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Notes on anthropogenic risks mitigation management and recovery of ancient theatres' heritage

Qualitative assessment and recommendations

Naif Adel Haddad
Faculty of Architecture and Design, American University of Madaba(AUM), Madaba, Jordan and
Queen Rania Faculty For Tourism and Heritage, Conservation Science, Hashemite University, Zarqa, Jordan
Leen Adeeb Fakhoury
School of Architecture and Built Environment, German Jordanian University, Amman, Jordan, and
Talal S. Akasheh
CulTech for Heritage and Conservation, Amman, Jordan

Abstract

Purpose – Ancient theatres and odea are one of the most significant and creative socio-cultural edutainment centres of human history that are still in use. They stood and served as huge multi-functional structures for social, religious, propaganda and political meeting space. Meanwhile, ancient theatres' sites have an intrinsic value for all people, and as a vital basis for cultural diversity, social and economic development, they should continue to be a source of information for future generations. Though, all places with ancient theatre heritage should be assessed as to their potential risk from any anthropogenic or natural process. The paper aims to discuss these issues.
Design/methodology/approach – The main paper's objective is to discuss mainly the anthropogenic and technical risks, vulnerability and impact issues on the ancient classical theatres. While elaborating on relevant recent studies, where the authors were involved in ERATO and ATHENA European projects for ancient theatres and odea, this paper provides a brief overview of the main aspects of the anthropogenic qualitative risks and related issues for selected classical antiquity theatres. Some relevant cases are critically presented and investigated in order to examine and clarify the main risk mitigation issues as an essential prerequisite for theatre heritage preservation and its interface with heritage reuse.
Findings – Theatre risk mitigation is an ongoing and challenging task. By preventive conservation, theatre anthropogenic qualitative risks' management can provide a framework for decision making. The needed related guidelines and recommendations that provide a systematic approach for sustainable management and planning in relation mainly to "ancient theatre compatible use" and "theatre technical risks" are analysed and presented. This is based on identification, classification and assessment of the theatre risk causes and contributing factors and their mitigation.
Originality/value – The paper also suggests a new methodological approach for the theatre anthropogenic qualitative risk assessment and mitigation management, and develop some recommendations that provide a systematic approach for theatre site managers and heritage experts to understand, assess, and mitigate risks mainly due to anthropogenic and technical threats.

Keywords Heritage preservation, Risk assessment, Cultural sustainability, Planning conservation, Management of archaeological sites, Policies

Paper type Research paper

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1. Introduction and scope

Until recently, conservation of ancient Greek, Hellenistic and Roman theatres and odea have not received the required attention they deserve. However, many of their technical aspects have attracted recent interest such as for their acoustic qualities.

There are many reasons why theatres should be treated differently from other heritage sites. Actually, they should be seen as creative socio-cultural edutainment centres, because they stood and served as huge multi-functional structures for social, religious, propaganda and political meeting space (Haddad *et al.*, 2007; Haddad, 2008). They give proof of a common heritage that can promote the mutual understanding and the dialogue between cultures. These cultural heritage sites have also an intrinsic value, as the vital basis for cultural diversity, social and economic development. They should continue to be a source of information for the future generations as one of the most creative edutainment megaprojects and structures of human history. They can also play a significant role in building a peaceful, democratic open minded society, as also in the promotion of cultural diversity.

Architecturally, they are among the most valuable and impressive monuments, mainly in the Mediterranean countries. Theatre architecture, actually, is the most appropriate typology for cultural sharing, with a socio-economic legacy at the Euro-Mediterranean level (Carbó *et al.*, 2010, p. 311). Many of these impressive structures from the classical antiquity still serve the function for which they were originally designed for. There are many classical theatres that are still used for modern performances, festivals, exhibitions, and events, etc. For example, Epidaurus and Herodes Atticus theatres in Greece, Kourion in Cyprus, Taormina and Syracuse in Italy, Orange in France, Mérida and Sagunto in Spain, Aspendos in Turkey, Jerash and Amman theatres in Jordan, and Bosra in Syria. Given also that the cultural significance of many theatres and odea is not readily apparent, conservation and restoration work, maintenance, interpretation and presentation, promotion and marketing, monitoring and re-assessment, as also guidelines for the acoustic adaptation for modern performance, all these together should enhance and preserve their integrity and their authentic scientific information (Haddad and Fakhoury, 2010).

Consequently, besides historical, archaeological and architectural studies, special attention should be paid to the assessment of the monument, relative to its present condition and decisions about adaptive and modern uses. However, their preservation by means of cultural activities allows, through art, the development of the traditional culture, the recovering of memory and consciousness of a shared history.

Unfortunately, some theatres are no longer used, while others are now incorporated within modern urban era buildings, thus forming unique structures of urban archaeology. Their cultural value and their significance are clear from their crucial relationship with other important buildings on those heritage sites and their design, structure and their architectural and acoustical concept.

Understanding values, cultural significance and protecting a theatre's site integrity by identifying, analysing, prioritising and mitigating risk are necessary steps towards the continuous efforts to save this creative socio-cultural edutainment vision of the Greco-Hellenistic-Roman world. In brief, we can identify their cultural significance in relation to their survival as ancient landmarks, as impressive architecture, their acoustic characteristics and qualities and their continuous reuse in modern socio-cultural edutainment performances and events (Haddad, 2007, 2008).

However, the desire to use ancient sites with theatres and odea for modern activities is very tempting for modern societies. Greek, Hellenistic and Roman theatres' heritage are exposed to multiple risks at varied times or simultaneously and managing these risks is relatively low. Today, many valuable theatres and odea sites are threatened, thus, there is an even greater need for risk mitigation and conservation plans to make better modern use of the existing theatre's cultural sites. Considerable decay is evident in many of the lime-based stone theatres (limestone and marble) as well as the silica-based types (sandstones), especially in aggressive urban polluted environments. Moreover, colour changes, patina, blackening of rock's surfaces in theatre and other associated phenomena have practically always been related to other environmental factors of deterioration.

Actually, there is no single reason why a theatre building becomes "at risk", as each case has different circumstances which have led to the theatre's building decay. There are complicated processes of destruction and distress that show divergence in theatre building materials' decay; eventually due to physical, environmental, anthropogenic and technical factors which lead to structural changes and different types of deterioration aspects. Therefore, the need for a general strategy seems to arise, thus involving the natural, anthropogenic and technical risks mitigation management.

The anthropogenic risk, within the scope and the aim of this paper, is the probability of damage, liability, loss or any other negative occurrence caused by human intervention and related activity to the ancient theatres. The anthropogenic risk may be due to the rapid transformation processes resulting from many factors such as urbanisation, development pressures, pollution, tourism, lack of awareness, and risks mainly due to improper modern uses. Another distinct category of risks can be identified as anthropogenic "technical risk" derived by incorrect new interventions of conservation. According to Germanà (2005, p. 673), technical risk refers to the "possibility that operations which have been carried out might turn out to be an ulterior source of danger, hindering or impeding conservation".

Therefore, the heritage community should start focussing on the issue of what scope, schedule, cost and quality problems could possibly emerge for the theatre's heritage risks we face; and mainly to discuss and list the main possible risk factors and their mitigation measures.

This paper presents the main results regarding the anthropogenic qualitative risks and related issues for selected classical antiquity theatres of the two main European projects conducted for recovery, adaptive and modern use of ancient theatres and odea heritage, ERATO (Identification, evaluation and revival of the acoustical heritage of ancient theatres and odea, 2003-2006) and ATHENA (Bianchini and Al-Adarbeh, 2009-2013) projects.

ERATO project is under the thematic title "Preserving and Using Cultural Heritage". Its main objectives are the identification, virtual restoration and revival of the acoustic heritage in a few, selected examples of the open air theatre and the roofed odea in a 3D virtual environment. The project also addressed the issue of establishing criteria for the assessment of the modern use of ancient theatres and odea. In order to support the improvement of knowledge about theatres, the virtual restitution integrated the visual and acoustic simulations, based on the latest research results in archaeology, history of theatre, clothing, theatre performance and early music.

Meanwhile, ATHENA project aims to minimise the progressive decay of ancient theatres and odea in terms of physical, cultural and socio-economic aspects. In the ATHENA project, an examination of specific risks and threats affecting ancient theatres was performed in order to suggest the best practices for the sustainable use of ancient theatres. According to Carbó *et al.* (2010, p. 313), this deals with "a complex 'scenario' formed of various categories of opportunities and problems that have to be organized and solved with the aim of creating a sustainable development for the sites belonging to the project partnership; archaeological investigation, restoration, legal frame of the managerial practices, dissemination, cultural and economic development".

Regarding ERATO project, the selected five theatres and odea were reconstructed acoustically, and comparison was made between present conditions and a virtual reconstruction. These are the Greek theatre at Syracusa in Sicily/Italy, the Roman theatres at Aspendos in Turkey and Jerash (South Theatre) in Jordan, and the Odea at Aphrodisias in Turkey and at Aosta in Italy. Acoustical measurements were made in the best preserved theatres in Aspendos and Jerash. It is found that the acoustical properties reflect the original different purposes of the buildings; the theatre is intended mainly for plays (speech) and the odea mainly for song and music (Rindel, 2011). The results about the criteria for modern use

and ancient theatres have also been published by Haddad (2007). It deals with problems related to festivals and deteriorations and threats due to improper uses of ancient theatres. More information can be found in Haddad (2006, 2007, 2008).

ATHENA project includes five countries of the Mediterranean Basin (Jordan, Tunisia, Algeria, Spain and Italy). Six Mediterranean ancient theatres have been the focus of a preservation programme that makes use of digital technologies, while at the same time generating a synergy between stakeholders, local institutions, tourist operators, etc., in order to achieve better economic standards. The archaeological sites are the following: Jerash and Petra in Jordan, Cherchell in Algeria, Merida in Spain, Carthage in Tunisia and Siracusa in Italy. A number of those ancient theatres are still being used for modern various activities.

Another expected result of ATHENA Management Plan is "the economic and cultural development of the population that lives in the Cultural Cluster by means of an integrated strategy that starts out with theatre valorisation without avoiding the compatible usage of ancient and 'fragile' structures" (Carbó *et al.*, 2010, p. 316). Questionnaires were conducted that aimed at a first analysis about the chosen sites (Carbó *et al.*, 2010, p. 315).

The aim of this paper can be summarised in the following three points:

(1) to discuss mainly the anthropogenic, technical risks, vulnerability and impact issues on selected classical antiquity theatres advocating a qualitative approach;

(2) to present a discussion on response and recovery operations in order to develop an adequate risk mitigation management and planning procedures; and

(3) to present recommendations mainly for site managers, in order to understand, assess and mitigate the different causes of anthropogenic and technical risks.

2. Charters and modern use and the selected theatre sites for analysis: a brief review and description

This section presents a brief review of the main issues related to the international charters on the use of ancient places of performance. In addition, it presents a brief description of the selected sites for analysis, their characteristics and geographic location. Thus, the rationale behind the selected cases either relates to the personal knowledge of the authors or is based on the structures studied as part of the European projects; ATHENA and ERATO.

There are three main international charters on the use of ancient places of performance; The Syracuse Charter (1994), The Segesta Declaration (1995) and the Verona Charter (1997). Their issues are related to the main reference points for the modern use of ancient monuments. The Syracuse Charter for the conservation, usage and management of the ancient theatrical architecture (The Siracusa Charter, 1994), developed many concepts related to ancient places for events, performances and representation. The main aim of this charter is to promote a general awareness about the theatres, proposed as an evidence of a common legacy.

It concentrates on illustrating evidence and developing planning practices, sustainable use and conservation of the ancient theatrical buildings of the Mediterranean Basin, these monuments can be found in a vast area that embraces three continents. The Segesta Declaration was adopted at the end of the congress "Salvaguardia e uso dei teatri antichi" (Segesta, Trapani, Palermo 17-20 September 1995). The main aims of this charter are developed along the following five main issues:

(1) to safeguard the ancient architectural heritage introducing, in particular the monuments destined for events and shows;

(2) a legislation that foresees measures of consolidation;

(3) protection and maintenance of the remains, once brought to the ligh;

(4) to develop the knowledge and the usage of the ancient theatrical architecture; and

(5) to promote their reuse by means of contemporary artistic creation, without altering their nature and damaging their structure.

The "Verona Charter on the Use of Ancient Places of Performance" (adopted at the International Colloquium held in Verona, Italy, August 1997) was one of the products of the MINOTEC project. This charter has the following four main aims:

(1) resource preservation, conveying accurate information, facilitating comprehension by the public;

(2) increase the value of sites by using them (for representation, cultural events and not just as ruins);

(3) managing the sites of performance and contributing to their sustainable development; and

(4) improving skills through networking.

The experts who took part in the activities of the European Network of Ancient Places of Performance and the MINOTEC project have drawn up a series of guidelines for implementing the "Verona Charter on the Use of Ancient Places of Performance". The main issues can be summarised as follows:

(1) facilitating comprehension by the public: such as the quality of public access and improving public understanding of the site;

(2) enhancing the sites by using them: to enhance the value of ancient places of performance by recognising them as places for artistic production and to use sites as a means of enhancement;

(3) managing places of ancient performance by contributing to its development; promoting the site image by guaranteeing high standards for visitors and spectators, and safety; and

(4) improving skills through networking.

According to Verona Charter, proper use of the sites should reduce the risks of material damage to ancient structures by performances and prohibit non-removable staging or modifications for the public.

After reviewing the general framework for the afore mentioned charters it was clear that there is a need to extend the understanding of management for theatres to a risk management approach, in line with the new literature on risk assessment and management.

According to Carbó *et al.* (2012, p. 124), best practices in ancient theatre management are explained by means of examples, with detailed descriptions of the activities carried out in the whole Mediterranean Basin and Europe (Orange, Mérida, Sagunto, Taormina, Siracusa, Amman, Kourion, Athens, Epidarius, Bosra, Aspendos). Nine theatres are selected for review in this paper; three theatres from Jordan (Jerash, Amman and Petra theatres), where Amman theatre is within an urban setting, while Jerash and Petra theatres are in archaeological sites. The three theatres hosted modern events and activities. From Italy, five theatres are selected, out from which are four from south Italy/Sicily and one from northern Italy, the Verona theatre. Verona theatre is within an urban setting, meanwhile, Morgantina, Eraclea Minoa, Solunto and Taormina are within archaeological sites in Sicily. From Turkey, one Roman theatre is selected, Aspendos theatre, which is within an archaeological site.

This paper, though, does not only focus on some of the selected theatres of ERATO and ATHENA projects, but actually focusses on the main theatres in Jordan, Sicily, northern Italy (Verona) and the best preserved theatre from turkey (Aspendos). The reason for this choice is quite clear; on one side the Jordanian and Sicilian examples appear to be more relevant in comparison with ATHENA activities. On the other hand, the selected Jordanian and Sicilian situation appear rich as also for this paper's objectives. Nevertheless, the information concerning some cases (as Jerash, Amman, Petra, Aspendos, Verona, and Taormina, for example) represents some of the very few best and worse practices to start from. Moreover, most of the selected and presented cases are in fact the commonly selected examples of ERATO and ATHENA projects (Jerash and Aspendos), as they present a great variation on the anthropogenic and technical risk sides.

As for the theatres from Jordan, the Jerash Southern Roman theatre is one of the most impressive civic buildings of the ancient city; it is in good condition, but due to the Jerash International Festival, which turns the ancient city into "one of the world's liveliest and most spectacular cultural events, many anthropogenic risks arise" (Carbó *et al.*, 2012, p. 125). Amman/Philadelphia Great Roman theatre, dated to the reign of the Antonine dynasty, is located in the downtown along the cardo and next to the colonnaded square forum. It is located on the northern slope of a hill and seems to be resting entirely upon the natural slope. The theatre together with the small theatre and the agora forms an impressive urban complex at the centre of the city. The Large theatre at Petra dates to the late Hellenistic period, set upon a natural slope above the riverbed of Wadi Mousa. The theatre's cavea and orchestra area were hewn out of the fragile sand stone rock while the scaene was constructed. The original stage building, though mostly destroyed now, apparently rose to a height of two storeys.

As for the theatres from Italy, mainly in Sicily, the present Roman structure of the Hellenistic theatre of Taormina (third century BC) was rebuilt upon the foundations of the older Hellenistic theatre. It is the second largest of its kind in Sicily (after that of Syracuse). The greater part of the original seats has disappeared, but the wall which surrounds the whole cavea is preserved. The cavea is all carved into the rock. The scaene is the most important part that remains of the theatre and preserves, in part, its original form. It is remarkably well preserved and it is frequently used for opera and theatrical performances, concerts and the annual Taormina Film Festival.

Eraclea Minoa Theatre is settled on the natural slope of the hill: the lower part is of marl and the superior one is composed from sandstone that is sparely cemented. There are no traces of construction of the scaene building. Many interventions of restoration was carried out, from which irreversible damage to the entire monument has been created, while the entity and the causes of degradations are various, a spontaneous vegetation reproduces the shape of the steps (Ruggirello, 2007).

The remains of the original Hellenistic theatre at Solunto, date to about second century BCE. It was built with rows of seating cut in part from the bedrock. Parts of the stands and the stage of the theatre are still also visible.

The early Hellenistic Morgantina theatre cavea is built with local limestone blocks, with horse shoe shape. A row of limestone blocks marks the shape of the orchestra. The blocks of the upper rows, that had excessive failure, have been dismounted and replaced.

Verona Roman theatre was built at San Pietro's hill side, around the end of the first century BCE. It is located in the modern city centre on the left bank of the Adige river, and must have been a magnificent sight in the Roman times. The cavea was emptied and it was thus possible to carry out some partial reconstruction of the structures. Its visible remains today include the stage, the orchestra, the auditorium and some galleries on two subsequent levels together with a top corridor. The orchestra is still partially paved with polychrome marbles. The stage is set up for modern performances, where the Verona Summer Theatre Festival was founded in 1948.

Finally, the Aspendos Roman theatre situated in the Southern part of Anatolia/Turkey is one of the best examples of Roman theatre construction, and is the best preserved of all Roman theatres, as all parts of the structure are still standing in full height. The three floor's scaene, which is as high as the cavea upper level, is made of regular blocks of conglomerate. The theatre's ancient to present continued use makes it a popular modern performance space.

3. Literature review for theatre risk assessment and management related terminology

Currently, there is a different definition of what risk is. According to UNISDR (2009), terminology on disaster risk reduction (p. 25) risk can be defined as "The combination of the probability of an event and its negative consequences". However, risk can be also defined as the probability that a certain kind of damage is realised (Ball and Watt, 2001; Paolini *et al.*, 2012). It is also defined as a function of hazard and vulnerability or the possibility of suffering loss. The risk is also defined as "the possibility of incurring misfortune or loss" (Moores and Champion, 1996, p. 55). It can also be noted that "people do not necessarily share the same perceptions of the significance and underlying causes of different risks" (UNISDR, 2009, p. 25).

Risk identification in the context of a theatre structure is "an attempt to determine risk factors that threat it with a systematic approach" (Wan *et al.*, 2010, p. 263). On the other hand, risk management is "the process of identifying, assessing and analysing expected and possible damage -in this context, to heritage sites- and of developing mitigation strategies in order to reduce the risk of damage". (Paolini *et al.*, 2012, p. 16). Hence, disaster risk management refers to the "process of implementing those policies, institutions and investments to strengthen the coping capacities of society to reduce the impacts of natural hazards and related environmental and technological disasters" (UNISDR, 2009; Shrestha *et al.*, 2011, p. 122). However, where a significant risk is determined, appropriate action to minimise the risk should be undertaken, and a risk mitigation plan should be prepared (ICOMOS, 1992).

The critical problem, though, with risk is that it "cannot be avoided, it can only be anticipated and its effects reduced" (Moores and Champion, 1996, p. 55). Risk reduction is one of the main aims of risk management. It can be dealt with in two ways: through prevention strategies and through mitigation strategies (Shrestha *et al.*, 2011, p. 67). A risk action plan should contain the following elements: responsibility, resources, time, activities, response measures, results and person in charge (Wan *et al.*, 2010, p. 265).

A concept model is usually constructed according to risk factors. Risk mapping can also provide tools for decision makers. For any risk to arise there must be hazard and vulnerability. The vulnerability of a structure is a measure of the effect of structural actions on its physical condition (Wang, 2012, p. 108). As actions increase, new types of damage gradually appear; cracks, permanent deformations, local collapses, total collapse (Smars *et al.*, 2012, p. 118). Risk analysis assesses "the loss probability and loss magnitude for each identified risk item, and it assesses compound risks in risk item interactions" (Wan *et al.*, 2010, p. 258).

The variability of risks refers to the chance of various risks "changing in terms of quality and quantity in the entire project process. As the project goes on, some risks will be controlled, some will occur and get handled, and at the same time, new risks may arise in every stage of the project. Especially in large projects, due to the more risk factors, the variability of risk is much more pronounced" (Wan *et al.*, 2010, p. 259).

However, the vulnerability of a theatre building, or its resistance capacity to destructive hazards, relates to the strength of its structure, construction materials, deteriorating condition, the existence of fragile elements or contents, improper modern use and

conservation practices. For all these cases, the conditions of risk obviously change. For a historic building, like a theatre, its vulnerability also comes from the embodied significance and repairability of its fabric and features.

According to Shrestha *et al.* (2011, pp. 34-35), there are three schools on vulnerability analysis; the first focusses on exposure to biophysical threats and hazards, the second looks at the social context of threats, hazards and relates social vulnerability to the coping responses of communities, including societal resistance and resilience to hazards. The third school, which has become increasingly significant in the scientific community in the recent years, combines the two approaches, and thus defines vulnerability as a hazard of place which encompasses biophysical risk as well as social response and action.

Therefore, the vulnerability has two dimensions -physical and social- that can be converted into qualitative categories and combined to obtain the overall total vulnerability, which can also be reported in qualitative categories (e.g. high, moderate, moderately low and low). Meanwhile, physical vulnerability is a function of susceptibility and exposure.

Risk and vulnerability, though, have many dimensions such as social, economic, and environmental. This has to be reflected in the approaches to assess and monitor risk and vulnerability. Risk and vulnerability are dynamic features that change over time and, hence, require continuous monitoring. The assessment of risk and vulnerability requires a conceptual framework to identify and quantify their various components.

Meanwhile, risk assessment and management can be seen as a systematic way of detecting changes that continuously affect the fabric of heritage places and sites (Vadafari *et al.*, 2012, p. 98). Risk analysis is generally divided into qualitative risk analysis and quantitative risk analysis. Qualitative risk analysis is a process to assess the impact of the identified risks and their likelihood and is based on developing a risk exposure matrix. Quantitative risk measures risk exposure using standard cost and probability measures.

Some theatre risk factors could include accessibility, availability for modern use for events' facilities, use of artificial acoustic facilities, and cost-effectiveness of the work. These are some of the many factors that could be converted to a qualitative assessment to estimate the vulnerability of a certain theatre in question. The qualitative factors are those that encompass different risk management measures such as security and safety systems, loss reduction measures, social awareness, and local community and visitors' attitude.

In contrary to the quantitative risks, qualitative risks do not operate on numerical data, where results are presented in the form of descriptions, recommendations, and risk assessment is mainly connected with the description of the so called threat scenarios by prediction of the main risk factors. Hence, the achieved results have a general approximate character, and cost-benefit analysis is more difficult during the selection of actions. Conversely, the quantitative risk gives a more accurate image of risk, still results of analysis may not be precise and even confusing, for even quantitative measures depend on the scope and accuracy of the measurement scale, in addition the normal methods must be enriched with qualitative description (in the form of comment or interpretation) (Rot, 2008). In this paper, the qualitative risk approach is adopted, where analysis is relatively easy and needs shorter time without big expenditures, and it also allows for ordering risks according to priority.

4. Theatre risk causes and contributing factors: qualitative risks classification/categories

The ability to define theatre qualitative risk categories is undoubtedly crucial. The approach here, however, is to define the most important theatre risk factor categories in the form of notes. The purpose, though, of this section is to discuss a draft of a list of risk theatre issues in order to surface new issues and move heritage experts and decision makers towards a consensus.

Building on the ERATO project results that have a beneficial influence on the modern use of ancient theatres, especially from an acoustic point of view, and the ATHENA Project where a deep examination of specific risks and threats affecting ancient theatres was performed, and on the basis of relevant case studies and general surveys, it is possible to classify the state of an ancient theatre's decay, threats, deterioration and risks under the following main original risk factors/categories; natural, anthropogenic and "technical risk".

Regarding the natural causes of deterioration/geo and bioenvironmental risks and threats and other such factors, damage and deterioration in this category are due to external factors and could have resulted mainly from climatic and environmental factors. Natural risks could be catastrophic and sudden or slow, such as erosion. Generally, many of the theatre ruins and structures suffer from many effects of natural factors such as threats of earthquakes, rainwater and inactive drainage system (flash floods), fire, landslides, physical deformation and structural deterioration, climate weathering and erosion (the wind, the sun, temperature and relative humidity). Such parameters remarkably accelerate the degradation processes for its building material: erosion, pulverizations and disintegration, scaling, gaps, exfoliation, separation, cracking, microbiological patina and efflorescence.

These factors can put ancient theatre heritage at serious risk. Therefore, all places with classical theatre heritage should be assessed as to their potential risk from any natural process, modern use for performance and cultural activities, and technical risks.

5. Anthropogenic theatre structural risks'; qualitative identification and mitigation due to improper modern use

The current modern uses and activities of theatres and odea create a continuous impact on their structures, originally designed for needs very different from contemporary ones. Since all ancient theatres have their own unique set of conditions, and reuse cannot be separated from the whole ancient/modern context that surrounds them, it is important to make clear that modern use is altogether different from ancient use (Haddad, 2007, 2008).

In general, anthropogenic causes of deterioration and threats to ancient theatres and odea face many risks that can result in the loss of the authentic technical, scientific information and their acoustic characteristics. Generally, many anthropogenic risks are due to economic constraints and lack of funding that can be observed in the maintenance and public services at ancient theatres and odea sites, combined with the growth of uncontrolled tourism and the limited theatre management plans and lack of compatible criteria for reuse.

In addition, there is a lack of cultural heritage education and limited public awareness about the values of ancient theatres and odea. This can be seen, for example, from many visitors that may stray into uncontrolled areas and often wear inappropriate dress and shoes, as also by the quarrying and stone-robbing activities and vandalism; many damages from stone robbers occurred due to the removal of some structural material from solid walls and auditoria, as also from vandalism due to graffiti. Causes of threats also can be seen due to conflict and war areas; as an example, the USA military turned the site of ancient Babylon into Camp Alpha in 2003 and 2004, inflicting serious damage according to an exhaustive damage assessment recently released by UNESCO. Bulldozers leveled many of Babylon's artefact-laden hills and Helicopters caused structural damage to an ancient theatre.

Identifying and controlling the qualitative risks associated with modern uses and urban development should be seen as a critical issue for the risk management of the ancient theatre's life since many severe risks are due to improper modern use. In fact, the theatre's modern use for cultural performances causes much of the risks concerning the physical

structure and threatens the authenticity of theatres' sites. In addition, there are several actions and events that may lead to a renewed settlement of the foundations that should be regularly monitored. This can include:

(1) Excessive traffic movement in the immediate vicinity.

(2) New construction or excavation close to the theatre building.

(3) Overloaded capacity and inappropriate reuse of theatres without implementing safety measures: a significant increase of the live load due to the overloaded capacity, without applying appropriate safety measures (Plate 1) such as at Jerash Festival/Jordan and the introduction of new equipments and installation systems for modern use. For example, the use of heavy machinery such as cranes, water tanks etc., can lead to vibrations on the structure of theatres, especially during festivals.

More analytically improper modern use – anthropogenic qualitative risk assessment-identification and mitigation can be defined and analysed in relation to these entire risks components as follows (refer to Figure 2).

5.1 Structural risks due to overloaded capacity during modern use events

Interestingly enough, Heron of Alexandria wrote about the algorithms aimed to solving the problem of capacity for the theatres, thus giving further proof about the level of dissemination of the design process of theatres (Heiberg and Alexandrini, 1976). Risks can be too high, with special regard to problems related to capacity and emergency exits, especially when they are used for festivals Figure 1), conferences, receptions, exhibitions/museums and tourism purposes. However, an empty theatre building can be in relatively good condition but still be rated as vulnerable, simply due to the theatre's building lacking of a viable use. Conversely, a theatre that is in poor condition but has a viable use may not necessarily be considered to be at risk, although it should normally be monitored as a

Notes: The International Jerash Festival for Culture and Arts at the Southern Roman theatre, launched in 1981 in Jordan, with a wide range of activities from all around the world. The arrows indicate some unsafe places for the crowds and audience to sit

Figure 1.
The stage of the southern Roman theatre at Jerash in Jordan

vulnerable building. Theatre's carrying capacity calculation is crucial; such planning of visitor's flow according to passage ways, parking areas, illumination, and service spaces should have to be discussed before the events (Çalişkan, 2015, p. 77). Therefore, the carrying capacity should be assessed according to the building and site's physical condition and the visitors' flow as prospective measures. Based on Athena project the assessment of the carrying capacity for the theatre's modern use is proposed in three-steps; the physical carrying capacity, real carrying capacity and effective carrying capacity.

5.2 Fire and thermal risks due to lighting systems and naked flames

Fire can be considered as a natural catastrophe and a man-made disaster. The sources of fire can be due to human error and naked flames such as in candles for lighting. Each theatre has its own degree of risk to fire and of a resultant damage. Reviewing the current preventive measures for the theatres' design for lighting and the protection capacity of the current conditions, it seems that no comprehensive lighting protection at many theatre areas is provided. In addition, the installed system affects the integral aesthetics of the architecture, especially when they are used at night. What is important here, during its modern use, is that the lighting system should not harm the theatre materials and should adhere to environmentally safe standards. Actually, the existing lighting system in many theatres is outdated (examples are shown in Plate 1), also not complying with outdoor climatic requirements.

Spectators' safety should be considered seriously as well as carrying preventive interventions to safeguard the theatre building against accidents due to the lack of efficient lighting, especially for events held at night. For example, Ephesus Theatre which was intensively used for several events (shows, concerts, dance performances etc.) for a period was damaged by the re-use of the building. Actually, modern light and sound

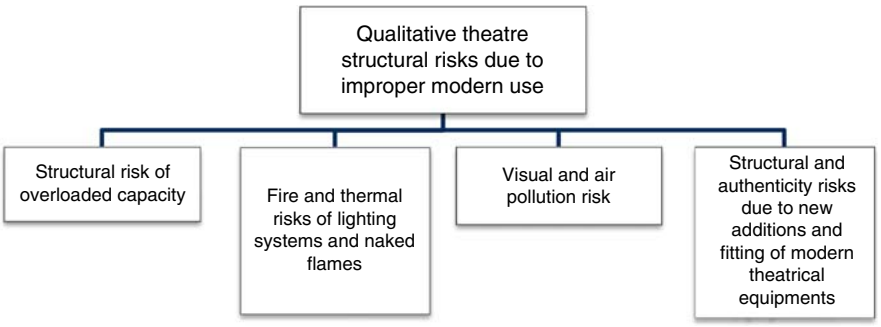

Figure 2.
Identification of the qualitative theatre anthropogenic structural risks due to improper modern uses

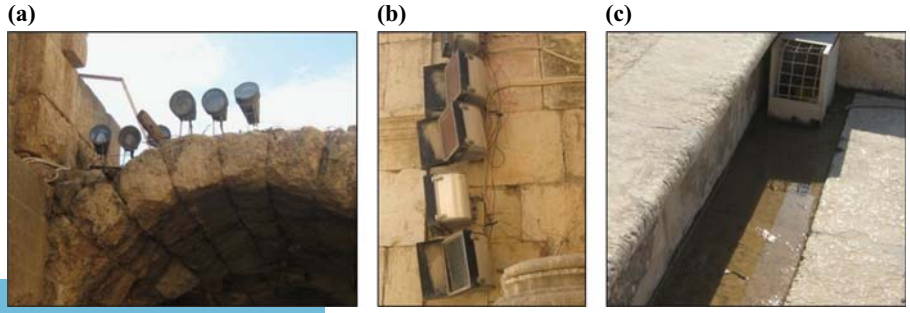

Plate 1.
Examples of the lighting system and modern equipment fittings that caused damages during the festival events at the Southern Roman theatre at Jerash in Jordan

systems have set up some problems due to their implementation and for the vibrations caused by the sound system which have negative effects on the theatre's structure. In another event, the light mechanism set up on the stage fell over the brick vault and caused damages (Çalişkan, 2015, pp. 76-77). Similar problems and decay were mostly caused by modern sound equipment's vibrations during 2013-2014 in Aspendos theatre. Constant modifications and improvements to the lighting design code for the protection of these structures are necessary.

The concept of fire precautions may be subdivided into two distinct subsections: fire prevention (measures to prevent fires from starting or from being started); and firefighting (measures to control the spread of a fire and to extinguish it). Many fires could be prevented by technical or educational measures. A wide range of the latest lighting technology with different systems is available now, ensuring a solution which is entirely satisfactory from both the aesthetic and safety points of view. A lighting protection programme should be developed based on the international standards and criteria.

Lighting protection devices must be selected in strict accordance with lighting protection requirements for the heritage theatre buildings, such as high reliability, durability and the capability of minimising lighting strike probability (Fei *et al.*, 2012, p. 92). These also need regular inspections. In addition, we need to establish a set of aesthetic rules concerning the best types, the distance between parallel sources of lighting, and the way the lighting should follow the architectural details, and so on.

By following these guidelines, and by employing skilled staff, it is possible to have the lighting fittings exposed in the sensitive places without affecting the general appearance and authenticity of the theatre structure, and thus to avoid such problems that can be seen in Plate 1). It is, therefore, necessary to update the lighting protection devices to ensure a comprehensive protection.

In addition, fire policy provisions, generally, require a fire protection strategy to be studied and adopted on a case by case basis, in such a way as to meet the protection objectives agreed in advance between owners, managers, the authorities, the insurers and fire protection experts. Fire-prevention planning includes the preparation of a fire management plan, and concurrently equipping the theatre building with firefighting facilities to match the special requirements of the fire code. In addition, managers of the theatre buildings should have to check for fire safety regularly by equipping firefighting facilities without destroying the original structure status (Shao, 2012, p. 71) of the theatre building.

On the other hand, to reduce the risk factors of a disaster, such as decreasing the risk of fire spreading, we must prevent grass fires from spreading to the theatre building area. All vegetation, though, should be removed up to a one metre wide buffer, to create a safety zone around the theatre building. Emphasis should be placed on the aesthetic appearance of this zone in order to retain the relationship between the theatre building and its surroundings. In addition, to reduce the risk of fire, all stores for modern use activities should be also cleared, taking care, of course, not to discard any valuable material, which might be there.

Sometimes, there are many plants including tall old trees at the theatre's site area, where a tall or single tree is very vulnerable to lightning. Given a large number of old trees at many theatre sites; especially in Greece, Italy and Turkey (for example see Plate 2), lightning not only can harm old trees by bark peeling or causing serious fires but can also be a serious threat to the nearby theatre building as well as to the audience attending performances. A lightning surge can affect high and low current equipment used in the theatre building and cause equipment failure or direct damage. Therefore, insufficient lightning protection will result in costly damage.

Though documentation of tall old trees in the theatre area is to be included in the risk identification and documentation process, further research is needed to develop a method for lightning protection coverage, which is better suited for the theatre buildings.

Plate 2.
Verona Roman theatre in Italy

Notes: The Roman theatre with several old trees at Verona in Italy is still used for modern performances, with an audience seating area in the orchestra. The stage is installed with removable structures

A lightning protection programme based on international and national standards and criteria should be developed. Lightning protection devices must be selected in strict accordance with lightning protection requirements for the theatre buildings surrounded by massive zones of tall trees with lightning strike probability.

Finally, there is a need for promotion and application of "3D Simulation of Lightning Protection System" at the theatre complex areas with tall old trees. In a recent study the use of advanced photography and 3D modelling could virtually display and integrally evaluate the extent of the current lightning protection system. The 3D modelling method can provide graphic evidence to inform decision makers of where modifications of the lightning protection systems are required as well as serve as a reference for developing design principles and specifications for the lightning protection of historical complexes (Fei *et al.*, 2012, p. 86).

5.3 Visual and air pollution risks and bio-deterioration

Visual pollution can arise from the supplementary lighting, sound and signage systems at the theatre area. However, site signage and panels, ticket office, and bookshop, etc. are needed for interpretation services. Therefore, regular visual assessment to the installations and services provided is required, especially during the seasons of activities and performance.

On the other hand, urban development at the theatre's buffer zone can also cause visual as well as air pollution. Pollution and pollutants from traffic, including tourist buses, especially, impact theatres and odea in a congested urban context. In particular and due to many sources of air pollution, many theatres suffered and are still suffering from some risk issues resulting from several anthropogenic threats and deterioration factors, either physical or chemical. However, this issue is not specific only to theatres, but it concerns every archaeological remain within an urban area.

For example, as in the case of ancient theatres in an urban setting, dissolution and erosion of stone surfaces are due to chemical effects resulting from acidity spots, composed as a direct result of the interaction with "acid rain" (Wei and Wang, 2005). This mainly appears in theatres within urban heavy traffic areas, due to direct synergetic effects between rainwater and soiling by particles, where some layers of patina and coloured surface crusts are often observed. Severe itching and loss of calcite grains of the theatre' stone surfaces result directly from acid rain effects because of the dissolution processes. This kind of risk feature is very clear in the upper parts of the Great Roman theatre of Amman, where the increase of the theatre's stone porosity, will lead water to penetrate more deeply and react with internal materials and calcite grains. It also increases the ratio of damage and leads to the loss of the cohesive index of the structure and eventually its failure, after the production of the so-called sugaring (Rands *et al.*, 1986).

On the other hand, micro-organisms, plants and animals cause serious decay to the theatre's building material; where decay due to animals is principally from goats if the theatre is not fenced. Meanwhile the bird droppings and their acidic metabolic products can severely damage the stone. Pollution due to bio-deterioration from micro-organisms, plants and animals at the theatre material is a complicated problem that needs an interdisciplinary approach by experienced conservators and specialised biologists.

5.4 Authenticity and structural risks to due to new additions and fittings from the modern theatrical equipment

Construction of new structures such as partitions, removable structures, or additional seats at the theatre's orchestra for additional audience and for fitting modern equipment, such as in the case of the Roman theatre in Verona (see Plate 2), where doors, shelters, footbridge, etc. are required sometimes to accommodate new uses and services for modern performances. These might have a negative effect on the theatre's structure, its aesthetic appearance and authenticity. For example, the Turkish authorities have suspended further shows at Aspendos theatre due to some damages caused by fitting modern theatrical equipment during the festival events, where some performers were located at the same orchestra (see Plate 3). For that, a new modern facility known as Aspendos Arena has been constructed nearby to continue the tradition in Aspendos.

Another example is what happened at Ephesus Theatre in an event held in 2001 for three weeks when a portable new stage supported by steel pipes was built, covering but also exceeding the whole original stage and orchestra. With this stage enlargement, the lower seats were unavailable, so the upper stairs, which were not safe in the forbidden area, were used by the audience. Even an old lady fell down between the stage and auditorium, and was carried on a stretcher outside, where there was no ambulance arrangement (Çalişkan, 2015, p. 76).

Recommendations for executing new ideas related to the construction and installation of some removable structures, with the aim of establishing specific regulations for theatres' sites, need to be safe, aesthetically and architectonically acceptable and compatible. More importantly, it is not to disturb but to provide enhancements for the theatre's authentic acoustic qualities, as shall be clarified directly below.

6. Qualitative assessment for theatre anthropogenic technical risks; identification and mitigation

Typically, masonry structures have problems and damage associated with one or more of the following: foundation displacement (also known as settling over time), water penetrating into structural walls; shoddy construction, poor materials, stresses on the masonry walls due to fluctuations in temperature, and ageing of mortar in masonry joints. According to

Plate 3.
Aspendos Roman theatre in Turkey

Notes: Aspendos theatre was used until recently for performances and festivals, with performers located at the orchestra. The well-preserved colonnade portico improves loudness of the sound for the remote seats

Germanà (2013, p. 190, note 15), technical risk refers to the following coexisting factors; "inadequacy of diagnosis in the projecting phase; absence of sufficient attention to the durability of materials and techniques to be employed and to the maintainability of the solutions adopted; incongruence between project and execution; insufficient checks throughout the phases of the process".

Generally, theatre qualitative anthropogenic technical risks are due to the limited techno-archaeological and historical research, which can lead to inappropriate development; the thematic patterns that could emerge from the research may be useful for the planners and interpreters. Meanwhile, the absence of a holistic and integrated conservation plan, lack of maintenance, poor application of conservation principles, and limited skilled people can also cause further decay to the theatre's infrastructure.

In addition, the limited scientific approach and methodology in the diagnosis and conservation of stone combined with the gradual disappearance of traditional stone crafts and skills, as also the limited detailed documentation of their environmental conditions (i.e. temperature variations, air pollutant levels, salinity of soil, the wind, etc.), poor legislation and related management programmes including special technical regulations to protect ancient theatres, can cause further decay and threats. Theatre deterioration and deformations can also be detected due to a previous poor quality of restorations and interventions through related excavation and conservation programmes. More analytically, qualitative anthropogenic technical risks' identification, shown in Plate 3, and mitigation can be extended and analysed in relation to the entire risks components as in the following:

6.1 Structural risks due to excavation interventions related to new settlement and backfilling

Theatre structures can be classified in relation to the landscape and topography according to three types. These are: on a hillside slope; on a purely flat site; and a combination of the two types (the lower cavea on a partially sloped hill site and the upper on a flat site)

(Haddad, 2004; Haddad *et al.*, 2007). For many ancient theatres, most of the settlement activities have ceased long ago. However, some changes to the theatre's building surroundings can bring about more differential movement. Changes, however, are often gradual and not noticeable over a short period of time (Figure 3).

Some of the common signs of settlement and shifting of foundations are misalignments and gaps around doors and openings at the *cavea* sloping and the stage, cracks in the orchestra floor, cracks in the stone and cracks in the foundations. However, several combinations of natural and man-made actions may lead to a renewed settling of the foundations that should be regularly monitored. This includes:

(1) oversized tree roots in clay soils;

(2) change in the level and quantity of ground and surface water around the foundations; and

(3) humidification that may result in an increase or decrease of the normal moisture content in the foundation or structural materials leading to shifting in the theatre foundation.

However, in archaeology, it has been a common practice that no concern had been paid to the necessity of requiring backfilling, where many excavated sites have been backfilled in a loose condition. Thus the excavation of archaeological trenches has caused structural stability problems (Iwasaki *et al.*, 2012, p. 46) in theatre sites, where the ground was excavated and backfilled without compaction work. Backfilling, actually, of an excavated theatre site without compaction can also cause sagging and displacement of pavement and requires restoration work.

The existing humid environment also fosters the bio-growth that could affect the stability of the theatre's engraved surface. For example, in the case of Morgantina's theatre, at east central Sicily in southern Italy, the filling material executed behind the right frontal *analémma* wall, created a serious structural collapse. Argillaceous ground water saturation has been recorded, thus irritating an excessive thrust on the *analémmata* wall structures. This bad intervention also enhanced the partial dismounting of the wall. Thus, in order to facilitate the water drainage of infiltrating waters to the material on the lower surface, it was needed to stop water infiltration, by means of water drainage at the base of the digging. In addition, the walls have been waterproofed with reinforced geomembrane, fixed to the geo-composite layer. Moreover, the use of mortars containing cement which were used to infill losses in the stone blocks created stains and efflorescence. Even discoloration at the stone surfaces was observed because of the new used mortar which was not compatible with the original colour and texture (Ruggirello, 2007).

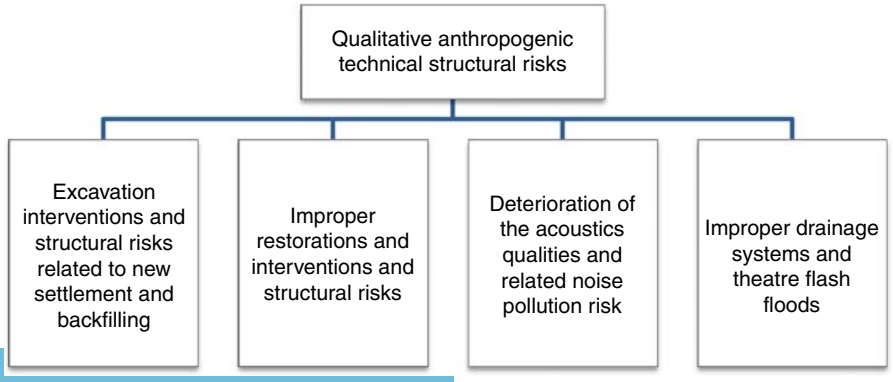

Figure 3. Qualitative anthropogenic technical risks identification for theatres

In fact, opened trenches at the foundations of a theatre structure, even if refilled, may change the compactness of the soil. This could also allow more water to go under the foundation. Therefore, the compacted earth at the theatre area, in fact, should be considered as one of its authenticity features, which should be respected as well as kept for structural safety. Those who conduct an archaeological survey in theatre sites should collaborate with geotechnical engineers, in order to keep the integrity of the theatre earth site. Moreover, if an excavation pit for any archaeological study is not filled back with the appropriate compaction, the integrity of the monument could be lost. In summary, the geotechnical properties should be studied and assessed in terms of soil compaction, and the backfilling of trenches at the theatre area should be considered to avoid any unfavourable effects that might be caused by backfilling without suitable compaction.

6.2 Improper restorations and interventions and structural risks

One of the main aims of ATHENA project was to detect problems concerning incorrect restorations and the integrity level of structures (Carbó *et al.*, 2010, p. 311). The improper introduction of materials without considering the conservation principles can cause many damages and irreversible harm to the historic theatre structures. Plate 1 and especially Plate 4 illustrate a severe technical risk example of using cement from previous wrong restorations at the Southern Roman theatre at Jerash in Jordan.

Moreover, the heavy machinery that was used in the restoration works to transport the needed materials and lift the stones, could have also led to vibrations on the theatre's structure. Mistaken attempts and poor quality of intervention and restoration had also led to many risks to the theatre's entity. For example, one of the most inferior and worse interventions was at Eraclea Minoa theatre in the province of Agrigento in Sicily. The wrong decision to cover part of the cavea with the transparent Perspex caused oxidation and corrosion of the metallic structure, followed by fissure of the stone, in addition, this transparent Perspex had the effect of a greenhouse which was an ideal environment for increasing the growth of vegetation (Ruggirello, 2007).

Plate 4.
Technical risks due to previous wrong restorations using cement at the Southern Roman theatre at Jerash in Jordan

In fact, one can notice several previous theatre restorations and reconstructions that are critical. Additionally, their functional properties have been ignored during these restorations, that several authentic traces of some parts may have been lost. A clear example of this phenomenon is the Greco-Roman theatre at Solunto in Sicily, where its reconstruction has actually been based on a stylistic approach, but without consideration of the archaeological evidence.

In addition, many interventions, such as the replacing of the stone seating and other architectural elements, had not been always compatible with technical conservation principles. They can be considered more as a stylistic/artistic restoration, which is far away from the intervention conception of "*anastylosis*". In the theatre of Taormina in Sicily, for example, the stairs *(klímakes*) have been replaced by concrete, thus they do not fit well with the rest of the authentic theatre cavea (*koílon*) (Ruggirello, 2007). The same faulty treatments are noticeably apparent at the Southern theatre at Jerash in Jordan, thus affecting the significant inscription, as shown in Plate 4.

In fact, water with the harmful soluble salts leaching out from the cement could be also slowly released through the joints between the cement and stone surface. Efflorescence or sub-efflorescence aspects affect the theatre's materials and permit the migration of different salts from inside to outside, such as calcium carbonate. This phenomenon depends essentially on the amount of salt present, its nature and the number of dry-wet cycles (Binda and Baronio, 1985). In addition, the disappearance of some parts of the stone surfaces can also occur as a direct result of salt crystal growth due to alternating processes between wet and dry cycles daily, seasonally or annually.

On the other hand, the poor ventilation of the theatre's structural parts such as the vaults, especially when they are being reused nowadays for exhibitions, offices or museums, such as in the case of the Great Roman theatre at Amman; the glass enclosure, actually, creates a micro-climate which disturbs the equilibrium that had long existed between the historic theatre stone structure and the natural environment, as well as sped up the weathering process indirectly. The new function created a micro-climate inside the exhibition with the temperature and humidity contrasting with the outside environment. A recent study shows that the new microclimate disturbed the equilibrium that has long existed between the rock carvings and the natural environment as well as sped up the weathering process indirectly (Antiquities and Monuments Office, 2012, p. 55).

6.3 Deterioration of the acoustic qualities and related noise pollution risk

Ancient Greek and Roman theatres are often considered acoustically perfect. However, the semicircular shape of the audience area, the "cavea" may cause acoustic problems. According to Rindel (2013), there is evidence that the ancient architects were aware of this. The acoustic quality, however, of many ancient theatres and odea are at risk. In most ancient theatres, the stages and the upper parts have been damaged. Conservation and restoration of ancient theatres and odea can enhance and preserve their authentic acoustics and scientific information since the cultural significance of many theatres and odea is not readily apparent (Haddad, 2007, 2008; Haddad and Fakhoury, 2010).

Many interventions of restored theatres have this deficiency. For example, in most cited theatres in this paper, as in the case of the theatres at Jerash and at Amman in Jordan, the stage scaene walls have been partially restored, but not to its original height; they were restored to the level of one storey only (see Figures 2 and 4). The scene wall and the colonnade improve the strength of sound in remote seats, therefore, there is a need for some anastylosis and restoration of the stage and the portico - which have an acoustic function- up to their original levels and layout (Haddad, 2006, 2008). In the case of Aspendos theatre (Plate 3), the existence of the colonnaded portico improves the loudness

Figure 4.
The great roman theatre at Amman in Jordan

Notes: Amman great roman theatre is used for performances and festivals. The stage wall has been partially restored, but not to its original height. Loudspeakers are placed on the stage, while they should be located in the orchestra to avoid problems with echoes

of the sound for the remote seats, thus providing acceptable voice strength to the upper levels. Figure 5 illustrates the main architectural elements and acoustical characteristics at a typical open–air Roman theatre.

Therefore, if we want to use the ancient theatres for modern performances with modern technology, we have to ensure that no harm is done to the original acoustic qualities of the building, especially from the modern sound equipment. Fixing the equipment onto the original material of the theatre's structure, including the positioning of loudspeakers and amplifiers in mistaken positions can seriously harm the ancient materials of the monument and its acoustic qualities.

The sound sources should preferably be on the proscenium, near the scaene wall, and not in the orchestra. Hence, in order to improve sound reflections from the orchestra floor, the orchestra should not be used as a seating area for the audience, and loudspeakers should be located in the orchestra to avoid problems with echoes. The present practices, in many performances, festivals and events, as shown in Figures 2 and 4, still place the loudspeakers on the stage. Hence, there is a need to employ the advantages of the new digital technologies to interpret and realise the distributions of echoes inside a theatre area to reach its acoustic qualities (Haddad and Fakhoury, 2010).

6.4 Improper drainage system mitigation and theatre flash floods risks

Today, new opportunities of risks are due to the consequences of global climate change with its risk of increased flooding in many unexpected parts of the world. Theatre sites were usually situated outside areas prone to floods (such considerations had a bearing on the choice of a site). The dangers of sudden flash floods as happened recently (2016) in the city of Amman/Jordan, which was triggered by a sudden and very strong intense rainfall, affected the Great Roman theatre at Amman downtown. This was an unexpected event, and

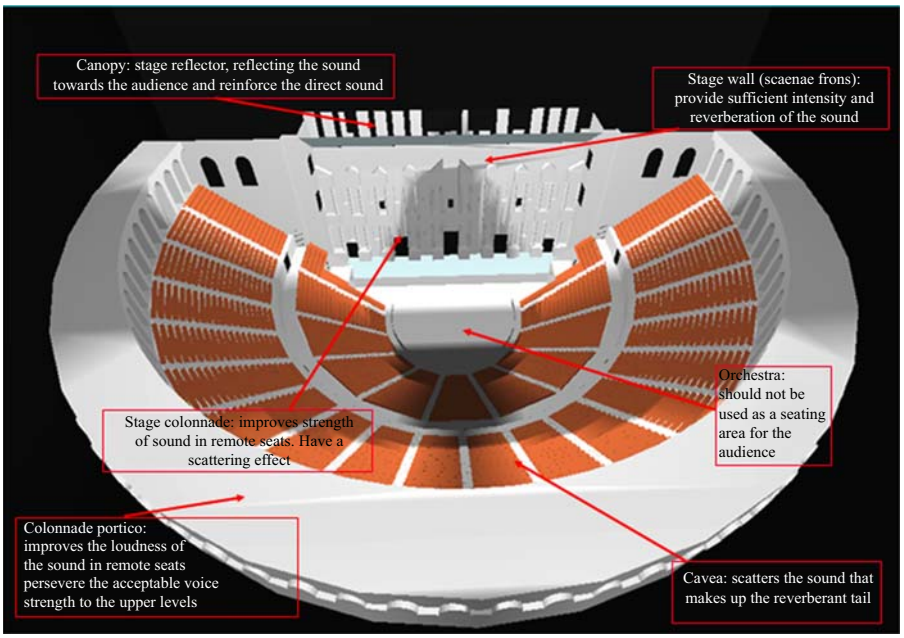

Figure 5. The main architectural and acoustic elements and characteristics of a typical Roman open air theatre

therefore this is not of minor importance when there is an inappropriate or inactive drainage system. Regular checking and maintenance of the theatre drainage systems to avoid any sudden flooding is critical. In addition, sudden flash floods, torrents and avalanches, in theatres' zones should be mapped and recorded systematically, in order to establish flood prevention measures and disaster management plans for the rainfall in catchment areas. However, the advanced hydrological analyses and extensive hydraulic engineering models for the theatre's sites would be sufficient to notably reduce the danger of flooding.

Therefore, flood protection studies for theatres, in addition to planning and construction of an urban flood protection system should be given more priority. Therefore, integrated planning procedures can provide opportunities to combine up-to-date flood protection with the preservation of the urban heritage and the general upgrading and stabilisation of historic river cities. For river cities with theatres, analysis of the topographical, spatial, environmental, historic, aesthetic and functional qualities of the city and its relationship to the river may lead to the formulation of site-specific design strategies and principles. Examples have shown that flood protected, well-designed and easily accessible riverfronts also improve the living and recreational conditions at the dense cores of old cities (Will, 2012, p. 14).

7. Towards an ancient theatre anthropogenic qualitative risk assessment and mitigation management: proposed approach and methodology

Generally, there are four main recognised and agreed steps, from the heritage community, in using a risk management approach for preservation issues: identifying all risks to the monuments, assessing the impact of each risk, identifying possible mitigation strategies, and evaluating the costs (where applicable) and benefits associated with each strategy.

Interesting enough is the risk management proposal that can be applied to heritage sites, as has been applied in the archaeological site at Petra in Jordan from Paolini *et al.* (2012, p. 18). According to Paolini *et al.* (2012, p. 18), this risk management proposal is enhanced and based on "two approaches for assessing and reducing risks to collections

and artefacts, Waller (2003) and the Risk Management Australian/New Zealand Standard (Standards Australia/Standards New Zealand, 2004), as applied by CCI-ICN and ICCROM". It provides a systematic tool to identify, assess and manage risks. In this proposal the systematic application of the risk management process includes six steps: defining the context and scope, including a documentation review as well as values, condition and management context assessment, identifying the risks, assessing the impact of each risk, identifying possible mitigation strategies, evaluating risks and mitigation strategies based on cost-benefit analysis, implementation of the strategies (preventively or actively) to treat risks.

The following proposal developed a holistic framework for the ancient theatre's anthropogenic qualitative risk assessment and mitigation management approach. This methodology can support capacity development and training of conservators, restorers, planners and heritage practitioners. It is based on recent case studies on risk management that could inform and guide decision makers and offers a sound methodology to incorporate the most recent risk management knowledge into current practice. It allows an integrated vision of all expected damages and loss due to anthropogenic and technical risks, in addition to natural factors affecting the theatre's cultural property and of their mitigation; thus providing a useful tool for the design of more efficient heritage conservation strategies for ancient theatres.

However, it is well known that the main challenge is to manage the quantity and level of risk. For that, we need to define the effective methods and guidelines concerning the modern use, materials and preservation measurements for restoring and maintaining the theatres under risk. This requires a multi-disciplinary approach where cooperation of monument owners, archaeologists, conservators, scientists and restoration experts is a must.

Figure 6 illustrates our suggested six-conceptual steps consequence model of the qualitative ancient theatre's anthropogenic risk mitigation management approach. Steps 1 and 2 are the main keys since a sensible definition of the attribute to be assessed is required. The six-steps to carry out a theatre risk management include the following:

7.1 Theatre risk assessment

The first primary step in the proposed approach is the theatre risk assessment of which the risk factors are likely to be important. In risk assessment, however, one should presume more than one scenario. This is the same as vulnerability studies which consider varied hazards and different scenarios (Coburn *et al.*, 1994; Wang, 2012, p. 108). This while, if we suppose only one scenario, we refer to a risk analysis that only considers a single intensity (or value) of the hazard threatening the construction (e.g. the occurrence of a magnitude 7 earthquake), then the view of what is a risk assessment is incorrect. For example, an earthquake hazard curve (used in an earthquake risk assessment) represents the probability of occurrence of different earthquake scenarios (i.e. the probability of occurrence of earthquakes with different

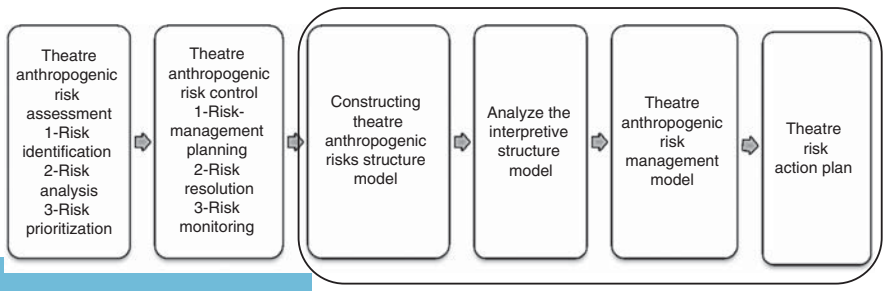

Figure 6.
The suggested six-steps conceptual consequence model of the ancient theatre's qualitative anthropogenic risk mitigation management approach

intensities) that are all considered in the assessment. Therefore, the risk is assessed by a combination of conditions and occupancy. However, the analysis leading up to risk assessment is a multi-step process, where the steps are: The collection of essential information as needed including the historical information on past threats due to modern use and technical risks, the actual hazard analysis and assessment, the vulnerability assessment, and the risk assessment. The critical issue, however, is to develop systematic techniques to discover risks. Risk assessment involves, risk identification, risk analysis, and risk prioritisation:

(1) Theatre risk identification: in fact, prior to mitigation, understanding the vulnerability of a building and cost-effectiveness of the work is critical (ICOMOS, 2003, Wang, 2012, p. 108). Though, information of the structure is essential; in its original and earlier states; techniques that were used in the construction; the alterations and their effects; the phenomena that have occurred; and its present state (ICOMOS, 2003). Risk identification can produce lists of the theatre-specific risk items, likely to compromise the theatre risk management success. The aim is to search for and locate risks before they become actual problems. Table I presents a suggested example of an evaluation form of the theatre anthropogenic causes of deterioration and threats, while Table II presents an evaluation form for the decay and deterioration due to improper modern uses of ancient theatres and odea. The proposed two tables were developed during the methodology stage by the authors while the field work had already been undertaken to provide a rough preliminary assessment. The tables have been introduced here, as guidelines to future anthropogenic ancient theatre risk assessment to be further tested.

(2) Theatre risk analysis: refers to the assessment of the loss probability and loss magnitude for each anthropogenic and technically identified risk item. The aim is to convert risk data into decision-making. Typical analysis techniques may include structural models, material and structural analysis.

(3) Risk prioritisation: it refers to the production of a ranked ordering of the anthropogenic and technical risk items identified and analysed. A classification with respect to the theatre location, type, and construction is needed in order to estimate among other things, their vulnerability. The main aim is to present the vulnerability-level or scale (risks classification and prioritisation). A risk-level scale is the product of hazard level assessment and an estimation of total vulnerability (Shrestha *et al.*, 2011, p. 34). Four levels of total vulnerability (high, moderate, moderately low, and low) can be classified and used to estimate the theatre risk level.

7.2 Theatre risk control

The second primary step is theatre risk control. It is a three-step process involving: risk-management planning, risk resolution, and risk monitoring with the aim of choosing risk mitigation actions:

(1) risk-management planning is the management of risk by prioritising the probability of the event and its impact on the theatre structure. It helps to prepare the team to address each risk item;

(2) risk resolution produces a situation in which the anthropogenic risk items are eliminated or otherwise resolved; and

(3) risk monitoring involves tracking the theatre risk event's progress towards resolving its anthropogenic risk items and taking corrective actions where appropriate with the aim of monitoring the risk indicators and therefore the ability to reassess the risks.

Table I.
Evaluation form of the anthropogenic causes of deterioration and threats

No.	Causes	Related sub causes	Not at risk 1. Excellent 2. Fair condition 1	2	Vulnerable to risk If problems not dealt with	Risk level; 1. high 2. moderate 3. moderately low 4. low 1	2	3	4	Mitigation strategy if applicable Mitigation method	Impact	Notes
1	Tourism growth	1. Uncontrolled										
2	Site management plan (SMP)	1. No SMP available										
		2. SMP available but not implemented										
		3. SMP available with poor implementation. (please mention reasons in notes)										
		3. Poor SMP (discuss why in the notes fields)										
3	Cultural heritage education	1. Lack of cultural heritage educ										
4	Public awareness	1. lack of public awareness										
		2. limited public awareness										
5	Archaeological research	1. Limited archaeological /historical research										
6	Conservation and conservation plan	1. Absense/poor conservation plan										
		2. Limited scientific studies for stone conservation										
		3. Lack /limited architectural documentation										
		4. Lack /limited environmental documentation										
		5. Poor previous restoration and restoration interventions										
		6. Use of new materials and additions										
		7. Poor maintenance/neglect										
		8. Poor legislation including special technical regulations										
		9. Stone robbing										
7	Air pollution	1.1 Traffic pollution										
		1.2 Others										
8	Conflict and wars											
9	Fire hazards											
10	Noise pollution	1. High noise pollution										
		2. Moderate noise pollution.										
		3. Low noise pollution										

No	Causes	Related sub causes	Not at risk 1. Excellent 2 Fair condition 1	2	Vulnerable to risk If problems not dealt with	Risk level; 1. high 2. moderate 3. moderately low 4. low 1	2	3	4	Mitigation strategy if applicable Mitigation method	Anticipated mitigation impact	Notes
1	Capacity	Overloaded										
2	New use	1. Conference 2. Museum 3. Visitors 4. Festivals 5. Others										
3	New Additions (define basic additions)	1. 2.										
4	Loss of ancient acoustic quality											
5	Noise pollution											
6	Lighting	Thermal risk										
7	Visual pollution	Light-sound-signage, graffiti										
8	Human induced use and its impact on theatre surface	1. Foot wear: high heels flat heels others 2. Touching 3. Leaning 4. Rubbing 5. Others										

Table II. Evaluation form for the decay and deterioration due to improper modern uses of ancient theatre

As for recommendations for ancient theatres' risk-management planning, response and recovery, according to Stovel (1998), the internationally accepted frameworks and procedures for "Environmental Assessment" can be applied in assessment and risk planning for any intervention. Eventually, the sharing of knowledge and promotion of the principles of risk theatre preparedness for cultural heritage is crucial in order to become more aware of the danger of the permanent loss of these resources to natural and anthropogenic deteriorations and risks.

7.2.1 Constructing an anthropogenic theatre risks' structure model. When threats and their agents are identified, the risk scale and level can be assessed and interpreted based on the possibility of the identified threat to occur and the severity of its impact (Vadafari *et al.*, 2012, p. 100).

The aim of the structure model is to identify and establish the theatre risks' levels in a hierarchical structure model and to indicate how low-level risk factors may affect high-level risk factors. Based on a case study on business risk management (Wan *et al.*, 2010, pp. 260-263), the following steps illustrate a suggested methodological approach to reach a risk structure model:

- identify theatre anthropogenic and technical risks related to improper modern use;
- construct a concept model and matrix according to risk factors;
- establish a re-ordered matrix after a class division of the different risk factors into different levels for the purpose of providing risk factors' structural framework with a good hierarchy and causal relationships for risk analysis and risk management; and
- construct the theatre risk structure model according to the re-ordered matrix.

7.2.2 Analysing the interpretive structure model. The purpose is to define the hierarchy of risk level structures for the theatre's risk factors and order them from lowest to middle and to high-level risk structures.

7.2.3 Theatre anthropogenic risk management model. In theatre anthropogenic risk management model, the higher priority shall be put on managing the evaluation of risks, concerning the theatre's physical structure in relation to "modern use". The aim is to share information on the theatre current and emerging risks, after the complete survey that should be carried out by using the appropriate testing tools (field observation, digital photography, a close visual inspection and others).

7.2.4 Theatre risk action plan. For preventive conservation, the theatre risk action plan can provide a frame-work for decision making, in establishing a mechanism to produce a system of regular and permanent maintenance plans, calculated to ensure the preservation and conservation of theatres and odea. Though, in terms of mitigating the damage to theatre heritage assets, there is a need to prepare a risk emergency action plan that can mandate the development of a comprehensive inventory, conduct/propose detailed actions to determine and deal with the different kinds of theatre vulnerabilities and recommend broad technical mitigation measures, and carry out the design/construction of a long term plan of the protection of the theatre buildings now and in the future.

8. Discussion and results: response and recovery for ancient theatres anthropogenic qualitative risk mitigation management and planning

Theatre anthropogenic risk mitigation strategies and management may be recognised and planned once all the related risks have been identified, accepted and their magnitudes assessed based on the qualitative risk approach. As shown in the previous sections, these cited anthropogenic ancient theatre risks may stem from exposure to one or more risks or synergy of many factors. We, therefore, need to link the risks that come from

anthropogenic factors, associated with social and economic development, with the theatre's natural risks.

However, this requires a holistic approach, and systematic methodology from various sources while incorporating specific actions, planning and strategies for each specific identified risk. Those involved in planning such projects should avoid a situation in which protective measures are extremely costly and produce negative overall effects. A database of theatres including cataloguing of their location, structural conditions, construction technology, and landscape in relation to natural causes of threats and vulnerability is to be critically evaluated and analysed, before any risk mitigation management action. In addition, ancient theatres' risk mitigation planning should take into consideration the following:

- A strategy based on practical testing, continuous monitoring and preventive care should take place in order to develop an appropriate methodology for each type of risk, i.e. small or large scale in situ testing and medium (or even long) term monitoring and back feeding.
- Analysis of risks and assessment of theatre heritage should begin by building on national inventories which will serve as the key instrument necessary for effective planning. Such inventories should be up to date, easily accessible and spatially related by using geographic information systems (GIS) and digital documentation tools (3D laser scanning, thermography, multispectral photography, etc.).
- A successful working schedule should be considered and include scientific tools to prevent the harmful effects on theatre material, based on scientific diagnosis, and through the use of several methods and analytical techniques according to its deterioration nature and status.

Clearly, the combination of many structural peculiarities and the other basic characteristic of age/decay create a challenging scientific and technological problem, in addition to the acute socio-economic consequences. Meanwhile, structural mitigation reduces vulnerability, however, by introducing new structural elements in the theatre building (anchors, tie-rods, concrete beams, fibre-reinforced plastic reinforcements, injections, etc.), unfortunately, this type of mitigation may endanger other values, based on the typical dilemma with all cultural heritage conservation principles. Though, non-structural mitigation techniques have the clear advantage of keeping the historical document intact but does not mean that this approach does not affect other values; context and perception will be modified (Smars *et al.*, 2012, p. 120).

In this respect, unfortunately, engineering procedures for the assessment and upgrading of the theatre buildings are not yet well developed and have not yet reached an adequate degree of refinement. An analysis of traces can help in understanding the potential effect of threats (ICOMOS, 2003). There are various reasons for this, not to mention the needs for unconventional analytical models and for a more general and complex reliable philosophy. In view of this, it is not surprising that previous restorations and solutions, offered to specific problems may hardly be considered as satisfactory; such an unsatisfactory situation is effectively faced in some cases, as for example the conservation and restoration work done for the theatres at Sicily/Italy by experts and specialists by means of rough but reliable rules based on available experience and repetition. Therefore, certain measures should be taken at the international level, aiming at the:

(1) completion of theoretical and experimental knowledge (models on analysis and resistance of masonry);

(2) development of methods of in-situ testing and monitoring; and

(3) development of methods for the overall testing for global verification and validation.

These methods, beside their obvious usefulness for assessment procedures, should be applied both as feedback in order to correct analytical models, and as a means to face unpredictable consequences of accidents (earthquakes, floods, fires, abnormal environmental influences, etc.). In addition, the following types of information should be taken into account:

(1) damages and risk history (frequency of tremors and their effects on theatre material and structures);

(2) the physical, environmental, geological and tectonic features, soil characteristics and its geotechnical behaviour including even the seismogenic sources and risks' mitigation arising from structural problems and ageing of materials;

(3) assessment of the vulnerability of theatre building/cluster and the way this varies spatially and over time including the impact of threats on individual and cluster of theatres; and

(4) the mapping of threats and risks in the different urban areas with theatres.

Thus, rational estimations and predictions can be made regarding the safety and performance of the theatre and a logical framework for decision-making can be secured with possible operations in mind. However, special attention should be paid to two assessment aspects of the theatre sites:

(1) The monument's present socio-cultural condition can impact the decision making regarding any alternative type of modern uses operation.

(2) Besides the historical, archaeological and architectural evaluation of the theatre, a complete structural evaluation of the present condition of the theatre is needed; the interaction between soil structure and building, characteristics and structural typology of the buildings; topography of buildings, interpreting the cracks at the theatre building within particular blocks where an examination of cracks can helps us to understand what has happened. We also have to know whether the cracks are dangerous or not. Laser scanner measurements can be a useful tool to study deformations and understand these damages.

Ultimately, sharing of knowledge and promotion of the factors of theatre anthropogenic risk is crucial. In order to tackle the aforementioned problems, improve the overall protection, and enhance the public visitation and local community awareness, addressing the reason(s) why a theatre building has reached such a bad condition is an essential part of the repair scheme. In addition, a well-documented relevant "local knowledge" for the theatre heritage conservation, construction techniques and risks could also "help to create new concepts, methods, or strategies for improved disaster management" (Shrestha *et al.*, 2011, p. 42). This while some inappropriate new adopted technologies, construction techniques, materials, and ideas, can be wrongly promoted owing to a misunderstanding of local contexts and its particularity – the result of which is often a negative impact on the monument environment and/or the image.

Alternatively, from the qualitative theatre risks factors described above, the key issues to be addressed here are: the improper modern use, safety preventive measures and the development of a community-based risk theatre mitigation programme. Thomas Will (2012, p. 10), however, argued that "preventive measures also have their price. They are tied to a longer planning process and they pose new risks because they often have side effects". The heritage community though should adopt different response strategies according to the theatre different conditions, different environments or different issues related to modern use requirements.

Typically, proper maintenance is the first important step in theatre protection against the devastating effects of any natural or anthropogenic risks and threats; Trees and gigantic bushes grown on the theatre ruins, particularly in the walls, can cause severe damage to the theatre stone structures and construction materials. For example; the ancient theatre at Thasos/ north of Greece has suffered from serious damages due to the intense vegetation in the region; 72 trees have grown in the cavea and have transferred diseases and fungus to the material of the theatre. The roots of these trees have also broken many seats. Therefore, the seasonal manual elimination of plants needs to become a regular part of the annual schedule for the management of a theatre site.

Another conservation key issue is whether biocide application should be performed before or after consolidation, cleaning, joining of fragments, filling of discontinuities and sealing. Microbiologists suggested that biocide application should follow conservation procedures and that biocides should not be removed after application. In contrast, the manufacturers' guidelines regarding both issues are variable. An additional concern is that biocides may gradually be converted to nutrients and enhance re-colonisation (Warscheid and Braams, 2000, Papida *et al.*, 2010). However, cleaning before biocide application resulted in the effective removal of epilithic mats. On the other hand, biocide application on unconsolidated surfaces inevitably causes greater material loss. Raw microbiological data up to now suggests that the action of biocides, applied after the treatments, was limited since re-colonisation time was shorter (Papida *et al.*, 2010).

Assessments need to be performed on the direct and indirect impact and damages due to intense vegetation and biotic coverage at the theatre to control bio-deterioration caused by micro-organisms and plants using biocides.The control strategy should involve careful *in vitro* and in situ examination of the stone substrates (micro) flora and fauna and biocides. This should include the identification of plants and micro-organisms that adversely affect the monuments.

Constraints that inevitably affect choices and treatment potential has also to be identified and include the varying condition of the stone, co-existing and synergic deterioration mechanisms, and the scale of the monuments and their exposure to the natural environment (Warscheid and Braams, 2000). A plan based on practical testing, ceaseless monitoring and preventive care should take place for the treatment of each type of substrate, and each bio-deterioration pattern.

Although the application of water repellent and biocide is effective to repel water and control the bio-growth respectively, the water repellent or consolidant only affects the moisture on the rock surface but not within the rock (Antiquities and Monuments Office, 2012, p. 56), and most importantly, both chemicals could cause irreversible damage to the rock-cut theatres. In the case of usage of "fragile" sandstone rock-cut theatres sites like the late Hellenistic theatre in Nabataean Petra (Plate 5), the crucial goal is to allow public to understand more about their fragility and to minimise preservation methods by limiting continuous human interventions for modern use. Interpretation signage is suggested to provide information to educate visitors about these fragile monuments.

Protective screens could be replaced with a controlled pathway or psychological barrier to facilitate the visitors' appreciation of the theatres fragility. This approach can enhance the public education and awareness as well as prevent the vandalism of the rock carvings (Antiquities and Monuments Office, 2012, p. 56).

In conclusion, for the ancient theatre risk mitigation and recovery it is anticipated that a database should be established for a core of cultural assets to include the following: a survey of all theatres at risk by gathering information about their condition and usage, catalogue their structural conditions and vulnerability, and take practical measures to safeguard these assets. Actually, the "Theatre at Risk Survey" can form the basis of a proposed "Theatre Buildings at Risk Register", with each entry being categorised according to the

Plate 5.
The hellenistic sandstone nabataean theatre at petra, used sometimes for cultural events, that caused risks to the fragile theatre material

Source: Photo by Ihab Amarin

risk scale and level. This enables monitoring, recording, and prioritisation, on a case by case basis. More analytically, the theatre risk mitigation management should pay attention to the following aspects:

(1) Develop guidelines for the planning of the mitigation measures and implementation of mitigation technologies and products; for example, the lighting systems, preparing evacuation plans and providing guidelines for community risk-volunteer training.

(2) Any rational policy and long term protection plan of action require coordination at the administrative level and relevant research and education. This is a rather difficult task; several legal, technical, social, organisational and financial aspects should be considered.

(3) Cooperation within the local communities. Many theatres are located in traditional historic and urban areas. We need to strike a balance between conservation and public appreciation so that the theatre sites would not be overly protected or aggressively promoted. In addition to building links within the community, theatre managers should initiate education campaigns for risk mitigation to strengthen the community's capabilities of anthropogenic risk mitigation and distribute tasks to community committee members. Therefore, we need to develop methods of transferring some scientific theatre risk information to the community. Taking into consideration that there is a growing body of research on the effectiveness of online serious games as creative learning tools (Haddad, 2016, p. 61), some serious games and kits about ancient theatres to encourage children and parents to look, explore and care for the wonders of the theatre cultural heritage should be designed.

(4) Regular monitoring plans of the theatre's physical fabric after conservation work and public events, in addition to scientific studies about overloaded capacity risks should be enhanced. However, monitoring the movement of the theatre's structure normally takes an extended period of time, but at least there is a need for the

inspection of the theatre's structure and foundations, following any nearby construction, excavation or maximum capacity for modern use. According to Wan *et al.* (2010, p. 265) the aim and role of the risk tracking is "to monitor the status of the risk and check the validity of risk counter measures and whether tracking mechanisms are in operation, continue to identify new risks and develop strategies to provide the basis for active risk control".

(5) The conservation principles adopted should be appropriate to the original building technology, partly to preserve the integrity of the original design but also for practical reasons. In addition, to prevent leaching of soluble salts from the cement structures, the conservators should also study and recommend suitable materials, such as siliceous grout.

(6) For theatres' sites with infrequent visitors, construction of a barrier is not recommended, but an information panel can be added as a psychological barrier. Thus, enhancing visitor interpretation to promote public awareness. This approach would help educate the visitors about the historical value of the theatre's sites, and also convey a message against vandalism in a gentler and visually pleasing way. For theatres sites in urban setting there is a need to be linked to their urban and human environment in order to well-build a relationship between the theatre and the living surrounding local community.

(7) Conservation and restoration of acoustical characteristics, in order to take advantage of the acoustical design of ancient theatres and odea, should be considered as one of the most critical issues of the theatre conservation process. A flexible approach of the theatre's acoustical significance is required. A dialogue, though, is needed between those technically specialised in acoustics and theatre managers; to discuss new ideas for the construction and installation of removable and compatible structures (Haddad, 2007, 2008). Therefore, the conservators and restorers that belong to the strict portrayal school should now accept that they have to deal with other new interpretation approaches and methods. Finally, it is necessary that a system for describing and rating ancient theatre acoustics is in place before any intervention is carried out on these monuments (Haddad and Fakhoury, 2010).

9. Summary and recommendations

This paper identifies the ancient theatre risks, and discusses the causal relationships among risk factors based on qualitative assessment, and proposes some suggestions on how to construct corresponding risk mitigation management models.

Risk evaluation is based on the uncertainty of a threat to occur and the accuracy of the risk assessment. This should help to prioritise the decision-making strategies while also taking into account the impact of risks. Interrelation of two components of risk impacts and uncertainty will give priorities for the decision-making process.

Ancient theatres risks mitigation mechanisms are correlated with several factors. There is no perfect method to prevent these risks. This makes theatre risk mitigation an ongoing and challenging task. Emphasis should also be placed on synergy and interaction between the natural and anthropogenic risks.

The suggested and discussed theatre anthropogenic qualitative risk mitigation management framework approach could inform and guide decision makers to incorporate the most recent knowledge into current practice. It allows an integrated vision of most expected anthropogenic theatre risks, and of their probable mitigation, thus providing a useful tool for the design of more holistic risk mitigation management and conservation strategies. In addition, we need to employ the up to date potentiality of the digital methods

to mitigate risk, restore and interpret those monuments, so that the general public can experience, understand and enjoy this rich and diverse edutainment achievements of the Greek, Hellenistic and Roman civilisations.

Theatre risk mitigation management should not be conceived only in some crucial and emergency situations, but interwoven into the practical management. By maintaining theatre heritage sites – repairing, cleaning, or correcting defects – we are not only preventing deterioration of precious original materials, but we are also ensuring that new possible risks can be controlled and avoided. Theatre heritage conservation should be seen as an integral part of all efforts in risk mitigation. However, in order to take advantage of the design of ancient theatres and odea acoustics, the conservation and restoration of acoustical characteristics should be considered as the most important support for the conservation process.

A holistic approach including community involvement is necessary to safeguard those theatre sites in risk situations. This requires a multi-disciplinary approach and team where cooperation of monument owners, archaeologists, scientists and restorers is a must. This should be considered as a critical component of any efficient risk mitigation management and conservation strategy. Therefore, any ancient theatres anthropogenic risk mitigation management and planning should take into consideration the following:

(1) A strategy based on practical testing, continuous monitoring and preventive care should take place in order to develop an appropriate assessment for each type of risk, i.e. small or large scale and medium (or even long) term in-situ testing, monitoring and back feeding and the adopted mitigation strategy. The absence of a planned monitoring activity, actually, can accelerate the process of the theatre's deterioration. However, any proposed theatre mitigation strategy may concern a four-fold action:

- Completion of the theoretical understanding of the theatre's masonry, structural and environmental behaviour, development of rational models, in addition to educating and training of engineers, technicians and conservators.
- Development of specifications and guide-rules for assessment and upgrading, including quality assurance and effectiveness.
- Reconsideration of the whole framework of administrative and legislative measures.
- Evaluation of risks to the theatre heritage, which entails estimating the hazard and assessing how vulnerable each particular theatre may be to that hazard and selecting the appropriate mitigation strategy including the method and level of control and whether the strategy is active or passive.

(2) Analysis of theatre qualitative risks and assessment should begin by building on national inventories which will serve as the key instrument necessary for effective planning. Such inventories should be up to date, easily accessible and spatially related to computer-based modelling tools such as GIS, and digital documentation tools (3D laser scanning, thermography, and multi-spectral photography), in addition to laboratory experiments.

(3) A database should be created to provide the cataloguing of the ancient and contemporary events and activities that contribute to the worth and originality of every theatre site. The aim is to control and make any needed corrections for the deviations from the risk mitigation plans.

(4) Maintenance procedures should be taken into consideration for minimising interventions in the future, while theatre buildings must be properly maintained to adequate conservation standards. This will enhance the establishment of a mechanism for producing a system of regular and permanent maintenance plans, calculated to ensure their preservation and conservation.

(5) Enhancing the scientific facts information and relevant "local knowledge" about construction techniques and materials based on conservation programmes, activities and management of ancient theatres. We have also to find the best compromise between the path of traditional repair and restoration and that of new solutions. A successful working schedule should be considered and include scientific tools to prevent the harmful effects on theatre material, based on tested scientific diagnosis, and through the use of several methods and analytical techniques according to the risk nature and status, especially for theatres hosting modern performances and activities.

(6) Assessment of executing new ideas for the construction and installation of removable and compatible structures, with the aim of establishing general regulations for the theatre use according to each theatre's case while maintaining the authentic acoustic qualities.

(7) Establishing margins of safety, in relation to durability, against all possible actions, including natural risks like fire and the critical environmental conditions, which may alter the material and structural properties. Construction of an interpretative panel as a psychological barrier for the fragile sandstone theatre sites and removal of all existing concrete additions and structures is required.

(8) As an outcome of the study, a mechanism for community-based anthropogenic qualitative risk management for the theatre's sites is required. Any management, intervention, or reconstruction plans should be aware that local communities within theatre sites are dependent on tourism revenues and that tourism facilities are planned with these communities in mind. It is crucial to raise awareness and educate the general public that the theatre buildings are not inherently dangerous, as well as educate stakeholders about how theatre buildings are more resistant.

(9) Preparation of educational materials on anthropogenic qualitative risks' mitigation for public information and awareness. Considering the issues and challenges described above, there is an urgent need for awareness, education and training among the local community, visitors and audience and key stakeholders to address the needs of theatre heritage threatened by the various related kinds and types of risks. It is necessary to establish an effective communication channel to ensure that risks mitigation can be carried out successfully. Developing supporting information that is accurate, easy to read, easy to understand and relatively easy to implement are a key issue. Though, there is a need to develop standards for rapid inventories.

Create educational kits to raise awareness for school children, taking into consideration that there is a growing body of research on the effectiveness of online serious games as creative learning tools. More serious games about theatres to encourage children and parents to look, explore and care for the wonders of the theatre cultural heritage is needed.

Early warning and proper response procedures need to expand its influence so that children at an early age are aware with regard to the theatre anthropogenic risk. Properly leveraging the multi-media can help raise awareness and educate. Web-based training also could be provided for professionals.

(10) In order to promote human comfort and take advantage of the acoustical design of ancient theatres and odea, the conservation and restoration of acoustical qualities should be considered as a priority. Though, there is a need to improve the perception and knowledge of the acoustic value of the theatre's cultural heritage. A complete quality-control system is an important leverage to promote the indigenous acoustical heritage in the restoration process.

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Corresponding author
Naif Adel Haddad can be contacted at: naif.haddad@aum.edu.jo