANNING & DESGIN

For centuries, the traditional instruments used for stage design are sketches, painted renderings, drafting, and scale models. These instruments are labor intensive and need a lot of human hours, the scale model for example needs 100+ man-hours and many expensive materials. (Reaney, 1995) Nowadays, the complexity of events - such as concert and theater performances – has been constantly increasing in order to make them more attractive and successful. In contrast, the financial budget and the realization period of a production remain constant or even decreases due to budget restrictions. (Michael Wittkämper, Eckhard Meier, Wolfgang Broll, 2001) For that reason, stage designers needs an intelligent tool as virtual reality, specially mixed reality systems to be able to visualize the design quickly and accurately.

5.2.3. APPLICATION (2): PLANNING THE MIXED REALITY STAGE

The planning process for an event like theater performance or a concert became very complex and needs a lot of creativity, imagination and gathering ideas from all the people involved. Planners used to illustrate their ideas by using 2d sketches or downscale models usually scale 4:1. Using of standalone physical models maybe effective for composing stage setups and testing different light arrangements but still very inflexible in planning very dynamic aspects of a stage event. (Wolfgang Broll, Stefan Grünvogel, Iris Herbst, Irma Lindt, Martin Maercker Jan Ohlenburg, and Michael Wittkämper, 2004).

In this application another approach will be given for planning a stage event by using the Mixed Reality Stage (MRS). In the Mixed Reality Stage, physical models are used for a realistic presentation of typical components such as the stage itself, the props, or the stage lighting fixtures. The stage is extended by interactive computer graphics using Augmented Reality technology. It is a combination between real and virtual system.

The following table is a description of Mixed Reality Stage application:

	Mixed Reality Stage
Objectives & goals	Combining real and virtual objects to overcome the individual limitations of real and virtual planning environments. Providing multiple users with the means to creatively plan stage shows and to flexibly experiment with different ideas. Facilitating the approach of expressive planning tasks such as arranging objects in space and time. Providing powerful awareness mechanisms rather than limiting the user's freedom by rigid synchronization and locking mechanisms. (Wolfgang Broll, Stefan Grünvogel, Iris Herbst, Irma Lindt, Martin Maercker Jan Ohlenburg, and Michael Wittkämper, 2004)
Application framework	**View Pointer:** An object is selected when it is directly in a user's line of sight, i.e. users select objects by looking at them. A crosshair shown in the HMD helps users "aiming". The selection is visualized using the object's bounding box as in **Figure 5.2-11**.  **FIGURE 5.2-11:** SELECTING AN ENTRY FROM A VIRTUAL MENU USING THE VIEW POINTER. (WOLFGANG BROLL, STEFAN GRÜNVOGEL, IRIS HERBST, IRMA LINDT, MARTIN MAERCKER JAN OHLENBURG, AND MICHAEL WITTKÄMPER, 2004)
	Virtual Menu: Virtual objects have menus that contain those operations which are applicable to the specific type of object. The user opens a menu by issuing a single, modal voice command. Navigation in the menu hierarchy and invocation of operations is accomplished by selecting menu entries via the View Pointer and activating them by voice command.

	Mixed Reality Stage
	Tangible Units: A Tangible Unit (TU) realizes an interaction mechanism that provides direct and seamless manipulation of the position and orientation of a virtual object as in **Figure 5.2-12**. A TU is composed of a tracked physical object (*realoid*) and an associated virtual object (*virtualoid*).  **FIGURE 5.2-12:** POSITIONING A VIRTUAL COUCH THAT IS PART OF A TANGIBLE UNIT. (WOLFGANG BROLL, STEFAN GRÜNVOGEL, IRIS HERBST, IRMA LINDT, MARTIN MAERCKER JAN OHLENBURG, AND MICHAEL WITTKÄMPER, 2004)
	Tools: The operations in a menu are tied to the virtualoid operand for which the menu was opened. Tools, on the other hand, are independent representations of individual operations in the workspace. As seen in **Figure 5.2-12**, the Tools on the right side can be used to play back animations. (Wolfgang Broll, Stefan Grünvogel, Iris Herbst, Irma Lindt, Martin Maercker Jan Ohlenburg, and Michael Wittkämper, 2004)
Operating systems and installation	 **FIGURE 5.2-13:** THE REAL MODEL STAGE WITHOUT VIRTUAL OBJECTS (LEFT) AND VIRTUALLY ENHANCED AS MIXED (WOLFGANG BROLL, STEFAN GRÜNVOGEL, IRIS HERBST, IRMA LINDT, MARTIN MAERCKER JAN OHLENBURG, AND MICHAEL WITTKÄMPER, 2004) **Display system:** Semi-transparent Head Mounted Displays (HMDs) which has an egocentric point of view for every user which serves to deepen the user's sense of immersion.
	Tracking system: The Head Mounted Displays (HMDs) is also used to track head position and its orientation**.** Two tracking systems were added recently; BlueTrak, a wireless inertial tracking system, used for head tracking, and an optical tracking system used to realize the tangible user interfaces.

	Mixed Reality Stage
	Input devices: There are two types of input devices. First is the voice command which is consciously limited to avoid interference with communication between the users. Second is wearable input device where it is designed according to the individual requirements of the user or the particular environment.
	Real system: A real control desk for stage machinery and a real stage lighting control board that allow planners to work in a familiar way without the need to learn new interaction mechanisms.
	Software interface: A hybrid collaborative user interface was developed by employing a variety of techniques - such as TUI - where they best suited the different interaction tasks. (Wolfgang Broll, Stefan Grünvogel, Iris Herbst, Irma Lindt, Martin Maercker Jan Ohlenburg, and Michael Wittkämper, 2004).
Innovation features	**Using Tangible Units & Virtual Menu**: Users may load virtual models from a Virtual Menu, arrange those using Tangible Units or employ more sophisticated functionality in the form of special Tools.
	Planning of choreographies for virtual character: it is major feature of the Mixed Reality stag. Animation paths may be recorded and walking styles may be defined in a straightforward way.

TABLE 5.2-3: DESCRIPTION OF MIXED REALITY STAGE APPLICATION BY (WOLFGANG BROLL, STEFAN GRÜNVOGEL, IRIS HERBST, IRMA LINDT, MARTIN MAERCKER JAN OHLENBURG, AND MICHAEL WITTKÄMPER, 2004)

5.3. DIGITALLY ENHANCED THEATER: VR AS A SCENOGRAPHIC TOOL ON STAGE

5.3.1. VIRTUAL REALITY ON A TRADITIONAL STAGE

The next step for VR technology in theater industry, after being used as a very effective tool in stage design, is to be a part of the stage by offering a unique scenographic tool for traditional performances. Recently," *a series of theatre pieces were produced using virtual reality as the scenographic medium; real-time simulations coupled with live actors to form a new form of stagecraft*" (Reaney, 2000). On a traditional stage, where the stage is the main domain and the only transmitter of all the forces on the auditorium space, virtual reality added another directional force on the audience "immersion". The audience is immersed into virtual worlds while sitting on his seat in the auditorium, looking through the proscenium opening and completely isolated from his real surrounding.

Mark Reaney (University of Kansas and i.e.VR – the Institute for the Exploration of Virtual Realities) is a remarkable director and one of the pioneers of using VR on stage is. He predicted the vital role that VR may play in the theatrical field. He believed that by VR further spaces of imagination may be created on stage. He noted strong potentials in his articles about using VR on stage that can be briefly listed as follows:

- It allows artists to communicate to a modern, media-savvy audience
- It provides a great deal of freedom and flexibility compared to conventional scenery.
- Budgets of money and man power won't constrain anymore Scene changes.
- Scene changes won't be limited to the physical confines of the theatre or even to the laws of physics. VR scenery is ultimately portable, entire productions being created with a computer and a video projector.
- Special effects can be achieved without extra cost, special equipment or danger to the performers.
- VR scenic environments have a malleable nature as they can move, grow or otherwise change in order to reflect the development of the drama. (THE MAGIC FLUTE, 2003)

According to Mark Reaney, traditional theater and virtual reality have common bases that should be take into consideration as they are considered strong potentials for using VR as an important scenographic tool on stage. In the same time, there are some differences that may lead to some degree of limitations that should be carefully studied while introducing such tool on stage. But on the other hand these limitations were used to create untraditional free space stages to occupy special VR theatrical experiences for the audience as will be studied later. The following table presents VR and traditional theater similarities and differences.

	Traditional Theater	**Virtual Reality**

	Traditional Theater	Virtual Reality
Similarities	Depends on live or real-time action (not recorded video as Cinema or TV) Occupy 3D space and rely on some form of illusion which achieved by different styles of production and mechanisms of presentation. It depends on mixing real with fake objects.	Must be experienced in real-time or otherwise will be considered pre-recorded computer animation genre Occupy 3D space with different styles such as projection on screens or by wearing HMD's Mixed reality also presents a combination of real and fictive space to the user.
Differences	It gathers a large number of people to share the same experience. Visual constrains can be limited by giving different degrees of acceptable sightlines. Audience control to the performance is very limited and indirect according to their life reactions towards the actors	In order to increase the sense of immersion, some applications are single user and others may gather 2 or 3 users maximum. Visual constrains limit the number of audience as poor sightlines affect the audience immersion. Audience may control the performance directly in different degrees according to the input device used.

TABLE 5.3-1: VR AND TRADITIONAL THEATER SIMILARITIES AND DIFFERENCES BY (REANEY, 1996)

The trial of introducing virtual reality in traditional performances through the last 2 decades appeared in most of the of the performance types such as dance, music, opera and drama. In each type some modifications were presented to the stage space area, including the onstage and backstage areas, to add the required magical illusion for the theatrical experience. The following section will present briefly some of such trials according to the type of performance.

5.3.1.1. OPERA AND DRAMA THEATER

Some directors like **Gorge Cotes** that were leaders in using multimedia theater as studied in chapter 4, introduced virtual reality as a scenographic tool in their theater productions. He presented on stage what he calls " soft sets". It is a thirty-foot by sixty-foot perforated aluminium screen where 3D computer-generated environments are projected to create stereographic scenography behind the actors. To watch such performances spectators must wear polarized glasses (Vogiatzaki-Krukowski, 2011). Cotes in his works introduced 3 types of interactivity using virtual reality.

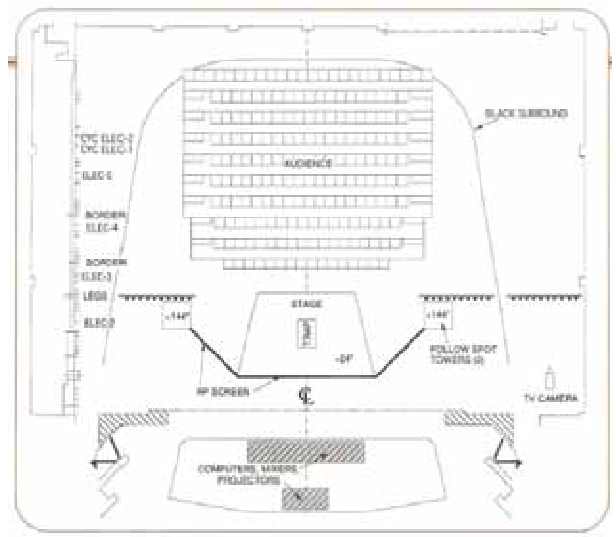
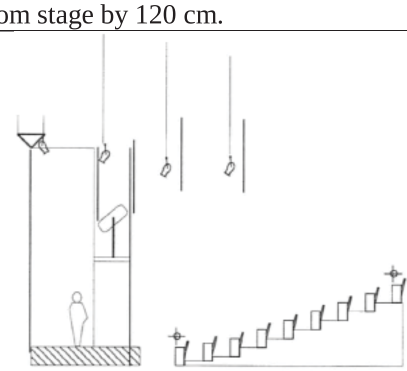
The first type is between the projected screen and the actors. It was controlled before by using backstage joystick but cotes succeeded to use real-time 3D animation to let the screen follow the actors' movement. The second type of interactivity is between performers from different places around the world on one real stage as they were broadcasted in real time via Internet. Using polarized glasses, the spectators are immersed in a mixed reality experience to view fascinating imaginary environments mixed between real and virtual. And the last type of interactivity is between the actors and virtual spectators watching the play through the internet as in his project *"The Crazy Wisdom"* (2001). He placed WEBenabled Teleprompters on the stage where the actors could be controlled by online viewers who at certain moments would submit their opinion or their "crazy wisdom". (Vogiatzaki-Krukowski, 2011)

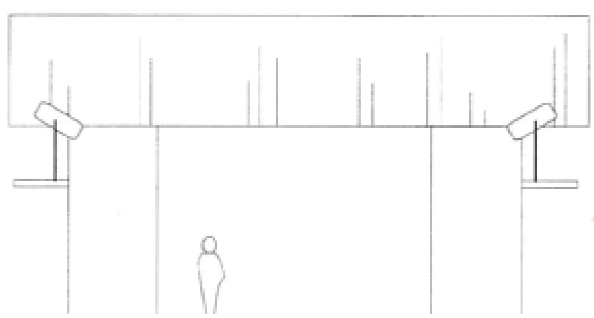
5.3.1.2. APPLICATION (3): UPGRADING A PROCENIUM THEATER TO ENHANCE VR TECHNOLOGY ON STAGE (CRAFTON-PREYER THEATRE)

In 1995 Mark Reany presented his first VR enhanced production "The Adding Machine". His main objective was "*to create a theatre piece enhanced by VR and not to produce a VR artwork using theatrical methods*" (Reaney, 1996). In his next plays he added other VR components to achieve a more "stereotypical VR experience". In 1997, audience had to wear half-silvered HMDs (a VR trademark at that time) to watch ieVR's production of Arthur Kopit's *Wings*. As seen in **Figure 5.3-5**, he updated the image sources, the stage configuration and the no of output displays.

In 2003, Mark Reaney brought virtual reality to Opera. His production "*The Magic Flute"* was an amazing production that examined new potentials of VR on stage. In this play he added more elements to stage to achieve what he called "the edge of illusion". He wanted the audience to experience the movement machinery of scenic changes such as in traditional Opera. He projected virtual characters on stage such as dragons, dinosaurs, amazons, sorcerers and other fantastic characters that inhabit the story and can hardly be presented by traditional means. (THE MAGIC FLUTE, 2003)

In order to achieve his goal he had to make some upgrades to the traditional form of the Crafton-Preyer Theatre on the University of Kansas campus. It is used to be 1800 seats Capacity with Orchestra, balcony and Proscenium configuration of height about 12 meters. The following table presents these upgrades for the previous 3 plays:

	Crafton-Preyer Theatre with Virtual Reality enhanced technology upgrades	
Auditorium	Seat Count	Reducing seating capacity to 150 seats. Later it was maximized to 190 seats.
	Plan arrangement	 **FIGURE 5.3-1:** CRAFTON-PREYER THEATRE GROUND FLOOR PLAN BY (REANEY, 1996) The seats were rotated 180 degree. Audiences were moved to the rear of the house to be close to the actors and the projections. First row away from stage by 120 cm.
	Vertical arrangement	 **FIGURE 5.3-2:** SIDE SECTION FOR CRAFTON-PREYER THEATRE BY (REANEY, 1996) Stage is raised by 60 cm. Seating platforms were built with steeper rake, rising ratio 1:3
	Materials	Both sides of the house were covered by the same black velour drapery at the stages Cyclorama to let the audience focus on the playing area and feel immersed.
Stage	Stage Size	Stage dimensions: 3.6 m deep * 6 m wide trapped to 4.2 m wide at the down stage edge.
	Stage shape	Trapezoidal plan

	Crafton-Preyer Theatre with Virtual Reality enhanced technology upgrades			
	Stage materials			Floor Material is black carpet to minimize the bounce of lights onto the projection screen.
VR hardware components	Display devices		Adding Machine	A black rear-projection screen was directly behind the platform. (it can be replaced by only more expensive "metalized" or "aluminized" front-projection screens) RP screen is 12.2 m width, extended 3 m on either sides of the platform. This extra screen space was angled toward the audience to somewhat surround the actors with the screen. The screen is 7.6 m height. Only 4.2 m height is used 2 projection screens of 3m wide were added to both sides of platform to add sense of immersion.
			Wings	Semi transparent HMD worn by each audience. Rear projection screen. Black scrim in the middle of the stage dividing it into upstage and downstage areas
			Magic flute	2 main rear projection screens. 11 m wide and 4 m tall. A 6.7 m tall screen on either side of the stage served to fill out the visual field of the proscenium opening. 6 different mobile screens which were pushed pulled, wheeled or carried by actors in order to bring virtual elements out into the playing space to interact with the singers. Special designed costumes, props and masks
	Mission control	Projectors	Adding Machine	 **FIGURE 5.3-3:** STAGE FRONT VIEW BY (REANEY, 1996) Two Dukane overhead projectors, each equipped with a NView LCD projection pad, in order to project graphics with an illusion of three-dimensionality.
			Wings	Rear projector to project on the rear projector screen. Front projector to project on the middle Black screen
			Magic flute	2 main rear projectors Mobile Digital data projector mounted on a shop-built follow spot-like stand located at the front house between the audience and the orchestra. Second spot style projector connected to vedia camera for special effects. The projectori is located at the far upstage. 2 35mm slide projectors located offstage in the right and the left.

Crafton-Preyer Theatre with Virtual Reality enhanced technology upgrades		
Image sources	Adding Machine	Each scene had its own computer modeled environment that could be traversed in real-time in correspondence with the actor's movements. These worlds were created and run on a PowerMac 7100/AV with special prototype software loaned by the Virtus Corporation of Cary NC.
	Wings	Real-time computer generated stereoscopic images Videotape of some preordered monoscopic images Binocular cameras for offstage actors. The third rear-of-house camera VCR. In the *Wings* production the stage will be provided by 5 different realities for the audience; Live actors performing downstage, dimly seen actors between the scrim and the RP screen, strong images fed to the semi transparent HMD, projections on the middle scrim and the projections on the rear screen which is mainly used for traditional background sceneries. (Reaney, 1998).
	Magic flute	Real-time computer generated stereoscopic images Videotape of some preordered monoscopic images CGI characters such as dragons.
Cameras	Adding Machine	Binocular Camera for Chroma-key special effects It is used to add live actors directly into the virtual worlds. Actors worked in front of a green chroma-key screen, listening for their cues from the stage. Necessary lighting was supplied on cue and a video camera captured the actors and sent a signal to the video mixers to be chroma-keyed into the virtual worlds.
	Wings	Binocular Camera for Chroma-key special effects. A back camera over the last raw of the audience to capture the same view the audience watch life.
Sound	Microphones in the offstage TV studio and sound outputs from the computers were connected to a small mixer which was connected in turn to the house sound system. Special speakers were mounted in the front of the playing platform at floor level.	
Mixers	The LCD pads were connected to a pair of digital video mixers.	

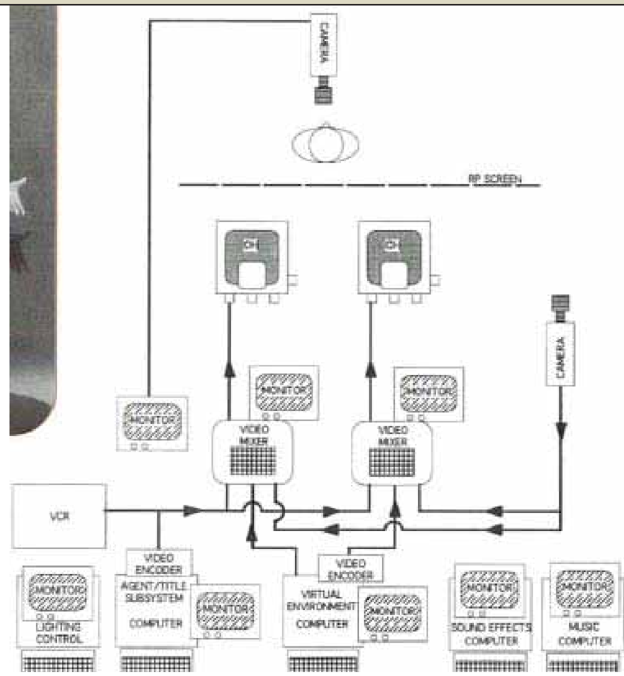
<table>
<tr><th></th><th colspan="4">Crafton-Preyer Theatre with Virtual Reality enhanced technology upgrades</th></tr>
<tr><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2">Control equipment diagram</td><td>Adding Machine</td><td>

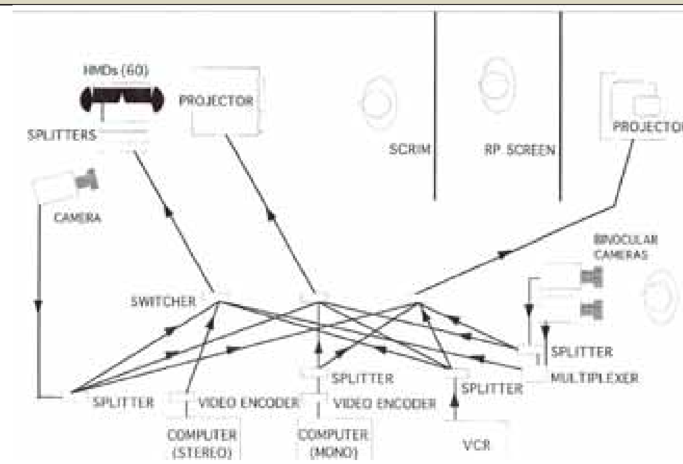
FIGURE 5.3-4: CONTROL EQUIPMENT DIAGRAM BY (REANEY, 1996)</td></tr>
<tr><td>Wings</td><td>

FIGURE 5.3-5: CONTROL DIAGRAM FOR THE "WINGS" PLAY BY (REANEY, 1998)</td></tr>
<tr><td>Conclusion</td><td>Auditurium</td><td colspan="3">The main limitation by using virtual reality on stage is the great reduction of audience number due to visual considerations.
The seat arrangement should be desgined with respect to the visual sightlines of real-time computer generated stereoscopic images.
Side aisles seating can hardly be found in a proscenium theater that enhance VR on stage.
Acoustics design should consider the integration of 3D sound and the location of the speakers.</td></tr>
</table>

		Crafton-Preyer Theatre with Virtual Reality enhanced technology upgrades
	Stage	Cyclorama can be used as a main VR output display in a procenium theater to present real-time rendered scenes as backgrounds. Complex and imaginary scenes, such as flying actors and spinning walls that could hardly achieved by the traditional stage machinery, can be created on a VR enhanced stage by using Chroma-key special effects. The stage with VR can be completely different than the traditional stage. The role of stage tower and stage basement will be reduced and as a result their architectural dimensions and configuration will change. The dimensions of the rear and side stages will depend upon the depth needed for rear and side projections.

TABLE 5.3-2: CRAFTON-PREYER THEATRE WITH VIRTUAL REALITY ENHANCED TECHNOLOGY UPGRADES BY (REANEY, 1996), (REANEY, 1998), (HUDSON-MAIRET, STEPHEN, MARK REANEY, AND DELBERT UNRUH, 2004) AND (THE MAGIC FLUTE, 2003)

5.3.1.3. DANCE THEATER

In 1994, Julie Martin creates first ‘Augmented Reality Theater production’, Dancing In Cyberspace, funded by the Australia Council for the Arts, features dancers and acrobats manipulating body–sized virtual object in real time, projected into the same physical space and performance plane. The acrobats appeared immersed within the virtual object and environments. The installation used Silicon Graphics computers and Polhemus sensing system. (Cathy, 2011)

Another innovative stage design to enhance virtual reality in Dance Theater is called the **Dancespace** presented by IVE (Interactive Virtual Environment) stage. The IVE stage is a room of 4.6 m * 5.2 m with good constant lighting and nonmoving background. The stage backdrop is a projection about 2.1 m * 3m as a display device as in **Figure 5.3-6**. The tracking system is a pointing wide -angle video camera mounted on top of the screen allows the IVE system to track a performer.

It is a great step into virtual reality as it doesn't enhance any mechanical tracking systems, such as the data suit, to track the dancer or performer on stage. The real-time computer vision that captures the performer’s posture, gestures, identity, and movement is called Pfinder, i.e., “person finder.”In the Dancespace, different parts of the dancer’s body (hands, head, feet, torso) can be mapped to different musical instruments constituting a virtual body-driven keyboard. To support many people or performers at once, infrared tracking of the performers can be used. (F.Sparacino, G. Davenport, A. Pentland, 2000)

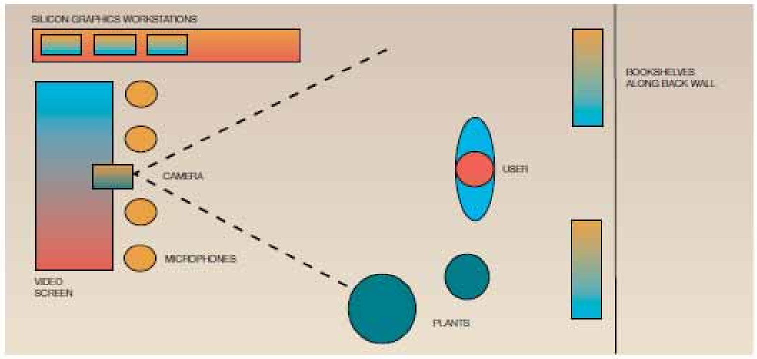


FIGURE 5.3-6: THE IVE STAGE, SCHEMATIC VIEW FROM ABOVE (F.SPARACINO, G. DAVENPORT, A. PENTLAND, 2000)

5.3.1.4. **MUSIC THEATER**

As Usual, Concert Stage is always a leading area in introducing new technologies to theater stages. One of the interesting installments of VR on Concert Stages is designed a system to produce interactive visuals for George Michael's live shows (see **Figure 5.3-7**). The singer wanted movement tracking and generative visuals controlled by his voice and other instruments for a range of songs within the set list. (Jason Bruges Studio, 2012)

FIGURE 5.3-7: INTERACTIVE VISUALS FOR GEORGE MICHAEL'S LIVE SHOWS BY (JASON BRUGES STUDIO, 2012)

5.3.1.5. APPLICATION (4): UPGRADING A PROCENIUM THEATER TO ENHANCE VR TECHNOLOGY (NEW WORLD CENTER BY FRANK GEHRY)

The New World Center by Frank Gehry at Miami Beach is one of the projects that enhanced interactive multimedia on theater stage and is considered a good example for theater-in-round interactive stage. The stage is surrounded by 360-degree video projection, and advanced audio systems, allowing world-wide simultaneous connectivity for distance teaching and performances. The following table presents the main features of such project:

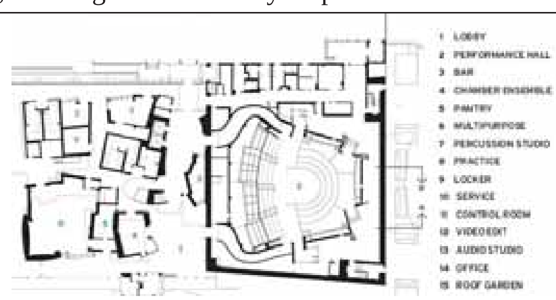
<table>
<tr><th></th><th colspan="2">New World Center Main hall features</th></tr>
<tr><td rowspan="3">Auditorium</td><td>Seat Count</td><td>The 756-seat room features 247 seats that retract to accommodate floor-level seating, standing and cabaret-style options.</td></tr>
<tr><td>Plan arrangement</td><td>

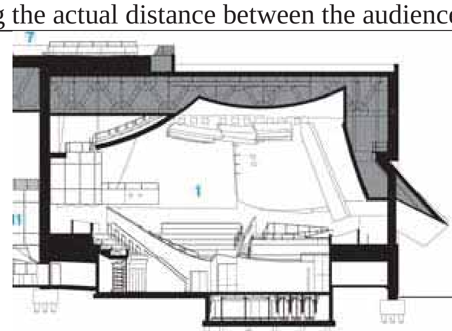
FIGURE 5.3-8: GROUND FLOOR PLAN FOR THE PERFORMANCE HALL OF NEW WORLD CENTER BY (NEWHOUSE, 2011)
It is theater-in- round form that pushes the boundaries of concert formatting while minimizing the actual distance between the audience and performers.</td></tr>
<tr><td>Vertical arrangement</td><td>

FIGURE 5.3-9: SECTION FOR THE PERFORMANCE HALL OF NEW WORLD CENTER BY (NEWHOUSE, 2011)
The vertical arrangement is steep ranked to allow the audience to watch the performance clearly and there is no seat in the auditorium more than 13 rows from the stage</td></tr>
</table>

		New World Center Main hall features
	Acoustical Materials	Five "sails," some 40 feet by 65 feet, are supported on curved steel tubes, studs, and box beams, supplemented by acoustical "clouds" coated with seamless, sound-absorbing plaster that hang from steel pipes.
Stage	Stage shape	It has distinctive and variable 14 configurations for the stage within the hall’s trapezoidal container. There are ten individual mechanical risers to create various levels within the 58 foot by 35 foot stage. In addition, four small satellite stages, located behind and above the main stage and elsewhere in the room, will permit the easy juxtaposition of orchestral and chamber music absent time-consuming stage moves.
Interactive Multimedia components	Screens	 **FIGURE 5.3-10:** A PHOTO ILLUSTRATE THE ACOUSTICAL SAILS THAT WORK AS SCREENS BY IWAN BAAN (NEWHOUSE, 2011) The huge acoustical sails will double as projection surfaces onto which evocative lighting and videographic effects can be projected. A retractable film screen will lower from the within the room's ceiling for larger video presentations and projected backdrops.
	Projectors	There are fourteen 30,000-lumen high-definition projectors that are discreetly built into the room's architecture.
	Light	The auditorium is additionally outfitted with 50 programmable moving lights hung from an overhead acoustical canopy, providing lighting onto the stage. Natural lighting into the room, from both a rooftop skylight and an architecturally embellished opening in the wall behind the main stage, is another important option for daytime performances.
Conclusion	This project presents an ideal example in integrating multimedia components in In-Round-Theater stage as main architectural item. The acoustical ceiling canopies acted as ideal screens for projections. Light ceiling is well designed and the light system is integrated in the canopies while the projectors are well located in the architectural form of the theater to present a highly integrated design for new technology possibilities.	

TABLE 5.3-3: MAIN FEATURES OF MAIN HALL, NEWWORLD CENTER ILLUSTRATED BY (NEWHOUSE, 2011) & (NEW WORLD CENTER, 2011)

5.3.2. VIRTUAL REALITY AND FREE UNTRADITIONAL PERFOMANCE SPACES

5.3.2.1. TURNING PUBLIC SPACES INTO THEATERS

Turning public spaces into theaters is considered the oldest type of theaters. It is known as "Street Theater" where the actors perform a kind of performance without any boundaries between them and the public and in the same time they highly interact with audience. Sometimes the performers want to present an interactive experimental theater to audience more than a traditional script as known on traditional stage theaters. They use props and costumes without any scenery in their plays. Enhancing of VR reality in such theater may enrich the interactive experience and offer new fields of creativity.

One of the applications of enhancing VR in public spaces is called "Body Movies" by Rafeal Lozano. It is an interactive installation that transforms public spaces with interactive projections measuring between 400 and 1,800 square metres. Thousands of photographic portraits, previously taken on the streets of the host city, are shown using robotically controlled projectors. However the portraits only appear inside the projected shadows of the passers-by, whose silhouettes can measure between two and twenty-five metres depending on how close or far away they are from the powerful light sources positioned on the ground. A video surveillance tracking system triggers new portraits when all the existing ones have been revealed, inviting the public to occupy new narratives of representation. (Body Movies)

FIGURE 5.3-11: BODY MOVIES INSTALATION IN A PUBLIC SPACE BY (BODY MOVIES)

Another application that was held in different types of public locations is called the "LEDs Urban Carpet". It is an interactive urban installation using a body-input as a form of a nontraditional user interface…. The installation represents a game with a grid of LEDs that can be embedded as an interactive carpet into the urban context. A pattern of lights is generated dynamically following the pedestrians movement over the carpet. In this case the pedestrians become active participants that influence the generative process and make the pattern of LED-s change." (Carolina Briones, Ava Fatah gen. Schieck & Chiron Mottram, 2007) In this application, passive passengers are divided into 2 groups; first group chose to be participant actor and second group chose to be the audience. It is a simple socializing urban installment that changed the public space into an interactive theater.

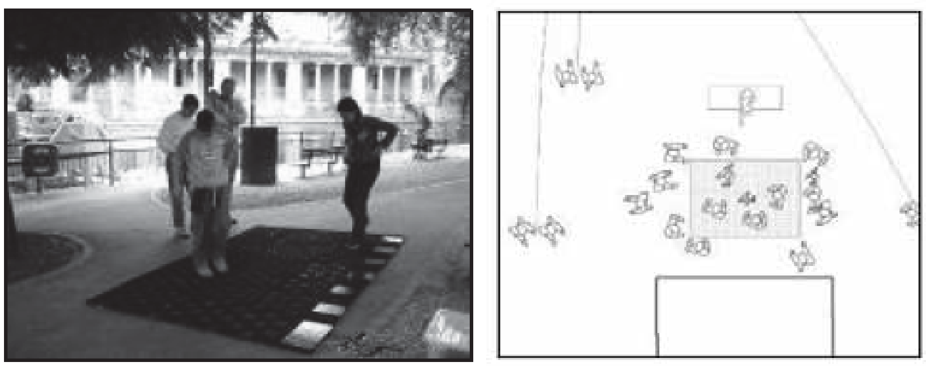


FIGURE 5.3-12: APHOT AND TOP VIEW FOR "*LEDS URBAN CARPET*" BY (CAROLINA BRIONES, AVA FATAH GEN. SCHIECK & CHIRON MOTTRAM, 2007)

5.3.2.2. UNTRADITIONAL IMMERSIVE THEATER

Experiencing interactive theater is not exclusive for public spaces. There are applications for interactive theatrical experiences in nontraditional forms of theater; in buildings or spaces that aren't design to be a theater venue. In these nontheatrical locations there aren't fixed seats or even auditorium space separated from the stage. The audiences participate within a great deal in the play itself. One of these applications is the theatrical production "Faust" by a theater company called Punchdrunk. The theater building is an old warehouse in London. The building is divided into 5 stores with 40-odd rooms (a diner, a corn field, a cinema, a laboratory). (Glusker, 2006)

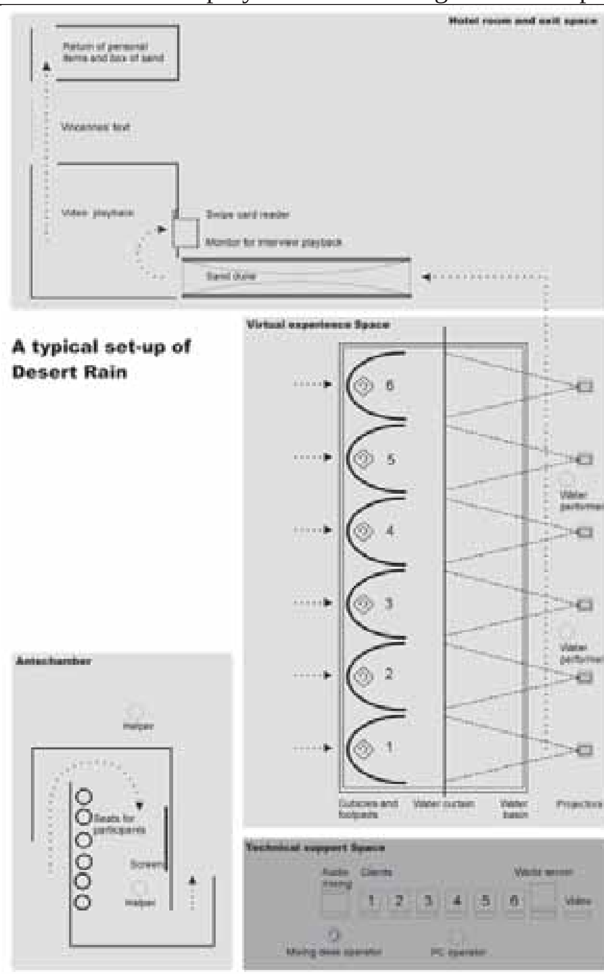
In this theater the audiences wear masks before they enter to be able to identify other audiences from actors. The audiences choose their own way and follow the characters they want to watch. Sometimes the audience enters in a middle of a dance or a fight and sometimes he stands alone in an empty room. He uses his imagination to fill in the blanks to follow up the story. The audiences present a group of actors in some scenes for other audiences. (Glusker, 2006) The whole production is a highly interactive experience that provides audience a very special thrilling immersive feeling.

5.3.2.3. APPLICATION (5): THE SETTING OF UNTRADITIONL PERFORMANCE (DESERT RAIN-THE BLAST THEORY)

Desert Rain is a pioneering large-scale virtual reality performance installation representing a synthesis of art and technology using innovative interface devices. The project was a collaboration between the performance group Blast Theory2, and the eRENA partners University of Nottingham, ZKM, and KTH. Blast Theory is a London-based performance group of four inter-disciplinary artists. (Jeffrey Shaw, Heike Staff, Ju Row Farr, Matt Adams, Dirk vom Lehm, Christian Heath, Marie-Louise Rinman, 2000)**.** It is considered an amalgamation of performance, game, virtual reality and political polemic. The piece takes the variance of different accounts of the first Gulf War (military, media, political) as a starting point, and addresses issues of perception and deception via innovative applications of virtual reality and other related technologies. (Seamus Ross, Martin Donnelly and Milena Dobreva, 2003)

The main reason of using virtual reality in such performance is the main features of the first Gulf War itself**."** The war itself made significant use of VR simulations, and was described by John A. Barry as the first 'technology war' (1992), by Carlo Formenti as the first 'postmodern war' (1991), by Mark Dery as history's first 'made-for-TV' war (1996: 122) and, most (in) famously of all, by Jean Baudrillard as a war which 'did not take place' (since it was virtual) (1995).**"** (Dixon, Digital Performance Archive, 2007) The performance was questioning the uneven nature of such war as just over one hundred American, UK and allied troops were killed in front of 100,000 Iraqi civilians and soldiers – most of whom, in an important sense, were civilians. (Dixon, Digital Performance Archive, 2007)Another reason for enhancing VR is the role of media in such war. The performance criticizes the Western Media coverage of events, and how it creates virtual realties that affect the sequence of happenings.

The following table presents a description for the application of enhancing virtual reality in such Nontraditional performance application:

	Desert Rain-the Blast Theory	
Objective & Goals	MR research objectives	A new relationship between performers and audience which can be experienced by the interacting audience members within a collaborative environment A new form of staging that extends narrative possibilities by using virtual reality technologies combined with real theatre elements and video A new, physically permeable mixed reality boundary technology by means of a rain curtain - a curtain of water spray onto which images could be projected
Basic Settings and Performance Sequence	 **FIGURE 5.3-13:** THE COMPLETE PHYSICAL DESERT RAIN SPACE BY (JEFFREY SHAW, HEIKE STAFF, JU ROW FARR, MATT ADAMS, DIRK VOM LEHM, CHRISTIAN HEATH, MARIE-LOUISE RINMAN, 2000)	

Desert Rain-the Blast Theory	
The Desert Rain performance lasts 30-40 minutes and 6 participants can experience it. The staged event consists of seven elements, six spaces and a couple of physical objects. The overall concept concerns modern warfare, represented by the Gulf-wars.	
Entrance	The audience is picked up the theatre entrance.
The antechamber 	The first station on the ’journey’ where the ground rules about the piece and a plastic card containing the targets’ name are supplied. They are to find a target - whose name is written on the back of a swipe card.
The cubicles 	A 3D world is projected on a water screen, through which the participant navigates, while standing on a footpad. Participants struggle to reach the name on their card. Once through, the game ends and they are led forward through the water.
The sand tunnel 	a 2 meters long tunnel fenced off by high walls containing sand through which the participants walks, ending up in a hotel room.
The hotel room 	The swipe-card is used to turn on a TV-set showing a number of video clips. If the partiicipants find their target, the real person that name represents appears on the screen and talks about their experience of the war.
The exit	Nine sentences all connected to the Gulf-war are pasted on the wall near the exit.
The sand box gift The box bore the inscription: **Desert Rain** estimated at hundred thousand grains "It's really not a number I'm terribly interested in." General Colin Powell New York Times, March 23 1991 p. A4	A little sandbox is left in the participant's pocket containing 100,000 grains. The figures symbolize the number of Iraqi people that were said to have been killed during the Gulf war The box also contains the text of General Colin Powell’s response to a journalist’s question about the 100,000 Iraqi dead: ‘It’s really a number I’m not terribly interested in

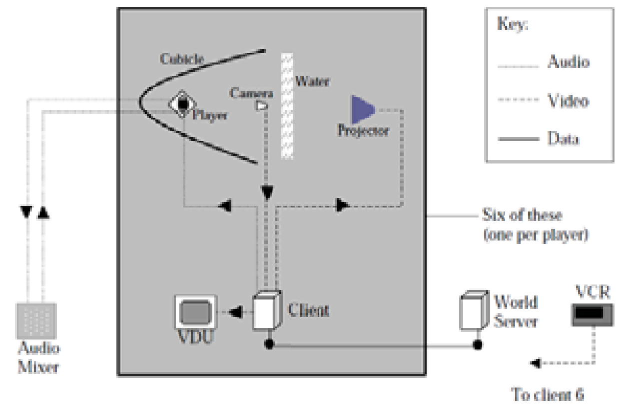
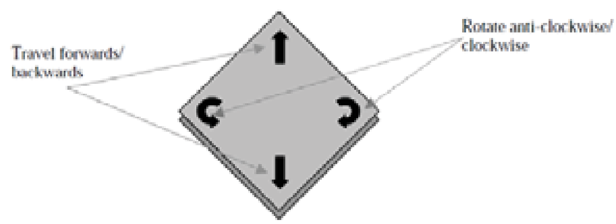
<table>
<tr><th></th><th>Desert Rain-the Blast Theory</th></tr>
<tr><td rowspan="4">Mixed Reality Innovative Features</td><td>The Cubicles set

</td></tr>
<tr><td>In front of the player is the projection surface that consists of a fine spray of water. Several feet behind the water curtain, a video projector produces the image of the client’s viewpoint in the virtual world.</td></tr>
<tr><td>The player interface

</td></tr>
<tr><td>To control movement through the virtual space, the player utilizes a wooden footpad that supports movement in four directions. Figure 3 illustrates the pad and describes the possible movements.</td></tr>
<tr><td>Conclusion</td><td>The Desert Rain presents a good example for free untraditional modern performances where in contrast to traditional, the stage is not yet separated from the audience space. There isn't a specific space to address as stage.
The enhancing of virtual reality gave other possibilities for creative untraditional theatrical settings that require new approaches in theater spaces to enhance such experimental theaters.
On the other enhancing of mixed reality tools, the number of participants is very limited (6 participants). Sometimes this limitation is in the side of the performance but in others it is a challenging point that needs to be developed.
Regardless the number of the audiences, they turned to be more active participant. Each audience acts, communicates and interacts with other participants, shares an interactive game installation and feels immersed in the mixed reality experience.
The introduction of innovative mixed reality features such as the water rain curtain affected the theatrical experience and added new creative visual tools.
The audience experiences a different kind of theatrical experience that can hardly be achieved within traditional theater. The experience will be more remarkable and unforgettable.</td></tr>
</table>

TABLE 5.3-4: THE DISRIPTION OF DESERT RAIN APPLICATION BY BY (JEFFREY SHAW, HEIKE STAFF, JU ROW FARR, MATT ADAMS, DIRK VOM LEHM, CHRISTIAN HEATH, MARIE-LOUISE RINMAN, 2000)

5.4. CYBER ADAPTED THEATER: VR AS MAIN SCENOGRAPHIC TOOL IN IMMERSIVE THEATERS

In this section, the study will be focused on one type theatre; the **Film Theatre** for entertainment and scientific facilities. The study will track the different types of immersive theatres. The main feature for such theatres is creating visually immersive environments that transform the entire theater space into a virtual environment in a way no other media can. (Jon Shaw & Ed Lantz, 1998). The architectural design of such stages is very innovative with different considerations regarding the traditional theatre design.

The main element that affects the architectural design of such type is the display screen. Immersive displays are generally categorized regarding their scale and the number of users. They fall within three categories: small-scale, single-user displays (head-mounted displays and desktop stereoscopic displays); medium-scale displays designed for small numbers of collaborative users (CAVEs, reality centres and power walls); and large-scale displays designed for group immersion experiences (IMAX, simulator rides, domes). (Ed Lantz* Visual Bandwidth, Inc., 2007).

In this study, applications for Immersive theatres will be divided into 3 main categories regarding the relation and degree of enveloping of the stage to the auditorium. This is completely opposite to the traditional theatre as studied in the first chapter where theatre types were categorized regarding the degree of enveloping of the auditorium to the stage. This is a main shift that should be considered while studying immersive theatres as the audience here is the main focus of the whole design rather than the stage. The three main categories of immersive theatre are as follows:

- Non-Enveloping Display.
- Partial-Enveloping Display.
- Full-Enveloping Display.

In this section the application will be given for the first 2 types only as there isn't any application for the third type till now. A patent for the third type will be studied in the next chapter as a case study.

5.4.1. NON-ENVELOPING DISPLAY IMMERSIVE THEATERS

The display unit in such theater is the flat screen. The architectural design of such theater type is very near to the traditional Film Theater. The display is facing the audience from one direction. The audience seating arrangement resembles the traditional theater arrangement as they are all directed to the center of the screen. The following table presents different types of screens that can be integrated in this type and their main features regarding their ability to provide immersive sense:

	Main Features
Cinema	It is the traditional form of Film Theater. Rarely provide audience with the illusion of true presence. There are too many cues which provide the audience with medium awareness, including editing technique (hard cuts, etc.), frame rate artifacts, scratches and dirt on the film, and the theater setting itself.
Stereoscopic Displays	The stereoscopic 3D effects brought audience closer to a sense of presence. Binocular depth cueing allows audience to better depict volume. Audience has to wear 3D glasses which are somewhat cumbersome and limit the field of view. Tilting the head causes a loss of convergence. It is a projection screen with finite extent. The screen edges often “give away” the 3D effect
Large Screen Cinema	In an IMAX_ film theater, an eight story high screen can occupy over 70° of audience visual field. Viewers are forced to move their head and eyes to track objects across the large field of view, giving a greater sense of presence. The phenomenon of optic flow across the peripheral vision reinforces motion cues. Steeply-pitched seating is needed to provide greater visual immersion. The ambient setting of the theater (floors, walls, ceiling, and other patrons) must not provide any stationary clues to let the audience feel more immersive.

TABLE 5.4-1: DIFFERENT TYPES OF SCREENS THAT CAN BE INTEGRATED IN NON-ENVELOPING THEATERS BY (LANTZ, 1995)

From this table it seems out that large screen cinema have provided the audience with higher sense of immersion and in the same time added some architectural considerations for traditional theater type. The main considerations are the steeply-pitched seating's and the ambient setting of the theater. All should serve the sense of immersion and provide more attention to screen.

An application of implementing VR in a Large-screen Immersive theater is the Spitz ElectricHorizon™ VR Theater. It is considered the first public installation for large-scale immersive video-based theaters for real-time 3D presentations. This theater seats 32 persons on an inclined seating deck and includes 3-button responder units for audience interactivity. The screen is a 200° horizontal by 60° vertical FOV partial dome with an 8.5 meters diameter. The image is produced by three edge blended Electrohome Marquee™ 9500 projectors. Image generation is provided by a single-pipe Onyx® Infinite Reality feeding three SVGA video channels. (Lantz, 1998) See **Figure 5.4-1**.

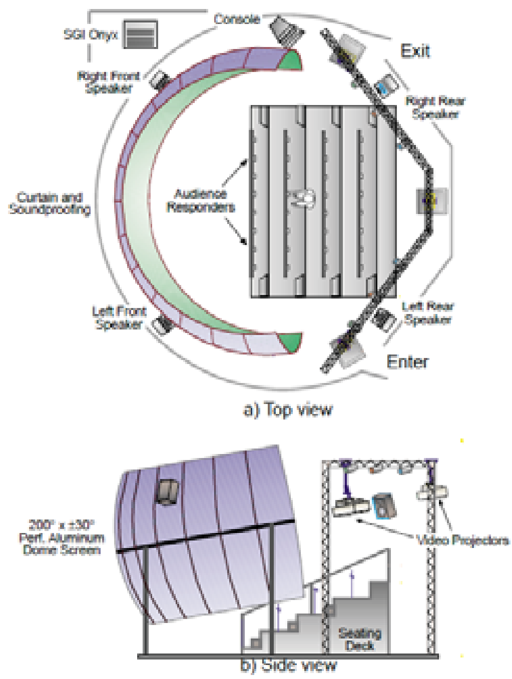


FIGURE 5.4-1: THE SETUP OF THE SPITZ ELECTRICHORIZON™ VR THEATER BY (LANTZ, 1998)

The advantage of using such theater format is the possibility of local production of digital imagery for large format video. It gave the ability to use different sources for creating shows. Print downs of existing film footage, video based material, scanned artwork, and post processing allows content to be created easily. By combining the panoramic video with all-sky (full dome slides) projection, laser systems, star projection and multi-channel sound, impressive environments and productions can be created at affordable cost. Lantz predicted that this type of theaters may bring life to old theaters or provide new venues to sites not previously considered. They can act as multi-use, multi-format Immersive theaters. They can be used for scientific or entertainment facilities, Video conferences, internet-based education, and digital film theaters. (Jon Shaw & Ed Lantz, 1998).

The development of Large-screen immersive theaters is increasing rapidly. It is predicted that such type will replace traditional Film Theaters specially after compromising its cost effectiveness. According to Lantz, wrap-around cylindrical or dome screens are preferred over rectilinear immersive screens in cinematic applications as they provide a more seamless appearance over a greater range of viewing angles and conditions. (Ed Lantz* Visual Bandwidth, Inc., 2007) A case study of implementing VR in non-enveloping theater is given in the next chapter.

5.4.2. PARTIAL-ENVELOPING DISPLAY– "DIGITAL DOMES" THEATERS

On studying the history of creating stereoscopic Image on stage before, in this chapter, it was found that the introduction of CINERAMA to Film Theater was a spark for inventing the "Sensorma" by Morton Heilig and a leading road for introducing Virtual Reality as a leading technology. Another road was taken in parallel which is the introduction of large-scale digital theatres, commonly referred to as “digital dome” or “fulldome” theatres (Ed Lantz* Visual Bandwidth, Inc., 2007), as highly developed immersive Film theatre. The innovations in digital projection over the last decade, such as in CINERAMA, IMAX, OMNIMAX (now IMAX Dome) and other large-format film variants, led to the Digital Dome Theatre invention. (Ed Lantz* Visual Bandwidth, Inc., 2007).

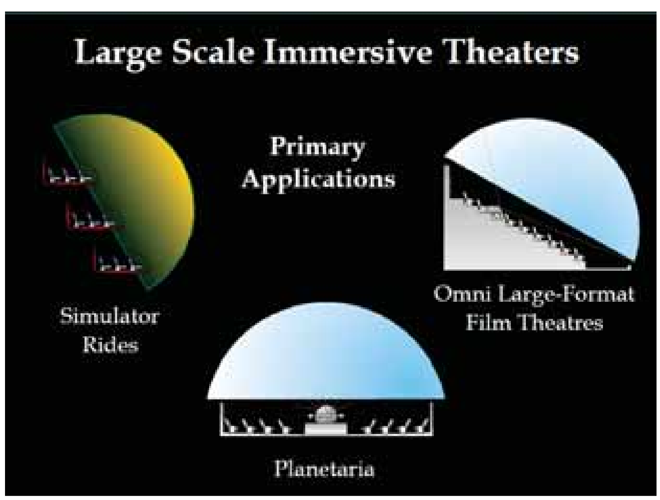


FIGURE 5.4-2: ILUSTRATIONS FOR LARGE SCALE IMMERSIVE THEATERS BY (LANTZ, 2001)

The introduction of the architectural dome shape as projection screens was by Zeiss Company through inventing the first planetarium in Munich in the 1920's. During the last Century, the planetarium took different phases and developments for the Dome theatre structure. At first it was highly expensive and was growing slowly. In the 1940's, Spitz started a new company in order to provide low cost planetariums. His first domes were for military purposes. (Jon Shaw & Ed Lantz, 1998)

Later, cloth screens were replaced by curved perforated aluminium panels. The perforations were provided initially for acoustic reasons to prevent audience sound from reflecting inside the theater chamber. They also allowed speakers to be placed on the back side of the dome and the sound to be projected through the dome. They allowed architects to design the theater chamber so the ductwork could be out of sight of the audience, and placed behind the screen, since the dome is transparent regarding design of the HVAC system in the theater. (Jon Shaw & Ed Lantz, 1998)

In the 1970's, the projection onto domes allowed the simulation of immersive environments where it can be used for entertainment facilities such as the Omnimax theatre 'Imax Dome'. Another step was taken into entertainment industry by placing motion bases inside of domes to provide a multi-sensory immersive environment as in riders and simulators. (Jon Shaw & Ed Lantz, 1998) Now the Digital Dome Theater is taking the lead in Immersive theaters. The reason of the rapid growth of Digtal Dome theaters is due to the retrofitting of analog planetariums with digital projection systems. (Ed Lantz* Visual Bandwidth, Inc., 2007) The following table presents the different venues, applications and facilities for Digital Dome Theaters.

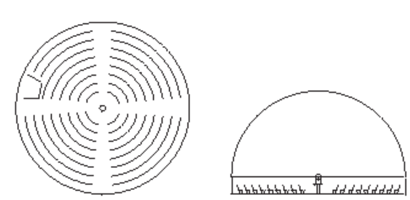
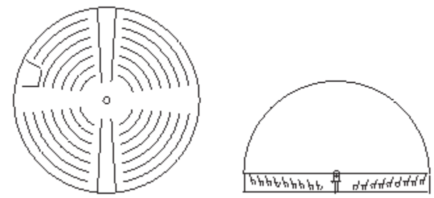
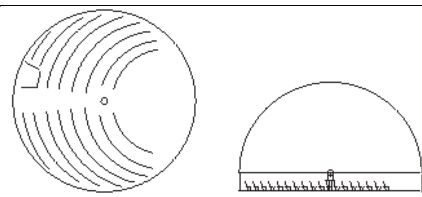
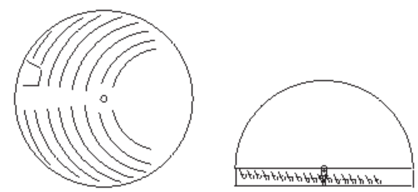
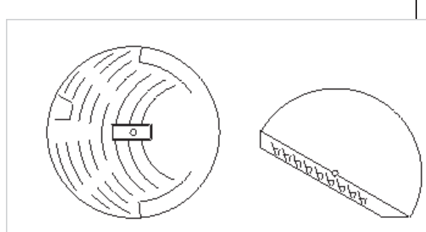
Main Features	Description
Facilities	Sciences or other topics beyond astronomy, for example earth sciences - climate change. Digital theater for large format (digital) movies – not literally IMAX content, but rival IMAX with high production values. This content can be either astronomy or other sciences. Public attraction for tourists and a local destination location. Rental facility for corporate events or events like weddings or receptions. Live entertainment that will exploit the intimate environment and visual capabilities of the immersive environment. i.e art and music.
Venues	Theme parks, planetariums and science centres Universities Corporate tradeshows and other special venues.

Main Features	Description
Applications	Linear playback of immersive cinema productions Real-time simulation of virtual environments. Live art performance. Audience interactive applications.

TABLE 5.4-2: MAIN FEATURES FOR DIGITAL DOME THEATERS BY (ED LANTZ* VISUAL BANDWIDTH, INC., 2007) & (IMERSA, 2009)

Planetarium rather than another Immersive Theatre, presents a good model for Digital Dome Theatres due to the long history and experience in hemispheric projection techniques. See also Appendix G: Comparison between planetaruium other Immersive displays. Due to the advance technology of such Immersive theatre, it offered high ability to control and synchronize many complex projection systems to produce high apparent resolution over a domed screen. (Lantz, 1995) Digital Dome Theatre design considerations can simply be studied by studying planetariums design considerations as summarized in the following table:

Auditorium Design Considerations		
General considerations	Transparency	The theater is designed to "disappear" during the presentation by using dark and non-obtrusive finishing and elimination of visible seams in the dome surface. Projection systems and computer equipment are hidden from view and acoustically isolated. Visual cues associated with the projection surface are minimized (i.e. seamless projection screen).
	Comfort	Seating is arranged to assure good sight lines and comfortable viewing for extended periods.
	Geometry	Since an entire group cannot simultaneously occupy the ideal eye-point of an immersive display, a projection geometry must be adopted which has a graceful degradation in arthroscopy as the viewer moves off-axis. Geometry should be "acceptable" from all paid seats.
	Interactive Ergonomics	Whatever method is used for group interaction with the immersive experience must be easy to learn, simple to use and accessible to a wide range of skill levels.
	Audio	Theatrical surround audio is common to all modern theaters and is a key to a compelling experience.
	Reliability & Maintainability	Theaters must operate cost effectively. This requires minimizing down-time and equipment maintenance costs.
	Throughput	Special venue theaters require ample seating and virtually no visitor training for an enjoyable experience. Emphasis is on providing sufficient visitor throughput to recover capital and operating costs.

Auditorium Design Considerations			
Positioning and seating	Seating for Horizontal Domes		
	Concentric		
		Concentric seating	Conical-concentric seating
		Classical version without a preferred direction of projection. Favorable for astronomical presentations. Maximum number of seats in a given dome diameter.	Concentric arrangement with the rows of seats rising from the center toward the edge of the dome. Favorable for astronomical presentations. Improved viewing conditions for all seats.
	Unidirectional		
		Unidirectional seating	Unidirectional, stepped seating
		The more common type at present. The audience sits in rows curved in varying degrees. The seats point in one preferred direction of projection (south/north). The planetarium projector should feature a vertical axis for azimuth rotation to permit changing of the horizontal directions. Advantages: identical alignment of the other projection media. Stereo and surround sound can be used. Small stage in the audience's direction of view.	Unidirectional seating with rows of seats rising from the centre toward the edge of the dome. It improved viewing conditions.
	Seating for Tilted Domes		
	Amphitheater		The horizon is tilted in the main direction of projection. as a result, the projection dome bring some comfort. Preferred configuration for large auditoriums where multimedia programs are frequently used. Dome tilt between 10° and 30°.
Technical Equipment	Projection systems	Slide and video projections are projected in a single direction. There will always be seats where visitors are forced to crane their necks to see properly. To avoid that, either the pictures are projected onto two or even three different positions in the dome, or all the seats are aligned for the same viewing direction.	

Auditorium Design Considerations		
	Sound and light	A planetarium requires high-quality sound reproduction, whether of language, music or noises. The systems have to be adapted to the special conditions provided by a spherical projection surface. Stereo and surround sound (5.1 sourround) are the most common audio configurations. Apart from the dome illumination included with the planetarium systems, a room illumination for cleaning and service, to be switched independently shall be provided. Dome effect illumination, emergency lights, stage illumination and spots shall be considered
	Control & Interaction	Planetarium instruments have their own control system for manual and automatic control. For the automatic run of an entire planetarium show including sound, lights and effects, a theater control system is recommended. As for visitor interaction, chair design must integrate input devices to allow audience to participate.
	Movie & Laser	Running movies and laser shows do not belong to the core missions of planetariums. Nevertheless, these kinds of presentations are common in many planetariums.

TABLE 5.4-3: AUDITORIUM DESGIN CONSIDERATION FOR PLANTERIUMS BY (ZEISS) & (LANTZ, 1998)

Adding to the functional form of the dome for Immersive theaters, it exerts a double fascinating for architects: the magical attraction of the dome and the architectural challenge this presents. All implementations, whether simple or complex, are based on a few basic shapes. (ZEISS) The integration of Dome feature in a building can be achieved by several design approaches as seen in **Figure 5.4-4**. One of the remarkable applications for Digital Dome Theaters is a local planetarium; the Planetarium Science Center of the Bibliotheca Alexandrina. It is an iconic architectural feature to the entrance of the Library as in . It is considered as a main scientific facility in Alexandria.

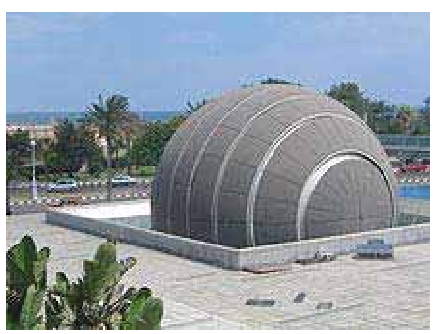


FIGURE 5.4-3: DOME OF THE PLANETARIUM SCIENCE CENTER OF THE BIBLIOTHECA ALEX.

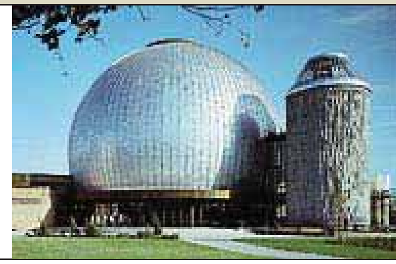
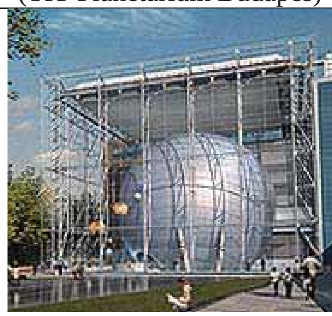
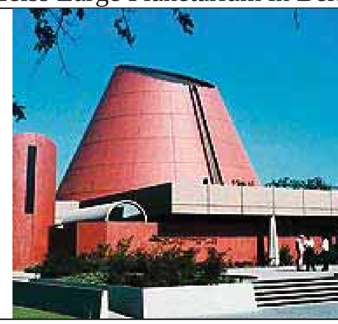
Basic shapes for Planetariums	
	
The hemisphere as the predominant part of the building (TIT Planetarium Budapes)	The three-quarter sphere as a conspicuous architectural feature (Zeiss Large Planetarium in Berlin)
	
The dome integrated into a sphere (Hayden Planetarium, American Museum of Natural History, New York)	**The dome in a truncated cone** (Planetario de la Universidad, Santiago de Chile)
	
The dome surrounded by a cylinder (Telus World of Science, Edmonton)	The dome as part of a combination of different geometric shapes (Heureka Finish Science Centre, Helsinki-Vantaa)
	
The pyramid (Laupheim Planetarium)	**The dome in an historical building** (Zeiss Planetarium, Palais de la Decouvérte, Paris)

FIGURE 5.4-4: DIFFERENT EXAMPLES FOR PLANETERIUMS BASIC SHAPES BY (ZEISS)

Although all the potentials of integrating virtual reality, the real-time synthesized imagery is not very common in such type of installations due to the high complexity and performance demands of the underlying system. (Athanasios Gaitatzes, Georgios Papaioannou, Dimitrios Christopoulos, Gjergji Zyba, 2006) There are still some challenges in developing the enhancing of VR in Digital Dome Theaters. The following table presents the potentials and challenges in front of VR:

	Description
VR System Potentials	Can offer a much more exciting experience and can turn each show into a performance where the spectators participate actively in the unraveling story. It can combine pre- rendered and real-time graphics in a seamless manner, as well as incorporate interactive, live on-stage action. Provides a flexible, extensible and sustainable infrastructure is properly designed and built. Provides a greater illusion of presence. VR systems induce greater fatigue for the audience and require extensive kinaesthetic involvement. It will bring out visual-based storytelling supplemented with narrative. It allow the creation of many new storytelling devices which are not yet possible or sufficiently effective with present visual systems. VR systems driven by artificial intelligence technology will allow interaction with cognitive-emotional agents to create drama. (Lantz, 1995)
VR Research Challenges	The proprietary nature of these displays, coupled with their high cost and large space requirements, which limits the accessibility by the research community. Collaborative research is challenged because of immersive displays optimization of image brightness and resolution, spherical multi-projector edge-blending techniques, real-time spherical mapping, spherical stereoscopic display, scalable database visualization, and standards development. (Ed Lantz* Visual Bandwidth, Inc., 2007)

TABLE 5.4-4: POTENIALS AND RESEARCH CHALLENGES FOR INTEGRATING VR SYSTEMS IN FULL DOMES BY (ED LANTZ* VISUAL BANDWIDTH, INC., 2007)& (LANTZ, 1995)

Regardless the challenges discussed above, the real-time VR Dome theater of FHW utilizes a fully digital projection system, configurable in a monoscopic, stereoscopic or a mixed mode of operation. It will be studied in the next chapter as a case study for partial-enveloping Immersive Theater.

6. CHAPTER (6): CASE STUDIES

6.1. CASE STUDY (1): COMPARISON BETWEEN THE STAGE SETTING FOR THE SAME OPERA PERFORMANCE IN TWO TRADITIONAL THEATERS WITH AND WITHOUT VR TECHNOLOGY

In fact, virtual reality made Wagner's dream for the audience to experience a legendary world in the 19th century come true in the 21st century. As studied in chapter one, Wagner's built his opera house in 1876, the Festspielhaus in Bayreuth, to create his own 'illusion machine' for his special operas where he tried to completely isolate and immerse the audience using complicated combination of stage machinery. In this case study, a comparison will be given between two traditional stages for a Wagner Opera called the Ring in two different stages.

The first one is the original performance in the Bayreuth Festspielhaus and the second is the contemporary performance played now on the Metropolitan Opera Stage by Robert Lepague. The reason of choosing both Opera’s stages in this case study is that they both have many similarities in their stage properties but in the same time they have completely different approaches in their stage setting. The old approach by Wagner had his great influence on Opera’s stage design in traditional theaters till now. As for the new approach in setting the stage of Wagner’s operas, this will change in future the concept of designing the traditional stage.

6.1.1. BAYREUTH FESTSPIELHAUS OPERA STAGE

Staging the '*Ring der Nibelungen*' was a complicated matter because Wagner wanted to achieve the perfect illusion. His artistic ideas were far ahead of the technical possibilities of his time, nevertheless the Bayreuth stage managers devised some ingenious set pieces for the staging of the 'Ring'. For example, the Rhine maidens living beneath the water were mounted on special carriages and had to sing on top of these devices, while the illusion of the river was created with the use of cloth, gloomy lighting and steam. The account of the experience of one of the first Rhine maidens, Lili Lehmann, gives an impression of just how difficult the entire operation was.

Bayreuth Festspielhaus

Ground floor plan

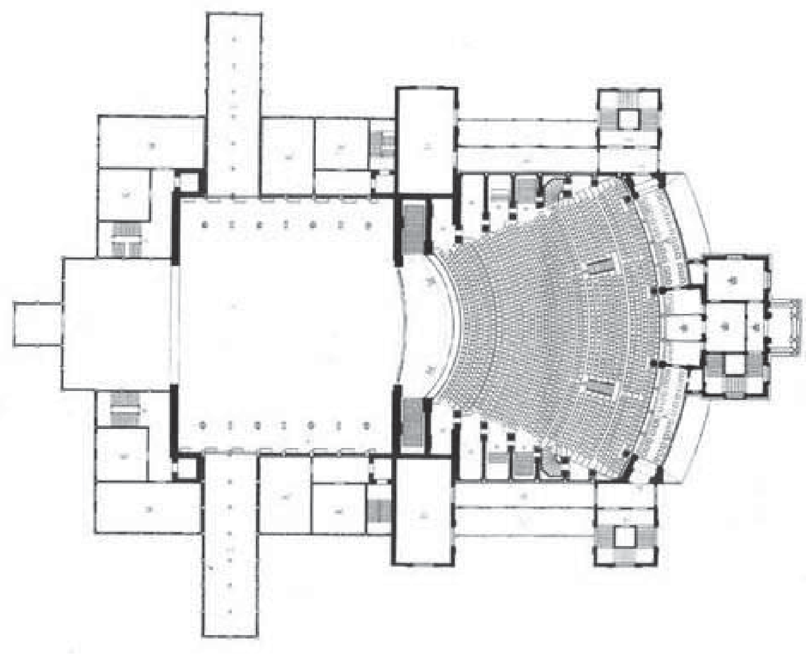


FIGURE 6.1-1: BAYREUTH FESTSPIELHAUS GROUND FLOOR PLAN BY (SACHS, 1898)

Auditorium	Fan shaped with a steep rise, it ensures that every seat has an excellent view of the stage.
Orchestra	One of the most revolutionary elements of the theatre is a submerged orchestra pit, partly situated under the stage.
Proscenium arch	The arch is in fact a triple arch, and together these *proscenia* form a kind of tunnel through which the spectators look at the stage. Because the distance to the stage is not clear, it is possible to create optical illusions with regard to the size of people and objects.

Bayreuth Festspielhaus

Stage Plan

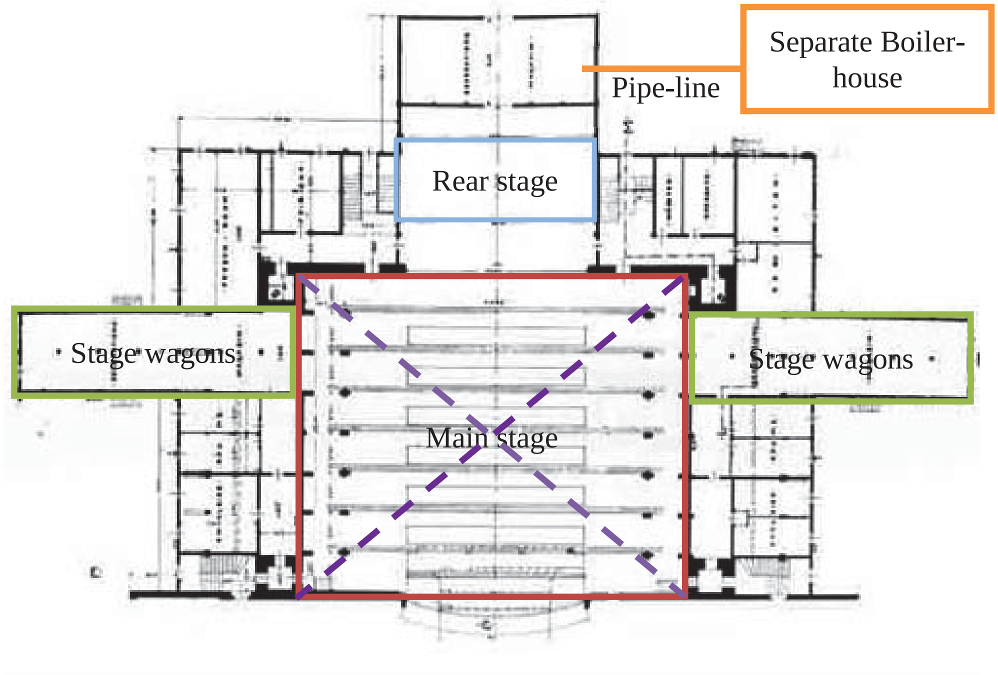
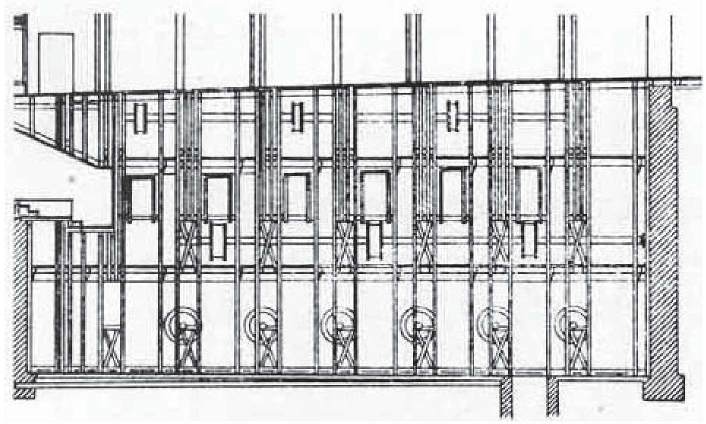
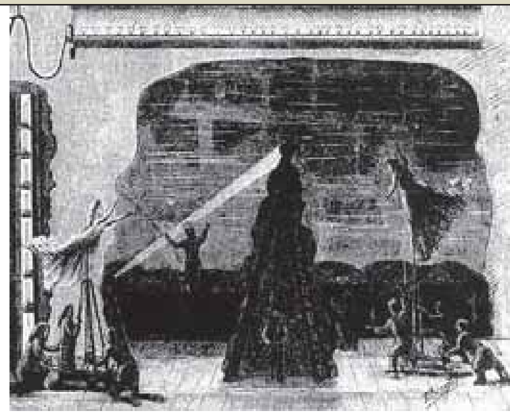
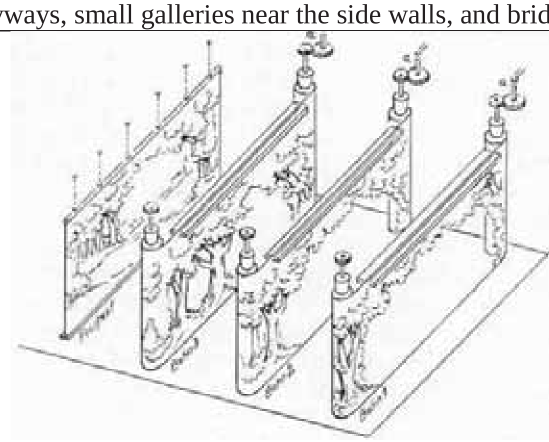


FIGURE 6.1-2: BAYREUTH FESTSPIELHAUS STAGE BY (THEATRON VERSION II)

Main stage	It is considered a huge stage area due to the high technical demands in order to produce the illusionistic effects Wagner desired for the staging of his operas. Its width is 28.2 meters and depth is 23.1 meters.
Rear stage	It is an additional space behind the main stage from which the equipment could be brought on and off with passage way of 13.4 wide between the 2 stages.
Fly tower	It is located over the main stage. It is the highest flytower in Europe at that time of 19.2m high. The main purpose of that height is to hide all the equipments and the set hanging, such as wings, backdrops, curtains…etc., and to avoid any visual contact between theses sets and the first row of spectators to achieve the perfect illusion. To change sets the scenery can be pulled up, down, or shifted horizontally. The present-day flytower is enlarged and there are three storeys of machinery available.
Stage wagons	It is used for carrying pieces pieces of scenery or machinery and could be rolled on and off quickly such as the boat scenery.
External Spaces to support the staging	An external Boiler-House, located next to the theater, was used to create the necessary steam for the stage effects by a special pipeline from this factory. The steam was used in hiding the scenic changes. It is one of the considerable technical efforts to create the virtual realities Wagner on stage.

<table>
<tr><th></th><th colspan="2">Bayreuth Festspielhaus</th></tr>
<tr><td rowspan="2">Basement machinery</td><td>Lifts & traps</td><td>
FIGURE 6.1-3: STAGE LIFT IN BARRUTH FESTSPIELHAUS BY (THEATRON VERSION II)
As seen in Figure 6.1-3, the stage floor is divided in seven sections or "streets". The set pieces that were raised and lowered fitted in the floor grooves.
Lifts of 13 meter long were located in six streets in order to raise and lower set pieces.
Movable traps and shutters were used for set changes and the appearance or disappearance of characters.</td></tr>
<tr><td>Winches & counter-weights</td><td>
FIGURE 6.1-4: MACHINERY BENEATH THE STAGE FLOOR BY (THEATRON VERSION II)
The basement height is 10 meter was a large part of machinery
Big winches and counterweights were used to control the lifts and traps. Later on, hydraulic and electrical devices would replace the manually operated equipment.</td></tr>
</table>

<table>
<tr><th></th><th colspan="2">Bayreuth Festspielhaus</th></tr>
<tr><td rowspan="2">Stage Tower</td><td>Special Effects equipments</td><td>
FIGURE 6.1-5: SPECIAL EFFECTS IN THE "RING" BY (THEATRON VERSION II)

A lot of additional equipment for special effects, such as thunder machines, wind machines, a lightning device and a wave machine to imitate a sea.
Most of the equipment was stored in the huge fly-tower and controlled from the flyways, small galleries near the side walls, and bridges.</td></tr>
<tr><td>Movable sets</td><td>
FIGURE 6.1-6: WANDELDEKORATIONEN BY (THEATRON VERSION II)

Movable sets installed is called ‘Wandeldekorationen’
It was a moving backcloth used to give the impression of transgression. While the actor it stood still but pretended to walk, the scenery moved behind him.
This cyclorama-like set consisted of a double sized (in length) backdrop that was wrapped on rolls. Several of these sets were placed behind each other
Not all spectators were convinced but it was a popular effect.</td></tr>
<tr><td>Stage</td><td>Stage lighting</td><td>In 1876 stage lights were fuelled by gas where a special pipeline was constructed to transport the gas from the factory to the theatre. Colored glass plates were used to produce colored light.</td></tr>
</table>

	Bayreuth Festspielhaus	
		In 1888, the electricity replaced the gas lamps and gave new potentials for lighting designers on stage. In 1924, light bridge was installed to give more flexibility in the use of light. Today the lighting system is fully computerized.
Special Scenic machinery	The swimming device	 **FIGURE 6.1-7:** THE SWIMMING DEVICE BY (THEATRON VERSION II) The Rhine maidens living beneath the water were mounted on special carriages and had to sing on top of these devices, while the illusion of the river was created with the use of cloth, gloomy lighting and steam. It is a basket that carries the singers and attached to an iron pole. The latter could be moved up and down by means of cables and pulleys. The pole and basket were placed onto a moveable carriage that was handled by three stagehands.
	The boat scenery	 **FIGURE 6.1-8:** CARRIAGE WITH BOAT BY (THEATRON VERSION II)  **FIGURE 6.1-9:** SWIMMING OF THE RINEMAIDENS BY (THEATRON VERSION II) The boats and the swimming of the Rinemaidens in *Rheingold* were rolled off and quickly pulled as other carried pieces of scenery and machinery into the stage wagons. The illusion of the river was created with the use of cloth, gloomy lighting and steam.

TABLE 6.1-1: COMPARITIVE TABLE FOR THE STAGING OF ILLUSTRATED BY (THEATRON VERSION II)

6.1.2. METROPOLITAN OPERA STAGE

Metropolitan Opera Stage

Ground floor plan

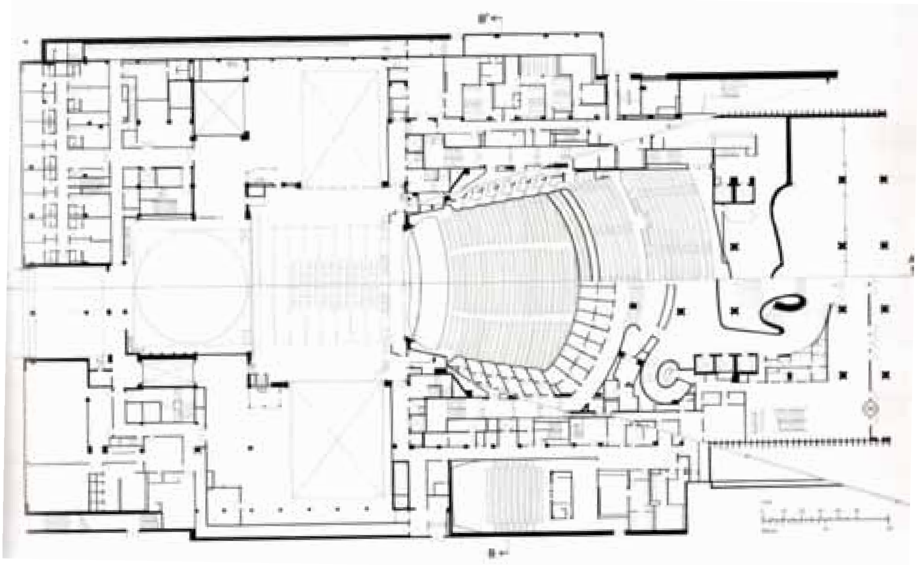
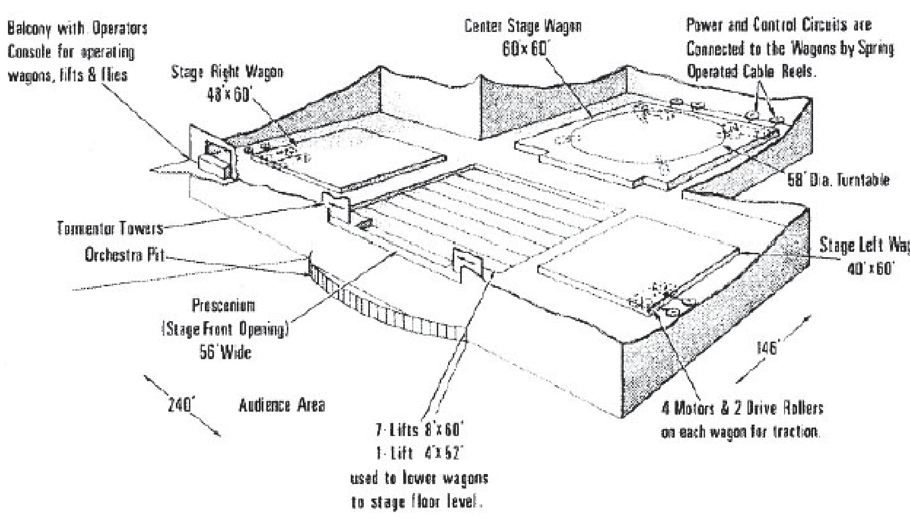


FIGURE 6.1-10: METROPOLITAN OPERA COMPOSITE PLAN BY (IZENOUR, 1996)

Auditorium	It is a hybrid theater form as seen in **Figure 6.1-10**. For audience sitting in the ring balconies floor, it is an Italian horseshoe-shaped opera house. Above the ring, it is unrelated stadium-seating balcony with different aspect to the stage. The reason of such shape is to achieve acoustical and seating scheme for more than 3600 seating in a horseshoe-shaped form. (Izenour, 1996)
Orchestra	It is also dipped between the audience and the platform to make a gap between the audience and the actor.
Proscenium arch	It has a proscenium arch opening that separate that presents the performance through the proscenium opening, of 16.5 m wide and 16.5 m height, as any traditional opera.

Stage Plan



	Metropolitan Opera Stage

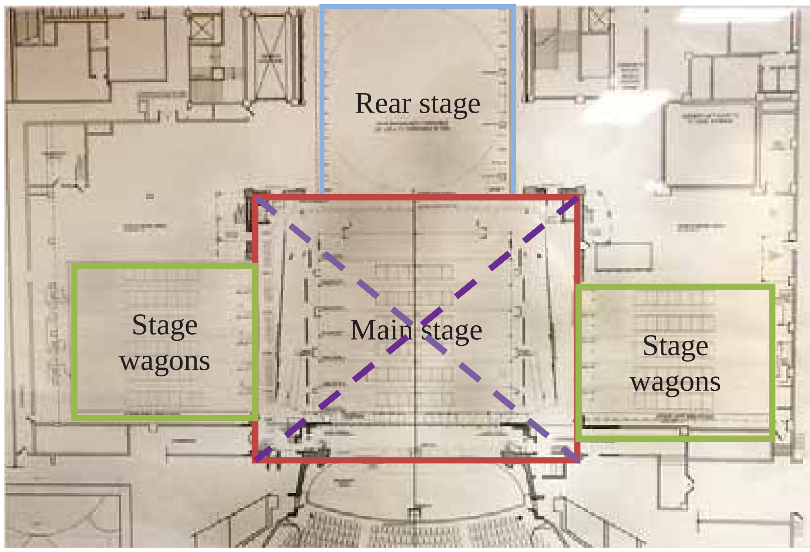


FIGURE 6.1-11: THE FLOOR PLAN OF THE METROPOLITAN OPERA BY (THE NEW YORK TIMES, 2010)

Main stage	The main stage area is about 32 meters wide and 27 meters depth. The width of the stage is about double the width of the proscenium arch.
Rear stage	Although the stage have a huge area of additional rear stage it isn't used in such performance because there isn't any need for removing or storing huge sets.
Fly tower	The height of the fly tower is about double the height of the proscenium opening. This huge height isn't used in such performance as there aren't isn't need of hiding and storing sceneries due to the use of projection screens on stage.
Stage wagons	There are two huge stage wagons at both sides of the stage. One is only used in this performance to restore the mechanical staging set when it is not in use.
External Spaces to support the staging	There is no need for any external spaces or (factories) to support the performance live on stage. But due to the complex mechanical installation made by Robert, it was made and stored in a warehouse in Montreal and then transferred to NY.

	Metropolitan Opera Stage	
Basement Machinery	Basement modifications	 **FIGURE 6.1-12:** STEEL BEAMS WERE ADDED TO THE METROPOLITAN OPERA TO SUPPORT THE STAGE BY (THE NEW YORK TIMES, 2010) Due to the heavy installation required by Robert on stage the only modification needed to be done for such performance is installing 65-foot girders under the stage. It is considered the most extensive work for a new production this structure is counted as permanent structural change to the opera house.. (The New York Times, 2010) Other traditional basement machinery isn't used in such performance.
Stage Tower	Special Effects equipments	In this performance the Fly tower isn't used in storing and changing scenery curtains and drapes as the scenery are digital projected on screens. The fly tower is only used for the hanging the flying machines for the acrobats and also for installing required projectors and lighting equipments.

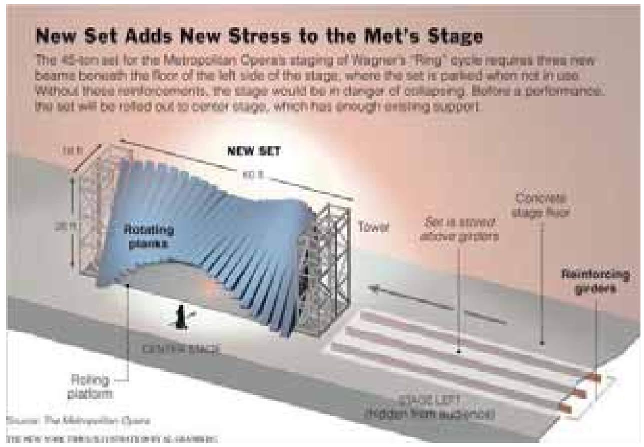
<table>
<tr><td></td><td colspan="2">Metropolitan Opera Stage</td></tr>
<tr><td rowspan="5">Stage Technology</td><td>Screens</td><td>

FIGURE 6.1-13: THE SETTIN OG THE METROPOLITAN OPERA'S STAGING BY (THE NEW YORK TIMES, 2010)

The screen design is a very innovative set composed of 24 triangular-shaped fiberglass-covered aluminum planks (each 30 feet in length), upon which video is projected.
The planks, which resemble seesaws, move independently of one another and can rotate 360 degrees around the hydraulically-powered central axis (a pair of pneumonic brakes can engage or disengage the planks from the central axis), which is secured by two steel, 26-foot tall elevator towers. (Romano, 2011)</td></tr>
<tr><td>Projectors</td><td>There are three video projectors that are very high on the balconies [in ceiling projection booth]
There are also six others that are on the lower [parterre] level.
All theses projectors are used due to the triangular shape of the planks, so by real time calculating, the best projector to cover a particular surface can be easily determined. (Romano, 2011)</td></tr>
<tr><td>Tracking system</td><td>Due to the movement of the planks, a tracking software system called the Sensei for interactive infrared (IR) video projection was used.
Body movements and vocal amplitude of the performers are detected via IR cameras/motion detectors and microphones; this audio and physical information is relayed to the Sensei tracking software, which triggers effects and images (everything from water bubbles to clouds) that are projected onto The Machine's 24 planks. And because of the triangular shape of the planks, the video projection was by three video</td></tr>
<tr><td>Stage lighting</td><td>Due to the small area of each plank and it deepness, in order to cover each plank and the apron, the stage lighting components were modified
There are 28 spot light profiles (VAR- Light) and 10 VL3500 washers in the air to cover every spot on stage. (Romano, 2011)</td></tr>
<tr><td>Computers</td><td>The system allows for a vast number of possible configurations and will be used to create each scene of Wagner's epic tale "in a chameleonlike fashion," The set will also serve as a backdrop for complex computer-controlled projections, showing the waves of the Rhine, flames around Brünnhilde's rock or a snowstorm swirling about Hunding's hut. The system makes for quick scene changes. (The New York Times, 2010)</td></tr>
</table>

<table>
<tr><td></td><td colspan="2">Metropolitan Opera Stage</td></tr>
<tr><td rowspan="2">Special Scenic machinery</td><td>Planks acts as wall, platforms and staircase</td><td>

FIGURE 6.1-14: THE SET FOR THE METROPOLITAN OPERA'S NEW PRODUCTION OF THE "RING" INCLUDES MOVING PLANKS THAT CAN PRODUCE MYRIAD SHAPES AND SERVE AS BOTH STAGE ARCHITECTURE AND CANVAS FOR PROJECTIONS. (ROMANO, 2011)
The elegant structural design and movement of The Machine's planks has allowed the production team a great deal of latitude, in more ways than one.
These planks can be transformed into the basic shape of whatever a scene may require (i.e. the body of a Dragon, a river, a staircase, etc.). During performances actors are attached to and stabilized via cables as they soar next to and scale these planks. (Acrobats often perform stunts for performers.) (Romano, 2011)</td></tr>
<tr><td>The swimming singers</td><td>
Mr. Lepage has created virtual scenery through sophisticated projections that can be shaped by the sounds of the orchestra and the movement of people on stage. (The New York Times, 2010)
The flying Rhinemaids interact with the screens as they form bubbles behind them</td></tr>
</table>

TABLE 6.1-2: COMPARITIVE TABLE FOR THE METROPOLITAN OPERA STAGING OF ILLUSTRATED BY (IZENOUR, 1996) (ROMANO, 2011) (THE NEW YORK TIMES, 2010)

6.1.3. CONCLUSION COMPARISON

	Bayreuth Festspielhaus	Metropolitan Opera Stage
Similarities	Both stages present the traditional type of Opera stages. They are similar in the backstage, rear stages, side stages, under machinery main features. Both theaters auditorium design emphasizes the complete separation between the audience and the stage, having the orchestra dipped between the audience and the stage as a barrier. Both performances depend of immersing the audience in a virtual illusion on stage. The auditorium design is subjected to that concern in every detail. Both have fan seating arrangement to emphasis that all the audience have the best possible sightlines.	
Differences	The percentage of seats that have acceptable sightlines is high. The stage illusion is achieved by complicated stage machinery. The backstage space used is very huge. Complex scenes is done by high manpower effort and costive. Sometimes the scene isn't that successful as designed to be. The sense of perfect immersion and illusion wasn't reached as Wagner dreamed.	The percentage of seats that have acceptable sightlines is less. The stage illusion is achieved by a combination of virtual and real, between multimedia and one huge mechanical machine on stage. Due to the installation of the Ring machine, the production cost is very high. But the integration of technology is very promising to reduce cost impact later. The only backstage used is the side stage for restoring the ring machine. The sense of perfect illusion is reached as Wagner dreamed

TABLE 6.1-3: CONCLUSION COMPARISON BETWEEN BAYREUTH FESTSPIELHAUS & METROPOLITAN OPERA STAGE

6.2. CASE STUDY (2): COMPARISON BETWEEN 3 DEGREES OF VIRTUAL REALITY ENVELOPING THE ADUTORIUM

6.2.1. GYEONGJU VR THEATER (NON-ENVELOPED IMMERSIVE THEATER)

6.2.1.1. PROJECT DESCRIPTION

Gyeongju VR Theater was built for the Gyeongju World Culture EXPO 2000, held in Korea. VR movie, "Intro the Breath of Sorabol," was the theme movie and was seen by almost one million people. The aim of designing and building the VR Theater was to construct a versatile public demonstration for VR technology as a new medium for interactive storytelling of diverse kinds of artistic expression and edutainment of virtual heritage to the public. (Changhoon Park, Sang Chu l Ahn, Yong-Moo Kwon, Hy oung-Gon Kim & Heedong Ko, 2003)

6.2.1.2. SUBJET OF STUDY

The reason of choosing such project for study is to give an example of implementing a VR technology System in a traditional theater to convert it into non-enveloping immersive theater. The implemented VR tool is projecting images on flat cylindrical screen on stage which is interactive with actors and audience. The project seemed to be successful in keeping the attention of the audience throughout the show and made their experience enjoyable. Among approximately 1.7 million visitors for the Gyeongju World Culture EXPO 2000, more than 67% rated the VR show as the best out of a dozen other shows. According to Changhoon Park, the success is thought to be owed to two main factors:

- The technology remained invisible, which kept the audience focused on the contents.
- Operations of the complex hardware systems, projectors, computers, and ventilation system were all remarkably stable with few failures: fewer than ten shows were affected by technical difficulties out of 2,500 shows since its opening in September 2000.

This demonstrates that the technology for running a fully automated VR theater is mature and ready for public deployment in various forms, depending on the application needs. (Changhoon Park, Tomohiro Tanikawa, Koichi Hirota, Michitaka Hirose,Hyoung-Gon Kim, Heedong Ko, 2004)

6.2.1.3. MAIN FEATURES OF THE GYEONGJU VR THEATER:

	Main features of the Gyeongju VR Theater

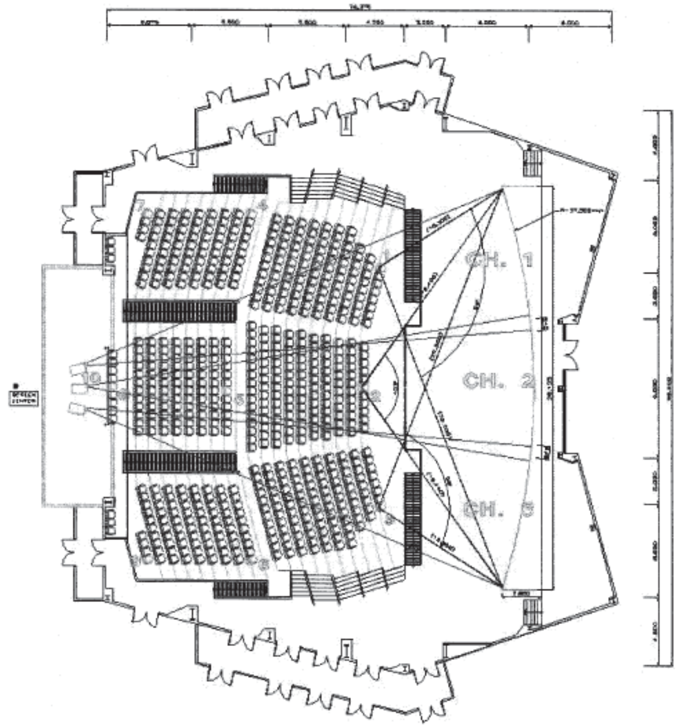
<table>
<tr><th colspan="2"></th><th>Main features of the Gyeongju VR Theater</th></tr>
<tr><td rowspan="3">Auditorium design</td><td></td><td>

FIGURE 6.2-1: THE LAYOUT OF THE INTERIOR DESIGN. (CHANGHOON PARK, SANG CHU L AHN, YONG-MOO KWON, HY OUNG-GON KIM & HEEDONG KO, 2003)</td></tr>
<tr><td>Original plan</td><td>The theater was already in place from Expo 1998 and used for film projection display.
The building was 36 m wide, 36.75 m in depth, with tapered heights from 14 to 10 m,
Seating capacity is 1,000 audiences for each show.</td></tr>
<tr><td>Plan modifications</td><td>The main consideration in designing the theater was to host as many visitors as possible because they expected close to two million visitors for the Expo 2000.
For implementing a VR technology, a new seating arrangement was achieved with a capacity of 651; the seats were arranged in three columns, and front/back rows and seats in either side of the middle column were skewed toward the center of the display screen to provide comfortable viewing angles.
The interior design proceeded with close attention paid to how the hall would be used for various public VR demonstrations for later exhibitions.
For efficient and safe entrances and exits, each step was made wide and low: the slope of the access door staircases was gradual and the highest in the back was 2.5 m above the ground.</td></tr>
</table>

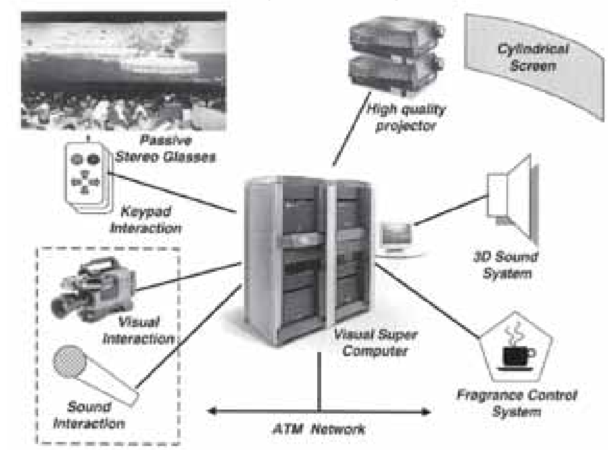
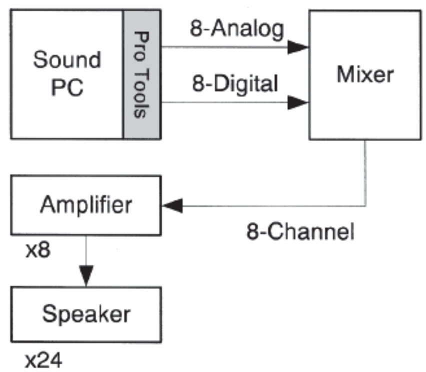
<table>
<tr><th colspan="2"></th><th colspan="2">Main features of the Gyeongju VR Theater</th></tr>
<tr><td rowspan="7">VR Hardware System</td><td></td><td colspan="2">The VR Theater facilitates an immersive environment by automatically controlled visual, aural, and olfactory rendering


FIGURE 6.2-2: HARDWARE FACILITIES OF THE GYEONGJU VR THEATER. (CHANGHOON PARK, SANG CHU L AHN, YONG-MOO KWON, HY OUNG-GON KIM & HEEDONG KO, 2003)</td></tr>
<tr><td rowspan="5">Screen</td><td>Size</td><td>27 * 8 m cylindrical screen with a radius of 37 m was erected vertically</td></tr>
<tr><td>Display</td><td>Passive stereo display</td></tr>
<tr><td>Type</td><td>Harkness Hall spectral screen that was manufactured meticulously in environmentally controlled factory and could be installed on a curved frame (highly reflective, and any impurities on the surface can become glaringly obvious).</td></tr>
<tr><td>Geometry</td><td>The screen frame was cylindrically curved with a radius of 37 m</td></tr>
<tr><td>Advantage</td><td>- Made the intensity of the reflected light as even as possible for the audience.
- Minimized the disparity of the intensity difference of reflected light from the screen to the viewers.</td></tr>
<tr><td>Projectors</td><td colspan="2">
FIGURE 6.2-3: DOUBLE-STACKED, SIX-PROJECTOR ARRAY FOR PASSIVE STEREO GENERATION.</td></tr>
</table>

	Main features of the Gyeongju VR Theater	
	Type	CRT projectors. six double-stacked projectors were used with a resolution of 3780 x 1024 pixels and a brightness of 4000 ANSI lumens.
	Location	Because the throw distance of the CRT projectors were only 10 m, it had to be stationed in the middle of the theater or in front of the theater, which greatly reduced the theater capacity.
	Advantage	They were most versatile in geometry correction and edge blending for tiling images from multiple projectors seamlessly and were most adaptive to screen geometry.
Computer Image Generator	System Type	SGI Onyx2 system with six IR2 graphics pipelines for interactive rendering of the virtual environment.
Computer Image Generator	Capacity	The computation was powered with fourteen 300 MHz R12000 MIPS process and 2 GM of RAM. The graphics pipelines provided an additional 64 MB of fast texture memory.
Computer Image Generator	Disadvantage	As the modeling task required close attention to the details reflecting the archeological findings and historical references faithfully, the size of the visual database was well over the limit of even the Onyx2 system. So, it was a major challenge to realize 30 fps images.
Key pad input device	 FIGURE 6.2-4: DESIGNED AND INSTALLED KEYPADS FOR AUDIENCE INTERACTION.	
Key pad input device	Usage	The 651 input keypads were the input channel for audience interaction. It was to provide interaction devices for the audience to let them experience the difference of VR from other film-based shows.
Key pad input device	How it works?	The interaction keypad was designed to have six keys (four directional and two selections). The audience was divided into three groups according to the seat groups. They used color to help people easily identify their group, with red, yellow, and blue assigned to the three groups. These colors were not applied to the seats directly, but to interaction keypads attached to every seat
Key pad input device	Advantage	It gave the ability for the audience to interact with three different scenarios.

		Main features of the Gyeongju VR Theater	
		Disadvantage	Interactive tool was through Key pad as computers. Not all the audience may get to it easily as other interactive tools. In other shows, it should be either changed to adapt the new show interaction demands or the show itself must be restricted to such interactive tool.
	3D Sound	 FIGURE 6.2-5: CONFIGURATION OF EIGHT-CHANNEL SURROUND SOUND SYSTEM.	
	3D Sound	Components	24 speakers and two control room monitor speakers
	3D Sound	Speaker Location	Four front bottom speakers behind the perforated screen, two front subwoofer speakers, eight front top and rear speakers, six speakers mounted on the ceiling, and two bottom stand subwoofer speakers underneath the access door.
	3D Sound	Sound Source	Wireless microphone, CD, and a PC controlled by Pro Tools with sixteen channels output to the audio mixing console, Yamaha O2R, as input sources
	3D Sound	3D surround sound	The sound system was designed to provide 3D surround sound in eight channel settings as well as vibration by the subwoofers attached to the access floor underneath the seats.
	Aroma Control	Installation	Air ducts were installed underneath the floor for ventilation and release of fragrance. The air compressor was stationed outside of the front side of the theater, and the main air duct was buried underground to be brought into the theater. The main duct was divided into multiple ducts under the access door, and vents were installed in the stairway steps to minimize the air intake and exhaust time period for interactive aroma display.
	Aroma Control	How it works?	The aroma generator had five containers for liquid fragrances and its controller was connected to a server in the control room so that the computer could select the type of fragrance and control the release time. The generator dropped the selected fragrance liquid onto a heated plate, it was released into the air duct, and the ventilation system carried the aroma throughout the theater.

	Main features of the Gyeongju VR Theater
Conclusion	The main challenge in implementing virtual reality in a traditional film theater is the arrangement of seating in order to achieve the best sightlines for stereoscopic image. In case of designing a new theater, the main element that affects the architecture of the auditorium is projection considerations. Otherwise, implementing VR projection in a non VR theater always reduces the seating capacity of the auditorium. The integration of projections should be hidden in the interior design of the theater to prevent the loss of immersion feeling. The most common type of implementing VR Technology in existing theater space, especially to a movie theater space, is projecting images on flat curved screen. The introduction of 3D sound system in a VR Theater can be achieved by adding subwoofers beneath the seating floor to increase the feeling of immersion In VR theaters, the image must reflect the result of the user interaction in real time. Creative and friendly use input devices are one of the main concerns of designing the audience chair. With the advancement of digital cinema equipment and real-time computer image generation, VR Theater will eventually replace IMAX film theaters. Interactive and real-time capabilities, combined with high-resolution immersive imagery, create a much richer understanding of any film performance.

TABLE 6.2-1: MAIN FEATURES OF THE GYEONGJU VR THEATER ILLUSTRATED BY (CHANGHOON PARK, SANG CHU L AHN, YONG-MOO KWON, HY OUNG-GON KIM & HEEDONG KO, 2003)

6.2.2. THOLOS THEATER (PARTIAL- ENVELOPED IMMERSIVE THEATER)

6.2.2.1. PROJECT DESCRIPTION

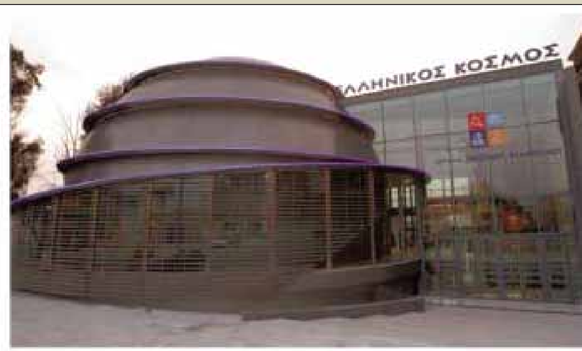
The Foundation of the Hellenic World (FHW), based in Greece, is a non-profit cultural heritage institution working to preserve and disseminate Hellenic culture, historical memory and tradition through the creative use of state-of-the-art multimedia and technology.(Dimitrios Christopoulos, Panagiotis Apostolellis & Abraham Onassiadis) The “Tholos” has been designed as a Virtual Reality museum, which will host FHW’s digital collections making them accessible to the public. These collections are testimonies of high cultural value, as they are developed and composed based on original and internationally innovative procedure of research, documentation and visualization of the historical and archaeological information. (FOUNDATION OF THE HELLENIC WORLD, 2006)

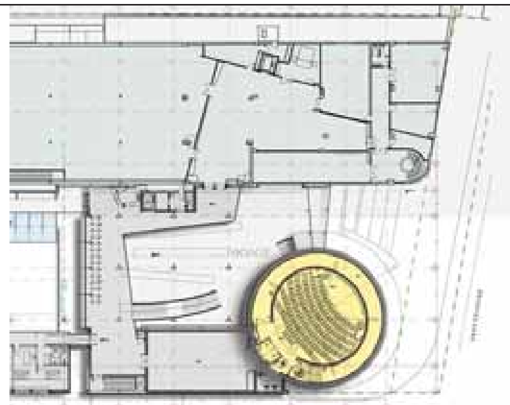
The "Tholos" resembles a planetarium regarding its natural and morphological characteristics. However, their only common characteristic is the semi-circular shape of the projection surface. The exterior shape of the "Tholos" refers to a whirling celestial body. It a sensation that is rendered through the processing of surfaces and the selection of materials, such as the successive rings that surround the external shell and the special lights that make it stand out during the night. Thus, the "Tholos" becomes a symbol of Hellenism and characterizes Pireos street. (Dimitrios Christopoulos, Panagiotis Apostolellis & Abraham Onassiadis)

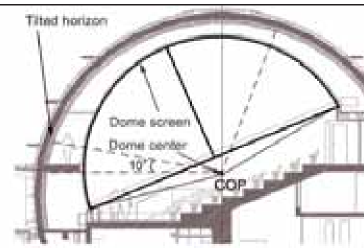
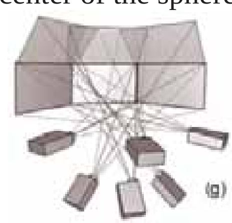
6.2.2.2. SUBJECT OF STUDY

This project was chosen to be an example for partial-enveloping immersive theater. It presents a unique type for Digital Dome Theater. It is a building of exceptional architectural design and with unique technological infrastructure. The peculiarity of the ”Tholos” is its ability to project onto projection surface, with an inclination of 23 degrees, fully interactive content. The main purpose for implementing VR in such theater is that the shows will be interactive, controlled by the spectator, and not static. It is a unique experience of immersion into the virtual world, which is characterized by immediate response, flexibility, originality and liveliness.

6.2.2.3. MAIN FEATURES OF THE THOLOS THEATER

		Description
Architectural design		 **FIGURE 6.2-6:** A DOME VR THEATER (FHW). (ATHANASIOS GAITATZES, GEORGIOS PAPAIOANNOU, DIMITRIOS CHRISTOPOULOS, GJERGJI ZYBA, 2006)

		Description	
	General	The building of the "Tholos" which covers an area of 2,256.68 m2, It is a shell that includes a semi-circular hall for digital shows, with concave interior space	
	Main hall	 **FIGURE 6.2-7:** THE PLAN OF THOLOS THEATER BY (FOUNDATION OF THE HELLENIC WORLD, 2006) It consists of a compact exterior circular shell In the interior, there is an inclined level where the spectators' seats are located amphitheatrically with capacity of 132 people. Access to the hall takes place through the unified area of entrance-reception, where visitors arrive either through Pireos street or through the Cultural Centre's underground parking area and through the atrium.	
	Reception	The reception area has the form of a hypostyle hall, where three columns support a wavy roof. On the roof there are fissures that provide the interior with ample lighting.	
	Construction	The shell of the "Tholos" is constructed by armed cement, which is sheathed by stainless grid. The sphere is surrounded by metallic "rings" that contribute to the image of a celestial body, but are also useful in the lighting of the shell. The semi-circular screen (Dome Screen), where digital projections take place, is constructed by perforated aluminum leaves on a metallic frame and is based on a parametric wall.	
VR Hardware	Screen	Size	13m in diameter, tilted 23 degree
		Display Module	TiDE (Tiled Display Environment)
		Geometry	Tilted hemispherical reflective surface

			Description
		Advantage	The horizon is tilted in the main direction of projection. As a result, the projection dome brings some comfort. It is a display module that operates as a projection matrix configuration mediator between the actual rendering procedure and the graphics outputs of a system. It can switch from one setup to another in real-time, as well as re-calculate the projection matrices according to the tracked input.
	Projectors	Image	 **FIGURE 6.2-8:** COP (CENTER OF PROJECTORS) IN THE CENTER OF THE SPHERE
		Type	6 pairs of seamlessly blended SXGA+ projectors
		Location	Projectors are placed mechanically in certain places in the dome so that all the projectors have single center of projector that should be in the center of the sphere  FIGURE 6.2-9: PROJECTORS ARRANGEMENT FOR DOME DISPLAY
		Advantage	The dome uses passive stereoscopic technology due to its low cost and high flexibility. It enables the splitting of the rendering load for a tile into separate graphics cards and drives them through a compositing matrix to the projector, for better performance scalability.
	Comp. Image Generator	System Type & application	- EVSSyncer; an application-independent library to handle data exchange and synchronization. - Twelve projectors and cluster PCs are chosen, each projector being powered by one machine and each pair of projectors/machines provide the stereo imagery for one of the six tiles on the surface.

		Description	
	Joystick input device	 **FIGURE 6.2-10:** INTERACTION SEATS	
	Joystick input device	Usage	Each seat provides a 2-axis joystick with analog values [0-1] and 4 buttons with discreet values [0/1].
	Joystick input device	How it works?	A custom PC interfaces the input hardware and communicates the data over UDP connection to the master.
	Joystick input device	Advantage	Increase customer participation every seat has its own unique controls
	Joystick input device	Disadvantage	Interaction options are limited down into 2 options (0-1).
	3D Sound	Components	Multiple subwoofer, stereo boxes and a special sound subsystem PD to handle, playback and synchronize the sound media.
	3D Sound	Speaker Location	Placed at specific positions behind the dome surface to provide immersive surround conforming to THX or Dolby Surround specifications.
Conclusion	The digital Theater Dome resembles the planetarium in main architectural considerations. All integrated systems; sound, light, projections, HVAC should be located and well designed behind the curved perforated screen which gives highly acoustic isolation. The main additive value by this theater is giving a real-time interactive system which can offer a much more exciting experience and can turn each show into a performance where the spectators participate actively in the unraveling story. A real-time dome display system can combine pre- rendered and real-time graphics in a seamless manner, as well as incorporate interactive, live on-stage action. The possibilities are limitless, provided that a flexible, extensible and sustainable infrastructure is properly designed and built.		

TABLE 6.2-2: HARDWARE SYSTEM COMPONENT OF THE THOLOS THEATER ILLUSTRATED BY (FOUNDATION OF THE HELLENIC WORLD, 2006), (CHRISTOPOULOS D., GAITATZES A., PAPAIOANNOU G., ZYBA G, 2006) & (DIMITRIOS CHRISTOPOULOS, PANAGIOTIS APOSTOLELLIS & ABRAHAM ONASSIADIS)

6.2.3. FULL DOME THEATER (FULL ENVELOPED)

6.2.3.1. PROJECT DESCRIPTION

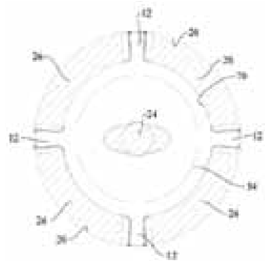
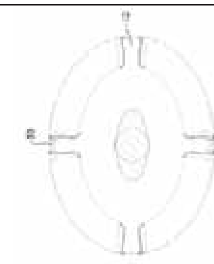
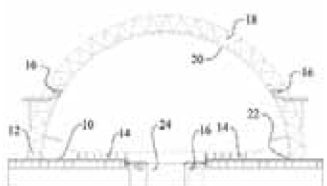
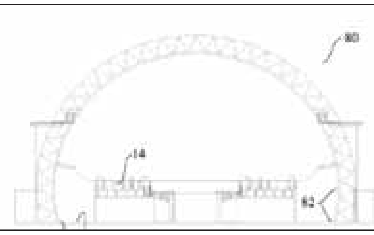
It is a patent by Cecil Magpuri in USA for a new type of interative VR Dome Theater. By his patent, the VR theater will be completely immersed and audience will be completely enveloped by the screen even the floor. The patent is a dome shape theater with a reflective floor. Audience members may sit or stand on a central platform viewing area surrounded by the screen. Audience members may access the viewing area via a tunnel passing under the reflective floor, by a movable bridge, or by passageways between divided sections of the reflective floor. A compound curved screen may alternatively lower from above to surround the viewing area. A 2D/3D projection system may be used to create images on the screen. Integrated special effects located throughout the theater can be synchronized with the media presentation. It is an object of the invention to provide an improved motion picture experience capable of showing a screen image to an audience, where the audience will perceive an illusion that they are viewing the images within a sphere or an ovoid. (Magpuri, 2010)

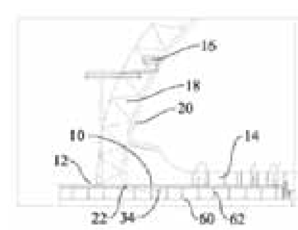
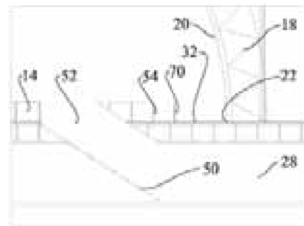
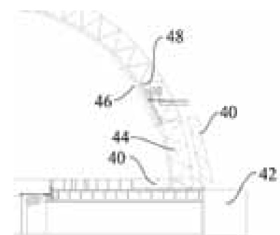
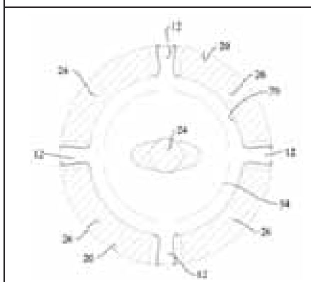
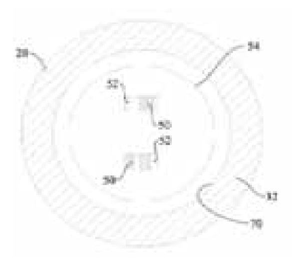
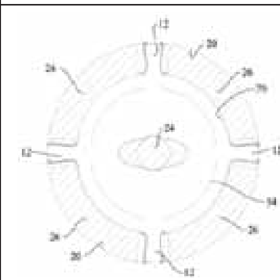
6.2.3.2. SUBJECT OF STUDY

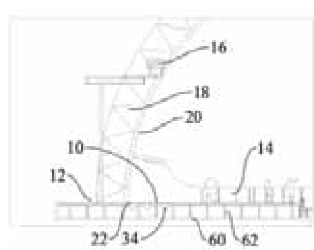
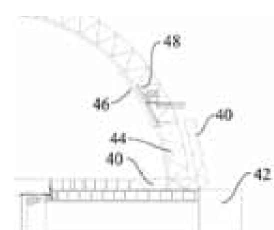
The reason of choosing such patent for this case study is to present an ideal example for the full-enveloped immersive theater. This patent will shift the concept and design approach of Film Theater into further expectations. By this theater, the audience is completely changed from passive observers into the main core and focus of the theater. The subject of study in such theater is the different proposals and alternatives given by such theater for experiencing VR performance.

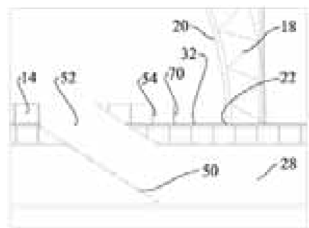
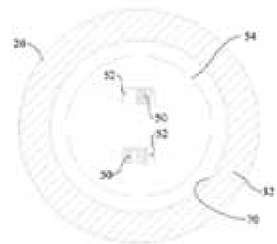
6.2.3.3. MAIN FEATURE OF "VIRTUAL REALITY DOME THEATER" PATENT

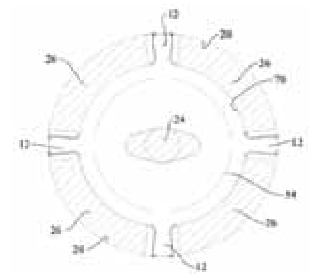
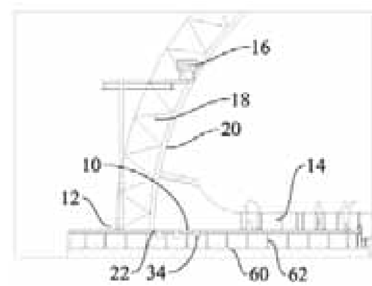
		Description
	General	An entertainment structure in the form of a dome-shaped theater that had a screen formed in a circular or elliptical shape. The size of the theater can vary based on the specific application of the theater and the visual content to be used.

<table>
<tr><th></th><th></th><th colspan="2">Description</th></tr>
<tr><td rowspan="6">Main Hall Design</td><td rowspan="3">Main hall</td><td>Circular Plan</td><td>Elliptical plan</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">The interior of the structure may generally be a circular, near circular or elliptical shape. Members of an audience may enter the theater through subterranean, surface level or elevated bridges or tunnels before the cinematic presentation begins. Alternatively, the audience may be mechanically moved into the theater on seating (or standing) platforms.</td></tr>
<tr><td rowspan="3">Seating arrangement</td><td>Non-elevated platform</td><td>Elevated platform</td></tr>
<tr><td></td><td></td></tr>
<tr><td>The sitting or standing arrangement may also range in circumference from 180 degrees to 360.
If seats are used in the theater, they can be equipped with a variety of effects including, scent, neck blast, wind blast, leg tickler and seat rumble.
If the audience views the presentation while standing up, rather than being seated, the audience members can more freely turn to view any area of the screen, including the areas directly behind them.</td><td>Rather than just having tier upon tier of stadium seating, the present theater may have an elevated and tiered viewing area in the center of the theater so that the audience, whether seated or standing within the viewing area, feels immersed in the images on the screen.
If the viewing area is tiered, each member of the audience has a generally unobstructed view of the screen.
The viewing area may be 1-10 meters above the floor.
The screen extends below the viewing area, with the bottom edge of the screen near or at the floor.
The viewing area may be arranged so that the section of the screen below the viewing area is visible, but the floor is not. Alternatively, a reflective surface may be provided on the floor between the screen and the viewing area.</td></tr>
</table>

<table>
<tr><th></th><th></th><th colspan="4">Description</th></tr>
<tr><td rowspan="6"></td><td>Seating capacity</td><td colspan="4">The viewing area may have capacity for one or more audience members, up to several hundred audience members, or more. The audience members may be standing or sitting in the viewing area and face radially inwardly or outwardly.</td></tr>
<tr><td rowspan="5">Exit</td><td colspan="2">Exit from the circumference</td><td>Exit from the center</td><td>Exit by movable bridge</td></tr>
<tr><td colspan="2"></td><td></td><td></td></tr>
<tr><td colspan="2"></td><td></td><td></td></tr>
<tr><td>Exit from the circumference</td><td colspan="3">The theater may have one or more entrances and exits to allow the audience members to enter and exit the audience viewing area.
If the theater is set up for the audience to stand in the viewing area, lean or guide handrails or bars may be provided in the viewing area, typically in concentric rings.
The reflective floor is provided in sectors that are separated by the entrance/exit passageways.
The passageways are conventional non-reflective floor materials, such as carpeting, since the audience walks on these surfaces. A barrier rail or other structure may be provided between the reflective floor sectors and the audience viewing area, to discourage or prevent the audience from walking or standing on the sectors.</td></tr>
<tr><td>Exit from the center</td><td colspan="3">An alternative design which allows for a continuous reflective floor ring uninterrupted by any entrance or exit. The audience enters the viewing area via a tunnel below the reflective floor.
Stairs, ramps, escalators or elevators then lead up from the tunnel to entrances/exits in the viewing area. The entrances/exits that interrupt the reflective floor are not used or needed, and the reflective floor may then be provided as a continuous ring.</td></tr>
</table>

<table>
<tr><th></th><th></th><th colspan="3">Description</th></tr>
<tr><td rowspan="8"></td><td></td><td>Exit by movable bridge</td><td colspan="2">The audience enters and exits the viewing area via a movable bridge.
During audience movement into or out of the viewing area, the bridge is down and extends over the reflective floor through a bridge door in the screen.
The section of screen at the bridge doorway is temporarily lifted up or to one side and out of the way by an actuator
. After the audience is in the viewing area, the bridge is lifted up, and/or pulled back and out of the bridge doorway via a bridge mover.
The actuator moves the screen section into the bridge doorway. The show in the theater then begins.
After the show, the bridge is moved back into the bridge doorway.</td></tr>
<tr><td rowspan="7">Floor Construction</td><td>Floor setting</td><td colspan="2">A reflective floor surface, such as a mirror, may be provided around the perimeter of the theater, so that it substantially completely surrounds the viewing area.
The reflective floor surface reflects the image on the screen. Thus, even if the audience looks directly down towards the bottom edge of the screen, the reflected image appears to extend beyond the plane of the actual floor. Hence, the audience has a greatly extended viewing, and perceives the illusion that the theater is a continuous sphere or ovoid.
The image projected onto the lower section of the screen may be adapted for this purpose. For example, the lower section of the image may be a landscape, seascape, outer-space scene, or similar image where the reflected image from the floor surface is visually consistent with the media program.</td></tr>
<tr><td colspan="3">Continuous floor</td></tr>
<tr><td colspan="2">Circumference Exit</td><td>Bridge Exit</td></tr>
<tr><td colspan="2"></td><td></td></tr>
<tr><td colspan="3">The reflective floor may be spaced apart above the structure floor on risers, with sub-floor lighting provided below the reflective floor and above the structure floor.
Also the alternative design of movable bridge allows for the reflective floor to be provided as a continuous ring</td></tr>
<tr><td colspan="3">Un-continuous floor</td></tr>
</table>

<table>
<tr><th></th><th></th><th colspan="3">Description</th></tr>
<tr><td rowspan="2"></td><td rowspan="2"></td><td colspan="2">
</td><td></td></tr>
<tr><td colspan="3">The reflective floor extends radially inwardly from the screen by a dimension DD. Dimension DD may vary depending on the dimensions of the theater and the type of image formation techniques used.
With projected images, if an audience member gets too close to the screen, the projected images may be blocked or degraded due to interference by audience member.
The barrier rail, if used, and the radial dimension DD of the reflective floor, are then positioned to prevent the audience from getting close enough to the screen to interfere with the image formation on the screen.</td></tr>
<tr><td rowspan="5">VR Hardware System</td><td rowspan="4">Screen</td><td>Size</td><td colspan="2">The size of the screen varies according to the size of he Dome</td></tr>
<tr><td>Location</td><td colspan="2">The screen may be moveable relatively to seating or to the standing space in the viewing area. For example, the screen may be moveable from a raised position, when the audience enters and exits the theater, to a lowered position during the cinematic presentation.
The screen may be hidden in a ceiling mount.
Conversely, the screen may be fixed and the audience viewing area lifted up to the screen, after the audience is seated or moved onto the standing space of the viewing area.</td></tr>
<tr><td>Geometry</td><td colspan="2">Whether it is a circular or elliptical shape, the screen generally entirely encircles the audience viewing area, providing continuous 360-degree+image viewing.
The screen may also curve partially below the audience, so that when they look down, their line of sight will intersect with the screen. Specifically, the lower edge of the screen may be positioned at, or just a few centimeters above, the theater floor on which the audience is seated or standing</td></tr>
<tr><td>Advantage</td><td colspan="2">The screen isn’t a permanent element. It is flexible and provides sustainable usage for the space.
It gives a highly immersive feeling due to its extend beyond the audience viewing area. It has strong connections with the reflecting floor.</td></tr>
<tr><td>Projectors</td><td>Type</td><td colspan="2">A 2D and/or 3D projection system may be oriented within the structure to project images on the entire screen.
Projection overlap and image edge blending may be used. Alternatively, other non-projecting image forming techniques may be used, such as having the screen itself generate the images, for example via LCD, plasma, DLP, etc.</td></tr>
</table>

<table>
<tr><th></th><th></th><th colspan="3">Description</th></tr>
<tr><td rowspan="8"></td><td rowspan="4"></td><td rowspan="3">Location</td><td>Dome Circumference</td><td>Dome Circumference</td></tr>
<tr><td></td><td>
</td></tr>
<tr><td>Projectors maybe integrated in the core of the dome in the special effect Core</td><td>Additional projectors may be located at other positions in the theater, and/or behind the screen to provide rear image projection.</td></tr>
<tr><td>Advantage</td><td colspan="2">The projection system is flexible and may blend different projection systems at the same time.
The projection system is well hidden and integrated in the dome structure which provides higher sense of immersion.</td></tr>
<tr><td>Computer Image Generator</td><td colspan="3">The controller may be operatively integrated with the media presentation, and operable in response to a signal or signals embedded in the media or emanating from the projection system.
Most conveniently, the controller includes a microprocessor for which, in either case, the projector or projector system is cued by the microprocessor.
The electronic control system thus may be synchronized with the sound and the projected media to give the viewer a vivid sensation of being completely immersed in the action on the screen, as if being there.</td></tr>
<tr><td rowspan="3">Sound , Light and special effects</td><td>Components</td><td colspan="2">An electronic control system may be used to synchronize the sound, lighting, and special effects with the visual images on the screen, to give the viewer a vivid sensation of being completely immersed in the images on the screen, as if being there.
The system may include a number of variations including a variety of seating orientations, as well as visual, visceral, tactile and audible sensations which simulate the sensations of being in a particular environment, storyline, experience, and/or action.</td></tr>
<tr><td>Effects Location</td><td colspan="2">A special effects core may be provided at the center of the theater. The special effects core may include projectors, and special effects equipment such as fog generators, lasers, sound equipment, etc.</td></tr>
<tr><td>Speaker Location</td><td colspan="2">In one form, the entertainment structure may have surround sound audio components with a multi-channel system including a respective speaker unit on each channel of the system. Speakers may be mounted for the optimal level of audience immersion.</td></tr>
</table>

<table>
<tr><th></th><th></th><th colspan="3">Description</th></tr>
<tr><td></td><td></td><td>Lighting location</td><td colspan="2">The screen may be embedded with source lights in the form of strobes, LEDs or any other lighting elements. Lighting elements may also be located in other areas of the theater such as in the flooring or around the perimeter of the audience viewing platform. Such lighting elements may be operated independently or synchronized with the media presentation being viewed.</td></tr>
<tr><td></td><td>Illustration Key plan</td><td colspan="2">10: Reflective floor
12: Exits
14: Audience viewing area.
16: Projectors
18: screen structure.
20: A dome shaped screen.
22: lower edge of the screen
24: A special effects core
26: Reflective floor sectors
28: tunnel
30: Exit doors
32: Continues ring
34: Sub-floor lighting & Projecting up through the floor
40: Movable Bridge</td><td>42: bridge mover
44:Bridge door way
46: Section of screen
48: actuator
50: Stairs, ramps, escalators or elevators
52: Centric exits
54: Single hand rail ring
60: The structure floor
62: The floor riser
70: The barrier rail
80: Design of the elevated platform.
82: The section of the screen below the viewing area is visible</td></tr>
<tr><td>Conclusion</td><td colspan="4">The VR Theater is a very flexible designed theater in order to provide many alternatives for usages and shows that can be presented inside it.
The center of stage is for audience seating not for performers to act on. The main focus is the audience now giving dozens of possibilities for his interaction with performance, the actors and the other audience.
New experimental materials can be offered by such theater in the field of art, music and performance.
The theater provides high flexibility for the audience seating.
The theater is very transparent were all integrated systems are well designed and hidden.
The VR Theater can rapidly replace the traditional film theater due to its highly professional integrated systems and also because of the great development of VR technologies and their cost effectiveness.</td></tr>
</table>

TABLE 6.2-3: MAIN FEATURE OF “VIRTUAL REALITY DOME THEATER” PATENT BY (MAGPURI, 2010)

6.2.4. CONCLUSION COMPARISON

	Gyeongju VR Theater (Project)	Tholos Theater (Project)	Virtual Reality Dome Theater (Patent)
	Non-Enveloping Immersive theater	Partial-Enveloping Immersive theater	Full-Enveloping Immersive theaters
Auditorium Design	Traditional shape of Film Theater with fan-shape seating.	Dome shape with amphitheater seating configuration.	Dome shape with different and flexible seating configurations.
Auditorium Design	Seating capacity is less than traditional theater capacity due to sightlines considerations.	Seating capacity is very limited and subjected to the scale of the dome.	Seating capacity is very flexible according to performance type and needs.
Auditorium Design	The back row seating is steeper than traditional Film Theater.	The seating is steeper than traditional film theater as planetariums.	The seating steepness is flexible according to the arrangement of the tiers of seating.
Auditorium Design	The access and the exits to the theater are like traditional theater from behid	The access and the exits of the theater like as for planetarium from behind.	The access and the exits are very innovative; they can be form the circumference, the center or even by movable bridge.
Auditorium Design	The stage area is completely identified and isolated than the auditorium.	There the stage area for a performer or presenter is in one direction.	The elevated platform in the middle of the dome is for audience not for stage.
Auditorium Design	The auditorium plan is rectangular shape and doesn't affect the exterior architecture.	The auditorium has a dome shape and affects directly the exterior architecture.	The auditorium has a dome shape and affects directly the exterior architecture.
VR Components Integration	The screen is a fixed curved flat display and it surrounds them only in one direction as in traditional Film Theater. The audience feels less immersed.	The screen is fixed, tilted 23 degree and surrounds the audience 360 degree in a hemisphere shape. The audience feels more immersed but still can feel the presence in a theater.	The screen can be fixed or movable according to the facility and it surrounds the audience completely by using the reflective floor. The audience feels fully immersed and the theater is transparent.
VR Components Integration	The projection depends on 6 pairs of front projection due to the lack of space behind the screen. This resulted in reducing seating capacity and loosing sense of immersion.	The projection depends on six pairs of projectors, placed in certain places in the dome to have single center of projector that should be in the center of the sphere. They are well integrated and provide higher sense of immersion	The projectors can be rear projectors embedded in the dome structure or integrated in the center of the dome in the special effects core. They are well integrated in the dome and provide higher possibilities or combination of different projection systems

	Gyeongju VR Theater (Project)	Tholos Theater (Project)	Virtual Reality Dome Theater (Patent)
	3D sound system is provided by 24 speakers added integrated in the traditional form of the theater and other subwoofers beneath the seats floor.	3D sound system is provided by subwoofers well integrated behind the screen in the dome section.	3d sound system can be provided by flexible means according to the facility needs.
	The audience is interactive with the performance only through input keypad attached to the seat.	The audience is interactive with the performance only through input joystick attached to the seat.	The interactive tools are flexible and can be designed according to the facility and performance.

TABLE 6.2-4: COMPARISON CONLUSION BETWEEN GYEONGJU VR THEATER, THOLOS THEATER & VIRTUAL REALITY DOME THEATER

7. CHAPTER (7): CONCLUSION

The dominate shape of the known traditional theater that has been leading theater design for centuries is about to take its next shift. By studying the history of theater design in chapter one, it was found out that the last shift for traditional theater was due to the machine revolution, which strengthened the proscenium form in traditional theater. The theatrical experience since then still depends on directional linear forces from the stage to the passive audience. Through all these revolutions of new technologies in theater industries still the influence of such form is very strong. New technologies were only used in order to emphasis such form and to support the whole traditional theatrical experience.

By the end of the last century, there were many successive trials for creating new forms of theater spaces. These forms have aroused new needs and approaches to create new relationship between audience and stage. This relationship is a grid (non-linear) form of communication between them, where the audience has a role in the theatrical experience. He is turned to be active observer with an important impact. He is also turned to be the focus of the theatrical experience not the actor as used to be for centuries. So the main architectural considerations for such theater are going to be changed than they used to be for the traditional theater.

On recalling the main objective of this study; **studying the impact of introducing virtual reality in different theatrical fields**, it was found out that VR technology will be a leading technology through the different stages of the theatrical productions. To trace such impact, it was studied through taxonomy presented by Schrum. It is a continuum for digital theater starting from one end by the traditional theater that doesn't enhance any digital technology and the other end by a futuristic form of interactive holographic theater space that is totally virtual. The theaters that are studied in this continuum are: **"Traditional Theater", "Digitally-Aided Theater", “Multimedia Theater",** "**Digitally-Enhanced Theater**" & "**Cyber-Adapted Theater".**

"Traditional Theater" is studied in details in the first unit. In the first chapter, the linear forces acting upon the auditorium design from the stage are studied in different types of theater stages through historical presentation of each type. In the second chapter, the principles that still affect and influence the traditional theater design are carefully studied to be used as a comparison base with other new forms of theaters. In the third chapter, the traditional stage and its components are studied and analyzed to provide a full picture for the traditional theater stage. The main features of such theater can be summarized as follows:

- The stage area is the main focus point in the design of any traditional theater.
- The main objective of traditional stage is implementing theater illusion on the stage platform regardless the means, time, money and power consuming to achieve such purpose.
- To achieve such illusion, the backstage area turned to be a busy factory with very complicated machinery and technology.
- More boundaries between the audience and the actor due to the introduction of such complicated machinery and technology on stage.
- Audience should be completely isolated than backstage zone and misses the main happening on the stage platform which is the creation process of such creative illusion.
- The main concerns of such theater are:
    - The additive volume around the stage needed to support the traditional stage machinery is more than triple the stage volume.
    - The theater stage is very inflexible and unsustainable as it depends on physical presentation that can hardly be used more than one time.
    - The introduction of a creative scenic setting always lead to high costly modifications.

“**Multimedia Theater**" is studied in the third chapter. Multimedia Theater is a theater that can enhance many digital technologies, not only virtual reality, to support the new forms of theatrical production. The introduction of Multimedia on theater stage is considered a recent issue. The enhancing of multimedia theater isn’t considered in most of the recent theaters. A proposal of futuristic Multimedia Theater is presented in the third chapter. On applying such considerations on the traditional theater, some modifications should be added for the main architectural considerations of such theater in future.

On recalling the third objective of enhancing VR in theater; “Adding new and strong stenographic tools to theater stage to develop multimedia interactive theater performances such as dancing, music, drama …. etc.”, the impact of introducing VR to multimedia theater can be summarized as follows:

- It gave powerful tool to theater stage to open a new channel of connection between the actor and the audience in modern theater.
- The theater has changed from being a tool of imitating the real life inside a box into a communication method to the audience to discuss futuristic issues and dreams, to discuss unrealistic matters that lead to more creativity and innovation.
- In some modern interactive multimedia theater, the audience has changed from being a passive observer into a participant and sometimes an actor on the stage.
- The new Multimedia stage is highly flexible and sustainable.
- The interior of such theater is very sustainable and must respect the multimedia effect on it.
- The main concern in using multimedia on stage is the balance between reel and virtual so as not to have a disappointing image on stage.
- The synchronization between different elements on stage and multimedia as all should have one reference in space and time.

"Digitally-Aided Theater" is studied in details in the fifth chapter. The enhancing of virtual reality in the theatrical production started in earlier phase before being introduced on stage; the pre production phase. It is used for **"theater education"** and "**stage planning and design"**. This will lead us to the first and second secondary objectives for implementing virtual reality in this study; “**creating virtual theaters with unlimited design creativity for entertainment and education by using different VR systems”** and **“visualizing and examining the stage setting design during the conceptual design phase by using desktop VR Systems.”** Many applications are given for such purposes. Two of them are applied in this study in order to analysis the historical milestones of the traditional theater and to understand some of complex stage machineries used in that stage.

Most of theater education applications are desktop VR system depending on online-based projects. These applications are categorized in this study into two main categories; the reconstruction of theater heritage and second studying theatrical elements on stage. The main features of implementing VR in studying theater heritage can be summarized as follows:

- VR provides the students with great variety of scholarly materials.
- It offers them an interactive exploration in a virtual environment.
- Students can have alternative choices in the way they confront such historical data rather than those offered by conventional means of education.
- It also gives the students an opportunity to interpret many destroyed and lost theaters in a very feasible way.

As for studying theatrical elements on stage, the main features that were added in theater education in such application can be summarized as:

- It gives the chance for different disciplines to study and cooperate together in one virtual environment.
- It gives innovative channels for students to create complete virtual performances and study all the factors that affect such performance on stage.
- It provides the users with great digital library to help him in creating his own performance.

The enhancing of Virtual Reality in stage design is the main key for introducing VR to the whole theatrical production. It added new facilities and possibilities for creative designers in stage setting. It presented highly successful achievements to the extent that some of these designers thought about implementing VR life on stage. One of the remarkable applications in using virtual reality in stage design is The Mixed Reality

Stage. It is a mixed reality application. Using mixed reality in stage design has a great role that can be summarized as follows:

- Combining real and virtual objects to overcome the individual limitations of real and virtual planning environments.
- Providing multiple users with the means to creatively plan stage shows and to flexibly experiment with different ideas.
- Facilitating the approach of expressive planning tasks such as arranging objects in space and time.
- Providing powerful awareness mechanisms rather than limiting the user's freedom by rigid synchronization and locking mechanisms.

Due to the notable developments of VR systems, the applications of implementing such technology in theater pre-production phase are increasing rapidly to produce highly interactive and friendly used methods.

"**Digitally-Enhanced Theater**" is studied in two different approaches. First is enhancing VR in traditional stage where it emphasizes the traditional form of theater and gives it new creative and innovative possibilities on stage. Second is enhancing VR in nontraditional stage where completely new forms of theater buildings and spaces can be achieved. The forth objective; **replacing real 3D simulations by virtual environment and reducing the high consumption of money, time and material**, was the main reason of studying the enhancing of virtual reality on traditional theater stage. A comparison case study between 2 traditional stages is given to study such purpose in the last chapter. Both stages present the same traditional Opera into two different approaches. By such comparison between both stages setting the following points can be concluded:

- The stage setting of a traditional performance can easily depend on Multimedia rather than complex stage machineries and technologies.
- The complex sceneries like flying actors or even presenting water and forests on stage can easily be achieved by Multimedia rather than any conventional means.
- The stage illusion should be achieved by a combination of virtual and real.

- The huge volume of backstage won't be needed anymore in the new theater design.
- Due to the installation of the Ring machine, the production cost is very high. But the integration of technology is very promising to reduce cost impact later.
- For highly synchronization between different elements on stage, the movement by actors or even sets should be well tracked by using developed tracking systems as infrared cameras.
- The main challenge in using 3D presentation on stage is the percentage of seats that have acceptable sightlines is highly affected and needs to be considered in designing VR traditional theater.
- The sense of perfect illusion is reached as Wagner dreamed.

By recalling the last objective in implementing VR; "**adding new architecture approaches to form spaces that can highly implement Virtual Reality Technology**" three applications are studied. The first was introducing VR to a traditional proscenium theater. The following architectural considerations can be concluded:

- The main limitation by using virtual reality on stage is the great reduction of audience number due to visual considerations.
- The seat arrangement should be desgined with respect to the visual sightlines of real-time computer generated stereoscopic images.
- Side aisles seating can hardly be found in a proscenium theater that enhance VR on stage.
- Acoustics design should consider the integration of 3D sound and the location of the speakers.
- Cyclorama can be used as a main VR output display in a procenium theater to present real-time rendered scenes as backgrounds.
- Complex and imaginary scenes, such as flying actors and spinning walls that could hardly achieved by the traditional stage machinery, can be created on a VR enhanced stage by using Chroma-key special effects.

- The stage with VR can be completely different than the traditional stage. The role of stage tower and stage basement will be reduced and as a result their architectural dimensions and configuration will change.
- The dimensions of the rear and side stages will depend upon the depth needed for rear and side projections.

The second application was for another type of theater, theater-in-round. This type is one of the theater types that were recalled by the end of the last centuries. It limitations were discussed in the first chapter. Implementing VR in such type reduced some of its limitations. One of the main features of such application is using the ceiling canopies as projection screens were light and sound systems can highly be integrated.

In the third application, VR is implemented in a completely non-traditional theater. It presents a new type of theaters that can be aroused by using VR. It is considered a successful type of performance that gives new innovative possibilities for theater free spaces where there isn't any stage. The following presents the conclusion of such application:

- The enhancing of virtual reality gives other possibilities for creative untraditional theatrical settings that require new approaches in theater spaces to enhance such experimental theaters.
- On Enhancing mixed reality tools, the number of participants is very limited (6 participants). Sometimes this limitation is in the side of the performance but in others it is a challenging point that needs to be developed.
- Regardless the number of the audiences, they turned to be more active participant. Each audience acts, communicates and interacts with other participants, shares an interactive game installation and feels immersed in the mixed reality experience.
- The introduction of innovative mixed reality features such as the water rain curtain affected the theatrical experience and added new creative visual tools.

- The audience experiences a different kind of theatrical experience that can hardly be achieved within traditional theater. The experience will be more remarkable and unforgettable.

As for "**Cyber-Adapted Theater",** it is studied with relative to only one type of theater, the film theater. VR can be considered the future of Film Theater. It highly affected this type of theater not only as unique tool for presenting new form of interactive performance, but also by offering untraditional shapes for film theater. The approaches of designing Film Theater will be completely different than the traditional one. In this study, three types are studied for Film Theater according to the degree of enveloping for the display to the audience which is the main contradiction between it and traditional theater where it is studied according to the degree of enveloping for the audience to the stage. This shift in approaches presented new types of theaters. The main considerations of such types can be summarized as follows:

- The separation between the audience and the stage will completely disappear.
- The audience will be the main focus of the whole design.
- The design approach will be due to the degree of enveloping of the stage or the display tool to the audience.
- The number of audience will be flexible according to the degree of immersion required for the facility used by this theater.
- The intelligent integration of different projection, light, 3D sound and special effects systems will enrich the theatrical experience and will give more possibilities for new and creative performances.
- The theater will be transparent as non of the architectural elements inside the theater will be noticed by the audience.
- More flexible theaters are going to be achieved in future in order to implement new developments of VR reality systems.
- The entrances and exits if such theaters will be highly innovative.
- The interior of the space highly affect the exterior architecture of the theaters.

The main recommendations of this study for theater architecture can be simply summarized as follows:

- Theater education should be enriched by the new possibilities given by implementing desktop VR systems where different disciplines should study the theater in parallel and interact with each other in the same time.
- Architects have to achieve new approaches for designing traditional theaters by integrating mixed reality systems inside the traditional form of the common used theaters now.
- The theater architectural principles that influence the design of a traditional theater should be updated by the implementing of highly digital technology on stage. New architectural standards must be studied for theaters.
- The integration of such new systems should be highly intelligent thorough the architectural space to avoid any inconvenience to the audience.
- Architects should innovate new forms of free untraditional theaters for entertainment and education were audience and actors are in one space with no separation.
- The main architectural consideration in the new theaters form is the audience not the stage.

For future studies, the architecture design of completely virtual theaters can be studied. Such theaters can be highly implement innovative and creative design approaches as they are not forced by any physical laws of nature.

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8. APPENDICES

8.1. APPENDIX A: MUSICAL TERMS DEFINITIONS

Term	Definition
Balance	Equal loudness among the various orchestral and vocal participants.
Blend	A harmonious mixture of orchestral sounds.
Clarity/ Definition	The degree to which rapidly occurring individual sounds are distinguishable.
Dry or Dead	Lacking reverberation.
Echo	A long delayed reflection of sufficient loudness returned to the listener.
Envelopment	The impression that the sound is arriving from all directions and surrounding the listener.
Intimacy	The sensation that music is being played in a small room. A short initial delay gap.
Liveness	The same as reverberation, above 350 Hz
Presence	The sense that we are close to the source, based on a high direct-to reverberant ratio.
Reverberation	The sound that remains in a room after the source is turned off. It is characterized by the reverberation time, which has been previously defined.
Warmth	Low-frequency reverberation, between 75 Hz and 350 Hz.

TABLE 8.1-1: DEFINITIONS OF COMMON MUSICAL/ACOUSTICAL TERMS (LONG, 2006, P. 658)

8.2. APPENDIX B: THE HISTORY OF VR IN ART

I. Legible City - Jeffrey Shaw and D. Groeneveld (1989)

The Legible City by Jeffery Shaw is considered one of the pioneer interactive installations. Audience are seated on a stationary bicycle and ‘move' through streets projected onto the surface in front of them. The streets here are literally legible, lined not by buildings but by letters. (Media Art Net, 2004) In this interactive installation, the audience is not passive but interacts through the bar handles to give direction and the pedals to give speed. (Boucher, 2011)

FIGURE 8.2-1: THE LEIGIBLE CITY BY (MEDIA ART NET, 2004)

II. Home of the Brain - Monika Fleischmann and Wolfgang Strauss (1992)

Another pioneer artist that achieved an international recognition is Monika Fleishmann and Wolfgang Strauss by their interactive installation "Home of the Brain". In this immersive installation, one of the visitors dons a HMD (head-mounted display) helmet and a dataglove and physically as well as virtually moves through an installation that comprises screens that allow external observers from the visitors to see what he sees. (Boucher, 2011) The virtual interaction by one of the audience using the dataglove became a performance to the other audience as seen in **Figure 8.2-2**.

FIGURE 8.2-2: FLEISCHMANN, MONIKA; STRAUSS, WOLFGANG, «HOME OF THE BRAIN», 1992 BY (MEDIA ART NET, 2004)

III. Dancing with the Virtual Dervish - Diana Gromola, Yakov Sharir, and Markos Novak (1991-1994)

It is a very well known dancing performance where the virtual interior of the performance is a large-scale model of the Sharir's body, organs and all, exists in perpetual motion. At the same time, the dancer's real-world self is captured on video and projected into the virtual space. The immersion in VR is provided by stereoscopic HMD and other VR gear where the user dance and interact with the virtual body. This performance is projected on large screens around the performer as seen in **Figure 8.2-3** (Immersive Environments, 2009) & (Boucher, 2011). So the dancer body is dancing inside the virtual body and projected behind the dancer real body.

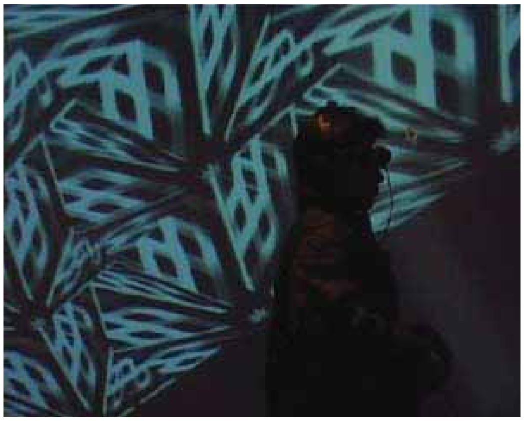


FIGURE 8.2-3: DANCING WITH THE VIRTUAL DERVISH BY (IMMERSIVE ENVIRONMENTS, 2009)

IV. Char Davies– Osmose (1995).

The Osmose by Char Davies is considered the most talked-about experience in the short history of VR art (Dixon, 2006). This installation consists of two spaces, one where a user (the "immersant") wears a HMD and a motion-capture vest equipped with breathing and balance sensors, and the other where spectators watch screens from which to see both the immersant's VR point-of-view and shadow as seen in **Figure 8.2-4** (Boucher, 2011). The interaction starts by the first breath by the participant to view a way into the forest. There are a dozen world-spaces in *Osmose*, most based on metaphorical aspects of nature. According to the participant breath and balance, he is able to journey anywhere within these worlds as well as hover in the ambiguous transition areas in between (Immersence Inc., 1995). So the interactive tool of such VR experience is through breathing.

FIGURE 8.2-4: OSMOSE INSTALLATION BY (ALAN B. CRAIG, WILLIAM R. SHERMAN, JEFFREY D. WILL, 2009)

FIGURE 8.2-5: DIGITAL STILL IMAGE CAPTURED DURING IMMERSIVE PERFORMANCE OF THE VIRTUAL ENVIROMENT OSMOSE (IMMERSENCE INC., 1995)

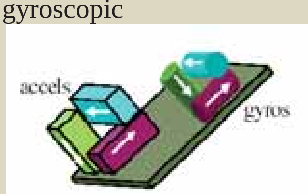
V. ConFIGURING the CAVE - Jeffrey Shaw, Agnes Hegedüs and Bernd Linterman (1996)

One of the notable examples of applying the CAVE system in art is ConFIGURING the CAVE by Jeffrey Shaw. The work utilizes the CAVE technology stereographic virtual reality environment with contiguous projections on three walls and the floor. (Agnes Hegedus, Bernd Lintermann, Jeffrey Shaw, 1996). Users transform imagery and sound within the CAVE by manipulating their life-size, puppet-like avatar as seen in Figure 8.2-6 (Dixon, 2006). By moving the puppet limbs the users control real time transformations of the computer generated imagery and the sound composition.

FIGURE 8.2-6: CONFIGURING THE CAVE (AGNES HEGEDUS, BERND LINTERMANN, JEFFREY SHAW, 1996)

8.3. APPENDIX C: BRIEF DESCRIPTION FOR DIFFERENT TYPES OF BODY TRACKING SYSTEMS

		Description
Electromagnetic  **Figure 8.3-1**: Electromagnetic tracking system by (Alan B. Craig, William R. Sherman, Jeffrey D. Will, 2009)	Components	Transmitter unit (can be mounted above the participant's head as in **Figure 8.3-1**) Receiver unit. (can be mounted to shuttering glasses as in image **Figure 8.3-1** or a head mounted display)
	Application	The transmitter generates a low-level magnetic field from three orthogonal coils in the smaller receiver unit worn by the user. The signal in each coil in the receiver is measured to determine its position relative to the transmitter unit which is fixed at a known location and orientation.
	Advantage	Small and convenient to mount on various devices. Have no line of sight Wireless systems have become available, reducing encumbrances on the participant.
	Limitation	Metal in the environment can cause magnetic interference. The short range of the generated magnetic field (range of 3-8 feet from the transmitter). Using multiple transmitters to extend the range is possible but difficult to implement.
Mechanical  **Figure 8.3-2:** Mechanical tracker used in the Grpsy motion to caputre suit by (Grigore Burdea, Philippe Coiffet, 2004)	Comp.	Transcoders mounted on physical linkages. (Example gloves or a more complex mechanical tracker as shown in **Figure 8.3-2**. It is a sensorized exoskeleton worn on a Lycra suit.)
	Appl.	The position of the end point can be calculated from the transcoders values.
	Adv.	Provides extremely accurate and precise position readings. Increase physical immersive sensation and decrease nausea. Exoskeletons provide force feedback. Used in Robotics
	Limit.	Physical attachments between the user and the real world often impede the user from moving in a natural way.
Ultrasonic  **Figure 8.3-3:** Basic ultrasonic tracking system	Comp.	Collection of transcoders. Transmitters (speakers) and receivers (microphones). Pass signal from one point to another.
	Appl.	By measuring the time taken from the signal to arrive, one can compute (using the speed of sound) the distance between the transcoders pair.
	Adv.	Cheap Small and light in weight.

	Description	
by (Alan B. Craig, William R. Sherman, Jeffrey D. Will, 2009)	Limit.	Not for noisy spaces. Line of sight required. Short range (few feet).
Optical	Comp.	Sensors (cameras) Infrared emitters (markers)
	Appl.	These devices use light to calculate a target's orientation along with position. The signal emitter typically includes a group of infrared LEDs. The LEDs illuminates in a fashion known as sequential pulses. The pulsed signals are recorded by the camera and then the information is sent to the processing unit of the system.
	Adv.	Accurate. Wide range.
	Limit.	Sight line is required The performance of existing optical trackers is adversely affected by ambient light and infrared radiation.
Video metric  **Figure 8.3-4:** the UCN ceilling trackers by (William R. Sherman, Alan B. Craig, 2003)	Comp.	Cameras (Example mounted on the user HMD and the ceiling as shown in **Figure 8.3-4**) Landmarks
	Appl.	Camera is fixed to the object to be tracked. The locations of landmarks in the space are known or discernible from other data in order to determine the absolute position of the sensing device.
	Adv.	Some AR systems already use a camera for input, so no added hardware required on the user.
	Limit.	Needs high computational resources to do the image analysis for locating landmarks.
Internal\ gyroscopic  **Figure 8.3-5:** Internal Tracker by (Savioja, 2010)	Comp.	Gyroscopes Accelerators
	Appl.	It uses electromechanical instruments to detect relative motion of sensors by measuring the change in gyroscopic forces, acceleration, and inclination.
	Adv.	No reference points needed (no range limit) Relatively cheap and fast. Move freely with the user in a big space Used in Maritime and flight navigation.

<table>
<tr><th></th><th colspan="2">Description</th></tr>
<tr><td></td><td>Limit.</td><td>Doesn't provide by itself enough information to determine location (used in conjunction stationary visual display)
The system needs occasionally to be manual realigned.</td></tr>
<tr><td rowspan="4">Neural\
Muscular

Figure 8.3-6: Muscular tracker by NASA researchers illustrated By (William R. Sherman, Alan B. Craig, 2003)</td><td>Comp</td><td>Small sensors attached to the fingers or limbs
Sensor holder in place</td></tr>
<tr><td>Appl.</td><td>The sensor measures nerve signal changes or muscle contractions and reports the posture of the tracked limb or finger to the VR system.</td></tr>
<tr><td>Adv.</td><td>Used in Tracking muscle oriented activities</td></tr>
<tr><td>Limit.</td><td>Not appropriate for tracking the location of the user.
Still under experiment and expensive</td></tr>
</table>

TABLE 8.3-1: DESCRIPTION OF DIFFERENT TYPES OF TRACKING SYSTEMS ILLUSTRATED BY (ALAN B. CRAIG, WILLIAM R. SHERMAN, JEFFREY D. WILL, 2009), (GRIGORE BURDEA, PHILIPPE COIFFET, 2004) & (WILLIAM R. SHERMAN, ALAN B. CRAIG, 2003)

8.4. APPENDIX D: BRIEF DESCRIPTION FOR VISUAL DISPLAYS

		Description
Stationary displays / Monitor based-Fish Tank  **Table 8.4-1:** Fishtank VR (monitor-based) by (William R. Sherman, Alan B. Craig, 2003)	Components	Standard computer monitor Sometimes a multiscreen approach Trackers: Monitor-top video camera for head tracking. Display tool Shutter glasses. Or Special filter over the monitor screen to create an autostereo effect. Input devices Keyboard, standard mouse, trackball, or 6-DOF pressure stick (e.g., the Spacetec Spaceball)
	Applicat ion	The system adjusts the perspective transformation to a user's eye position can simulate the appearance of stable 3D objects positioned behind or just in front of the screen.
	Advantage	The least expensive of the visual VR displays Easy to use. It is used Testing VR applications that are under development.
	Limitation	The user must face in a particular direction to see the virtual world. Less immersive than most other VR systems. Provides only a limited field of regard
Stationary displays / Projector based- Large Screens	Comp	Fixed-position screens. Projectors (mostly rear projectors) In future rear-projected systems and screen will be replaced by large, flat monitors (flat panel displays) Trackers: Head-orientation data tracker Display devices: Shutter glasses Polarized glasses

		Description
 **Figure 8.4-1**: CAVE System by (Mario Arturo Gutiérrez Alonso, Frédéric Vexo, Daniel Thalmann, 2008)  **Figure 8.4-2:** ImmersaDesk smillar to CAVE system but with lower cost by (William R. Sherman, Alan B. Craig, 2003)	Appl.	**Semi-immersive**: approach consists in positioning one or more users in front of a large rear-projection screen displaying the virtual world. Stereo glasses and 3D surround sound enhance the experience. **CAVE systems**: displays wrap screens around the participant, surrounding the user as much as possible with the visual representation of the world. **Allosphere**: is three-story-high cubical space comprises an anechoic chamber with a spherical display screen, 10 meters in diameter, surrounding from one to thirty users standing on a bridge structure.
	Adv.	Full field-of-view (FOV) coverage. For CAVE system but less for table or desk displays. Reduced amount of hardware worn by users. The ability of the user to continue to see the physical world while viewing the virtual world also improves the safety of the system.
	Limit.	Incomplete view of the virtual world (field-of-regard) Cost increase accordingly to the degree of surrounded screens and powerful computer is required to create a high-resolution image. Difficulty of masking the real world if desired.
	VR systems	CAVE Wall displays, and Table or desk displays
Head-based displays  **Figure 8.4-3:** Different types of head-mounted displays by (Mario Arturo Gutiérrez Alonso, Frédéric Vexo, Daniel Thalmann, 2008) 	Comp	Small and lightweight screens. Trackers For HMD, trackers are built right into the display unit. For BOOM, mechanical linkages are used.
	Appl.	They may have either one or two (for stereoscopic vision) small displays with lenses and semitransparent mirrors embedded in a helmet, eyeglasses, or visor. Most of them include speakers or headphones so that it can provide both video and audio output. Almost include a tracking device so that the point of view displayed in the monitor changes as the user moves her head.
	Adv.	Users can turn their head to see any direction. (100% field-of-regard) Require less space. Cheap More portable.
	Limit.	Cause nausea or a headache for the user. Most of them are heavy with cables. Limited to a single user at a time. Narrow field of view. User is completely isolated from people.

	Description	
Figure 8.4-4: Boom3c Device by (William R. Sherman, Alan B. Craig, 2003)	VR systems	Head mounted displays (HMD) Counterweighted displays on mechanical linkages (e.g., the *BOOM*) Small screens designed to display a virtual image several feet away (e.g., the *Private Eye*) Experimental retinal displays (which use lasers to present the image directly onto the retina of your eye)
Hand-based displays 	Comp	A screen small enough to be held by the user. Trackers: Traditional trackers are not used. Some may use GPS combined with internal trackers Trasmitters: Short-range television signal transmitter,
Figure 8.4-5: Use of handheld devices in VR applications by (Mario Arturo Gutiérrez Alonso, Frédéric Vexo, Daniel Thalmann, 2008)	Appl.	The image on the screen reacts to changes in the viewing vector between it and the viewer
	Adv.	It can be combined with either physical reality (as an augmented reality display), or in a screen-based virtual reality display such as a CAVE. It tends to not be very encumbering.
	Limit.	Provide very limited FOV. Are less immersive, except when used to augment a larger view (real or virtual).
	VR systems	Augmented reality applications. The binocular “magic-lens” Palm Devises.

TABLE 8.4-2: DESCRIPTION OF DIFFERENT TYPES OF VISUAL DISPLAY ILLUSTRATED BY (ALAN B. CRAIG, WILLIAM R. SHERMAN, JEFFREY D. WILL, 2009), (GRIGORE BURDEA, PHILIPPE COIFFET, 2004) & (WILLIAM R. SHERMAN, ALAN B. CRAIG, 2003)

8.5. APPENDIX E: MAIN COMPONENTS OF SOFTWARE INTEGRATED IN A VR SYSTEM

	Description
Laws of nature—simulation code	Governs the behaviors and interactions carried out by the objects in the world. Allows several explicit cases of behavior to be executed under specific conditions. Can have global behaviors such as gravity, plus individual rules that apply only to specific objects. May closely mimic the real world by adhering to mathematical descriptions of real physics.
Rendering libraries	Convert the form of the world from the internal computer database to what the user experiences. Generally include features to render the basic elements of a “scene” along with features to enrich the display.
VR libraries	Achieve rendering appropriate outputs depending on the user’s current position and actions. Acquire the necessary information about the participant by interfacing with tracking and other input hardware. Operate in “real time.
Ancillary software	The creation of a virtual reality experience also requires the use of various software in addition to the software required during the presentation of the experience. Independent user interface libraries might also be linked with a VR experience to allow the operator to control parameters of the experience.

TABLE 8.5-1: SOFTWARE COMPONENTS OF VR SYSTEM ILLUSTRATED BY (ALAN B. CRAIG, WILLIAM R. SHERMAN, JEFFREY D. WILL, 2009)

8.6. APPENDIX F: DISCRIPTION FOR TECHNICAL EQUIPMENTS SYSTEMS OF A PLANETERIUM

		System Requirements	
Technical Equipment	Projection systems	Planetarium projection	Projection of the naked-eye stars, the Milky Way, open star clusters, gaseous nebulae and galaxies Projection of Sun, Moon and planets Presentation of the rising and setting of all celestial bodies (diurnal motion), the changing aspect of the sky during the year (annual motion), the change of geographical latitude (polar altitude motion), and rotation about a vertical axis (azimuthal motion) Simulation of flights across the solar system and observation from other planets Didactic projections (astronomical coordinates, great circles, scales and markers) Dome lighting and special lighting effects Lift for lowering the projector
		Fulldome video projection	Fulldome images composed of multi-channel video projection Image generator Remote control
		Multivision slide projection	Projection onto several dome fields Cross-fading capability Zoom function Image rotation Projection with motion control about two axes
		Panorama & all-sky slide projection	360° full-circle panorama for horizontal domes Image projection onto the entire dome surface (360° x 180°) Duplicated sets of projectors for fading
		Effect projection	Astronomical effects: Satellites, comets, shooting stars ... Atmospheric effects: Lightning, rainbow, snow ...
	Sound and light	Sound system	Reproduction, mixing Voice transmission (microphone) Sound production Intermission music Simultaneous interpretation, playback of recorded foreign language narration
		Lighting effects	Sky blue Twilight Moonlight Straylight Equipment illumination Color light effects

		System Requirements	
		Auditorium and stage lighting	Intermission lighting Floodlights Stair and aisle lights Emergency lighting Bright lighting for cleaning and maintenance Control console and stage lighting
	Control and	Common control System	Director system for the common control of all partial systems Time-code-controlled synchronization
		Visitor interaction	Decision and selection via input units (one per seat) Calling up alternative or branch programs Test and evaluation of visitor responses
	Movie & Laser	Wide-angle movie projection	Wide-angle (about 160°) movie projection for tilted auditoriums Primarily: documentary or feature films, unrelated to astronomy
		Laser projection	Laser light effects (beam effects, scatter effects ...) Laser graphs, laser animations, logos, text, etc. Visual phenomena

TABLE 8.6-1: DISCRIPTION FOR TECHNICAL EQUIPMENTS SYSTEMS BY (ZEISS)

8.7. APPENDIX G: COMPARISON BETWEEN PLANETARUIUM OTHER IMMERSIVE DISPLAYS

Simulators and Omni Theaters	Planetariums
Simulators are required to produce graphics which are generated in realtime, necessitating powerful graphics engines with lower quality rendering.	The latest planetarium video projection systems utilize component level laser video disc technology such as the Sony CRV_ format with interpolation line doubling for playback. Images can therefore be rendered in non-realtime with much greater detail, but still retain some interactive qualities due to the rapid laser disc access times.
Simulators require user inputs to be directly linked to physical models which determine and limit image characteristics such as the motion path.	Planetarium shows are carefully scripted in advance, allowing the layering of complex effects sequences. These sequences or show segments can still be triggered in realtime, or used to enhance lower resolution realtime computer graphics projections.
Both simulators and omni theaters attempt to reproduce daytime outdoor scenery which causes the greatest contrast washout due to cross-dome scatter.	Much of the imagery in planetariums is projected against a black background, often with stars. The low ambient light environment prevents screen washout, provides a greater illusion of depth, and tends to hide any seams or imperfections in the projection surface as well as hiding the theater itself.

TABLE 8.7-1: COMPARISON BETWEEN PLANTERUIUM OTHER IMMERSIVE DISPLAYS BY (LANTZ, 1995)

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الملخص

إن تضافر استخدام تكنولجيا الذكاء الصناعي في صناعة المسرح قد أدى إلى تغير حقيقى في نهج التصميم المسرحي. كما أدى طرح تقنيات وتكنولوجيات جديدة على خشبة المسرح لزيادة تفاعل العروض المسرحية مع المشاهدين، التأثير الواضح على التصميم الداخلى والخارجي لفراغ المسرح.

من احدى التقنيات الحديثة التى طرحت عن طريق الذكاء الصناعي هي "الواقع الافتراضي" Virtual Reality. تلك التقنية من الممكن تنفيذها داخل تجربة المسرح بأساليب مختلفة وعلى عدة تطبيقات . إن بناء عالم افتراضي Virtual Environment قد يطبق داخل تجربة المسرح فـي عدة مراحل مختلفة، بداية من تصميم مبنى المسرح قبل انشاءه عن طريق صناعة عالم افتراضي كامل للمسرح من السهل اختباركل عناصر الرؤية والسمع به ،و نهاية بأن يكون إحدى أهم أدوات السينوغرافيا شديدة التفاعل مع الجمهورعلي خشية المسرح.

الهدف الأساسي من تلك الرسالة هو دراسة تأثير تطبيق تكنولوجيا الواقع الأفتراضي على التصميم الخارجي والداخلي لفراغ المسرح.

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