# Local Management Strategies for Preventive Conservation of Historic Buildings "Controlling Deterioration Caused by Air Pollution"

GEHAN NAGY, KHALID DEWIDAR, MONA AZOUZ, MARIAN NESSIM, DINA SALEM, YASMINE SABRY, FAYROUZ ASHRAF
Architecture Department, The British University in Egypt, Housing & Building National Research center, Zagazig University
EGYPT

*Abstract:* - The current local strategies are reactive in response to risk or damage, usually in the form of treatments, repairs and retrofitting on the building scale, there is a need for proactive strategies that rely on preventive conservation concepts which can be more sustainable and cost effective as it minimizes the possibility of deterioration and risk through controlling its cause on different scales. In order to conserve historic buildings from deterioration caused by air pollution, the impact of air pollution on these buildings need to be specified and quantified in order to be controlled below the tolerable thresholds using convenient strategies on the appropriate scale. The main objective is to minimize deterioration of Historic Buildings caused by Air Pollution through the development of a framework for local management preservation strategies. A survey was also conducted to validate the framework. This will lead to types of preventions (UNESCO PRECOMOS Chair) as follows; primary prevention by avoiding the causes of the unwanted effect (damage), secondary prevention as the means of monitoring that allow an early detection of the symptoms of the unwanted effects, and tertiary prevention that allow avoiding further spread of the unwanted effect or the generation of new unwanted (side) effects.

*Key-words:* Management strategies; Preventive conservation; Historic buildings; Air pollution and pollutants

Received: July 23, 2021. Revised: May 17, 2022. Accepted: June 8, 2022. Published: June 23, 2022.

## 1 Introduction

Air pollution plays a major role in the lifetime of a building. Many climatic events through the last century to our present-day resulted in an increase in temperature, precipitation levels, high sea levels, changes in soil conditions, and other extreme weather conditions [1]. The pollutants given out into the atmosphere by any means of air pollution sources such as vehicles exhaust, burning of urban waste, or burning of agriculture are massive and often of a permanent impact, especially on buildings surfaces [2]. Historic buildings or sites would be severely affected by the chemicals and polluted substances which will lead to its destruction, consequently to huge economic losses and losing the history and identity of our heritage Egyptian culture. This study will go through a literature review on air pollution impacts, preventive conservation, and heritage management strategies and systems, in order propose steps of management stages. These stages were also classified according to each role of administrative bodies involved in the management strategies applied. Moreover, comparative analysis between chosen case studies were illustrated in relation to these management stages. This paper differs from the related ones in the technical literature as the paper takes in consideration the administrative bodies in decision making as well as the scientific community. The paper concluded into a framework of management strategies for preventive conservation of historic buildings.

## 2 Air Pollution and Impacts on Historic Buildings

Below are the types of damages and the impacts of air pollution on historic buildings:

### 2.1 Physical Damage

External forces such as from loads, movements, impacts, human actions, etc.… or internal forces as for example generated by forced deformations at uneven temperature and moisture changes causes the physical deterioration of materials. The factor of time is also crucial in the damage occurring. A mechanical breakdown happens as a result of the physical damage [3].

### 2.2 Chemical and Biological Damage

Reactive compounds present in surroundings or by biological factors affect material chemically. This damage could be originated by physical factors such as thermal conditions, for e.g., light or temperature or radiation, and photochemical damage. [3]

### 2.3 Soiling

The phenomenon of soiling affects historic buildings in decreasing its serviceability and appearance defects such as dark crust on facades which causes increasing in building temperature. Soiling can be caused by alterations, deposition and biological colonization [3].

## 3 Preventive Conservation

The aim of preventive conservation is to reduce the rates of deterioration and limit risks to be occurred which is included in the risk management process. It is relatively considered a new field compared to traditional methods of conservation. The field is involved in several forms of sciences such as materials, building science, chemistry, physics, biology, engineering, systems science and management, as well as in technical fields [4]. Specialists carry the responsibility of maintaining a safe environment for historic elements as daily diagnosis lowers the costs of restoration. Therefore, on the long run, the preservation of historic buildings will be more cost efficient. This system of data gathering during regular inspections eases monitoring the state of preservation of historic buildings. [5]

### 3.1 Types of Preventions

According to UNESCO PRECOM³OS Chair [6], there are three types of preventions:

- Primary prevention: aims to avoid the causes of any unwanted damage.
- Secondary prevention: aims to monitor for early detection of the indications of any unwanted damage.
- Tertiary prevention: aims to avoid further spread of the unwanted damage or the generation of new unwanted damage as a side effect.

### 3.2 Preventive Measures

Building maintenance strategies undertaken are mostly remedial but are necessary as it acts as preventive measures, such as re-painting walls or repairing deteriorated elements, are important to prevent further deterioration. Buffering and tempering historic buildings are also considered a preventive conservation strategy for amending damage in addition to direct interventions regarding the building usage, fabric or site. These interventions, for example, application of plasters, mechanical removal of accumulated salts, are viewed as preventive and requires regular monitoring to determine the efficacy of the action/s over time.

## 4 Common Maintenance and Management Strategies

The main maintenance strategies differ in their timing [5],

- Emergency or accidental maintenance: The intervention is needed immediately when the damage occurs and can be avoided with a right preventive maintenance plan. This strategy is not part of the planning.
- Preventive-predictive threshold maintenance: The intervention includes all the regular preventive actions agreed for maintenance. It depends on historic and experimental data. This strategy depends on detecting damage probability. It is needed in situations with high criticality and require regular conservation with known durability and damage rate.
- Preventive maintenance condition-based: It consists of preventative maintenance operations based on knowledge of durability and life cycle connected to monitoring results; it is possible to change the scheduled operations and their frequency based on monitoring findings. As a result, the true goal of scheduling is to keep track of what has to be done and when it needs to be done. It is particularly successful when applied to historic buildings, especially if they are of high cultural value, because irreversible damage could have an unquantifiable cost, or at the very least one that is far greater than the expense of ensuring ongoing monitoring. Furthermore, this method is particularly well suited to restoration and consolidation interventions.
- Opportunity maintenance: All operations are planned ahead of time to take advantage of opportunities that allow them to attribute their convenience to another cause; the goal is to take advantage of installations and resources that have already been mobilized for other interventions or to seize the

opportunity provided by a sudden need for intervention on other parts of the building. In any case, the preventive-opportunity measures must be evaluated on factors related to the life cycle of the element that has to be fixed. Because it combines multiple interventions into a single session, it allows for the conservation of economic resources, lowering costs, assuming that it is well-executed.

## 5 Heritage Management Systems

Three elements define a heritage management system; they are: a legal framework stating the reasons for its existence, organizational needs and decision-making through an institution and operative measures as human, financial and intellectual resources. To guarantee a sustainable way for conserving and managing of heritage structures, these elements help in the actions of planning, implementation and monitoring. The application of the system could be on a single heritage property or a group of properties or a whole area. To achieve the ultimate heritage management system, specific results are expected to both the property and its stakeholders. These results are reached by delivering outputs with regular improvements in response to defects or the need of new actions. [7].

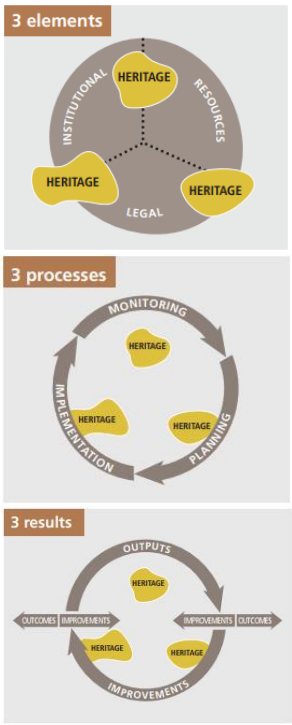



Fig. 1: Heritage management systems in general and in World Heritage [7]

## 6 Proposed Stages of Management Strategies

In reference to the previous section, the following are the proposed stages of management strategies:

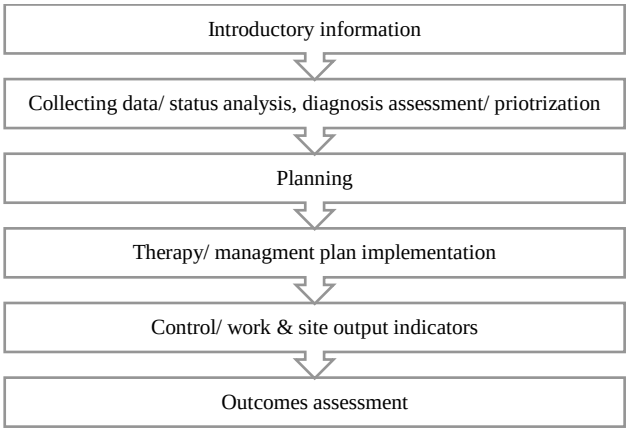



Fig. 2: Proposed stages of management strategies

## 7 Case Studies

Below are three case studies; two are international cases (Taj Mahal and CULT-STRAT project) and one is an Egyptian local case study (Saqqara). These were selected upon the following: (1) Considered a historic building, (2) Application of a management plan. Each case study contributes to the framework criteria to be developed.

### 7.1 Taj Mahal

#### 7.1.1 Problems and Challenges

Pollution along with tourism pressure are the greatest threat. The Taj Mahal itself is in a good state of preservation. Minor defects such as cracking of stones have occurred and are addressed as part of a regular maintenance program. Serious air pollution has led to the deterioration of the white marble, stone inlays and sandstone of the site. There are also concerns about the yellowing and soiling of the Taj Mahal and the possible impact of sulphur oxide and associated atmospheric depositions as well as the impact of dust and aerosols (Banerjee & Sarkar, 2019). Another problem is the absence of communication and co-ordination between concerned authorities responsible for the conservation, management and development of the properties.

#### 7.1.2 Plan Objective

The main objective was to have an integrated management plan for the sites of Taj Mahal and Agra Fort to facilitate a participatory planning,

conservation, and management process involving regular all stakeholders related to the site.(UNESCO WHC, 2004)

### 7.1.3 Stakeholders & Actors

This preliminary plan was developed as a result of the cooperation of the National Culture Fund, the Archaeological Survey of India (ASI), and the Indian Hotels Company Ltd., then the Taj Mahal Conservation Collaborative (TMCC) was founded to be consultants to advise on the development of the projects.

### 7.1.4 Funding

A French private enterprise, Rhône Poulenc granted a fund a three-year research project for the conservation of the Taj Mahal and monuments at Agra Fort and to establish a conservation laboratory in Agra Fort. This will also fund UNESCO participation in the TA-2474 Agreement for the Environmental Improvement and Sustainable Development of the Agra and Mathura Trapezium Program, funded by the Asian Development Bank. (TMCC,2003)

### 7.1.5 Considerations

The conservation plan considered the different forces influencing the site, cooperation of a much larger constituency of related stakeholders, setting an institutional and legal framework, conservation perspectives and practices, horticultural and water management concerns, and visitor management and facilitation of the Taj Mahal. It also aimed to address regional concerns related to the city development such as lack of drinking water or electricity, which directly affect the management and maintenance of the Taj Mahal site itself. (TMCC,2003& UNESCO, 2004)

### 7.1.6 Operational Scale

Since Taj Mahal is recognized as World Heritage, the conservation plan is according to a World Heritage mandate integrated with acknowledged need that conservation and preservation of historic sites is processes of consultation and participation at the local level.

### 7.1.7 Documentation and Research

The Archaeological Survey of India (ASI), responsible for the repairs, conservation and maintenance of the Taj Mahal, has taken adequate measures to preserve the monument without compromising its originality. Documentation and recording of the Taj Mahal complex is crucial, therefore the management plan proposed by TMCC starts with historic building fabric survey followed by scientific investigation and analysis. Documentation includes all physical evidence and features of the building and site as well as an inventory of the traditional materials and their sources and properties whereas scientific investigation includes environmental studies and tests to be carried out on the existing building fabric and new materials that are to be used for the conservation work, tests needed to be carried out before, during and on completion of the work.

### 7.1.8 Programming for Conservation Projects

An implementation mechanism is also proposed to ensure regular monitoring, intensive documentation and periodic reporting, while maintaining transparency in financial transactions.

### 7.1.9 Monitoring and Reporting

According to UNESCO WHC, the State Party report provided the same reports of technical conservation and restoration work projects carried out on the property since 2004 and some of the work lack sensitivity in design. The State Party submitted a state of conservation report that addresses the progress made in the implementation of Decision made by the World Heritage Committee. It also reports about the development of the Integrated Management Plan and that consultation process with the State Government, Department of Tourism and Advisory Committee for World Heritage Matters, in order to assess the complex management issues. Reporting also include any new development in the site in order to avoid any contradiction with the conservation measures.

### 7.1.10 Preventive Measures and Special Considerations

The archaeological Survey of India (ASI) and the Government of India have cleaned the surfaces of the stone, replaced deteriorated panels, and taken measures to reduce air pollution by imposing various restrictions on the industries concerned. Internal combustion engine vehicles have been banned whereas electric three-wheelers (e-tuktuks) and electric buses were introduced as an alternative. A comprehensive action plan is launched by the government includes vehicle emission control, suspension of road dust, emission control from biomass and municipal solid waste burning, industrial emissions, air pollution from construction and demolition activities and monitoring of air quality, scientific assessment of sources and capacity building. Also, the construction of a new industrial complex was recently prevented. An

emergency plan is necessary to maintain the state of conservation and prevent any further deterioration.

## 7.2 CULT-STRAT project

CULT-STRAT (Assessment of air pollution effects on cultural heritage - Management strategies) was a Specific Targeted Research Project supported by the European Commission from 2004 to 2007. The aim of CULT-STRAT was to establish a scientific reference for developing strategies for policy and decision makers on European and national levels within the CAFE (Clean Air for Europe) Program and for decision makers and heritage managers for strategic decisions at a local level.

### 7.2.1 Problems and Challenges

Air pollutants, which together with climatic parameters, are of major importance for the deterioration of many materials used in cultural heritage objects, are emitted all over Europe by industrial activities and by the transport sector. To prevent or reduce harmful effects of pollutants on human health and the environment the Council Directive 1999/30/EC has been issued relating to limit values for sulfur dioxide, oxides of nitrogen, particulate matter and lead in the ambient air. These have been established with reference to health and ecosystem effects and have not, so far, included effects on building materials.

### 7.2.2 Project Objectives

The major objectives were providing a timely impact assessment on the effects of current and projected air pollution levels on cultural heritage materials on regional and city levels through a choice of material indicators and pollution threshold levels based on best available scientific data including deterioration models, spatial distribution and mapping of pollutants and of stock of materials at risk, cost estimates throughout Europe for current pollution levels and the CAFE baseline scenarios for 2010 and 2020, and comparison studies off different conservation approaches.

Table 1. CULT-STRAT objectives

| | |
|---|---|
| **Local management strategies** | ○ Damage inspection<br>○ Conservation practice including preventative maintenance<br>○ Local perspectives |
| **Strategic decisions** | ○ Policy (informed by scientific evidence and values such as sustainability of heritage resources)<br>○ Analysis of strategic data including air pollution, environmental status and stock at risk<br>○ Estimates of damage impacts on life cycles of materials and benefits arising from pollution reduction |

### 7.2.3 Operational Scale

Methodologies for performing stock at risk studies of cultural heritage objects on different geographical scale have been developed: European level (UNESCO World Heritage Sites), on country level (Italy, Czech Republic, France, Norway), on city level (Madrid, Milan), for parts of historic town areas (Paris, Venice, Rome) and for individual historic buildings (S. M. della Vittoria and Aldobrandini Villa in Rome).

### 7.2.4 Contractors and Coordinators Involved in the Project (Actors)

(1) Corrosion and Metals Research Institute (Sweden), (2) Norwegian Institute for Air Research (Norway), (3) Italian National Agency for New Technologies, Energy and Environment (Italy), (4) Middlesex University (United Kingdom), (5) Umweltbundesamt (Germany), (6) Laboratoire Interuniversitaire des Systèmes Atmosphériques (France), (7) Institute of Theoretical and Applied Mechanics-Building Research Establishment (Czech Repuplic), (8) Consejo Superior de Investigaciones Cientificas (Spain), (9) Swedish Corrosion Institute (Sweden)

### 7.2.5 Applied Methodology, Scientific Achievements and Main Deliverables

#### 7.2.5.1 Model for ranking Effects of Pollutants on Corrosion and Soiling

The overall aim of the project is to assess the effects of different pollutants on materials and objects of cultural heritage in the present multi-pollutant situation and to identify material indicators and threshold levels of pollutants, which will be used for development of management strategies for protection of the European culture heritage.

- Models for corrosion
- Soiling of modern glass
- Risk of present and future pollutant exposure for degradation of cultural heritage buildings and structures exposed to the ambient atmosphere

#### 7.2.5.2 Analysis of Variability of Pollution Concentrations at Different Geographical

Data sources and models for spatial distribution of pollutants

- Wind and eddies around buildings.
- Recommendations for the evaluation of strategic actions to reduce pollutants in the proximity of areas with cultural heritage

### 7.2.5.3 Stock of Cultural Heritage at Risk in Different Areas

Within this work package, methodology of performing stock at risk at different geographical levels were considered and developed. Case studies of stock at risk at different scales: (continental, national, city, district, single monument) were performed by different partners. In the sequel a selection is given of the obtained results. The CH (Cultural heritage) objects with historic and cultural value were selected subdividing them in 3 levels: the 1st level will contain the CM (Cultural Monuments) situated in the capital of the respective country or in very important cities, the 2nd level in the big cities of the country and the 3rd level in the medium and small CH towns of the country.

*7.2.5.4 Analysis of life cycles and costs for cultural heritage materials at different pollution scenarios*

The strategies considered both knowledge of dose/response and damage functions gained from long term exposure programs and possible effects of expected future changes in the air quality, including new multi-pollutant situations and effects of reduction of emissions. During the project work, 20 studied materials have been selected and their damage functions reviewed as a basis for cost analysis at different air pollution scenarios. Seven groups of items have been selected that represent typical conservation/renovation works for further study. They are roof envelope, non-plastered masonry, glass walls, plastered façades, painted wood, sculptures and sculptural items, supporting works. When dealing with costs, it is useful to distinguish between different types of actions and to break them down accordingly. It has been accepted as practical to consider three modes of intervention, though subtler categories can be defined. These three modes are: maintenance, conservation, and renovation. In the framework of the project, the costs of construction work or building elements related to appropriate units have been reviewed. The costs include material costs and labour costs, together with the mean transportation and scaffolding costs relevant for low rise buildings up to 3-storey. The costs are derived from known examples (mostly restoration costs), official price lists and long-term statistical surveys (general repair & construction costs).

Table 2. Comparison of typical modes of intervention concerning costs and lifetimes in 2005

| No. | Surface layer or system | Unit | Guided cost EUR | | | Lifetime in years | | |
|---|---|---|---|---|---|---|---|---|
| | | | Min. | Max. | Avg. | Min. | Max. | Avg. |
| 1 | copper sheet – total replacement | $m^2$ | 55,65 | 85,00 | 67,82 | - | - | - |
| 2 | steel galvanized sheet – total replacement | $m^2$ | 16,04 | 52,00 | 30,59 | 5 | 45 | 25 |
| 3 | plain tiles (double) – total replacement | $m^2$ | 30,23 | 43,32 | 36,58 | 40 | 100 | 70 |
| 4 | flap pantile roofing – total re-placement | $m^2$ | 24,23 | 45,39 | 37,65 | 30 | 70 | 50 |
| 5 | wooden shingle split – total replacement | $m^2$ | 35,16 | 83,68 | 58,04 | 50 | 80 | 65 |
| 6 | paint on steel sheet – renewal | $m^2$ | 3,75 | 5,48 | 4,62 | 3 | 9 | 6 |
| 7 | paint on galvanized steel sheet renewal | $m^2$ | 5,53 | 57,00 | 26,02 | 5 | 11 | 8 |
| 8 | paint on wooden shingle roofing | $m^2$ | 5,32 | 43,32 | 17,96 | 5 | 8 | 6,5 |

### 7.2.5.5 Selection and Testing of Indicators and Threshold Values for Cultural Heritage

The main objectives of the work package are to give recommendations for materials useful as primary cultural heritage indicators and corresponding levels of damage, to show how the levels of primary cultural heritage indicators correspond to pollutant levels as secondary indicators, to evaluate the practical applicability of selected indicators and threshold levels

#### 7.2.5.6 Strategies for Air Quality Policy and for Prevention and Maintenance of Cultural Heritage Objects

To achieve these objectives, two workshops have been organized within the project. Following the workshops, the CULT-STRAT partnership undertook extensive work to integrate the material from the project, the workshops and other sources into a reference manual.

## 7.3 Saqqara

### 7.3.1 Problems and Challenges

The risk factors that cause the deterioration include Chemical agents (air pollutants), it was found that the total suspended particulate matter in the atmosphere is much greater than the permissible value, as the urban areas adjacent to the site depend on the use of fuel in factories scattered around the site, transportation and household uses, which leads to a high rate of air pollution. Human pressure and tourist flow cause an increase in the rate of humidity, which affects the paintings and causes cracks in the walls, in addition to human violence in direct dealing with the heritage elements of the site. Vibrations caused by the spread of many excavations near the site also which poses a danger to the site in the long run, as well as biodynamic decay factors and thermal changes resulting from the effect of solar radiation causing loss of the original colour pigments. Among the most damaging factors is water that damages stones and walls and cause the formation of salts.

### 7.3.2 Plan Objective

The main objective is to analyse and manage the risks on the Saqqara region and all its monuments and identify the places of danger and places of loss.

### 7.3.3 Stakeholders & Actors

The Department of International Cooperation at the Ministry of Foreign Affairs in Italy, in cooperation with the Supreme Council of Antiquities and under the supervision of the University of Pisa, a (non-executive) department was created in the Council called the Technical Office for Management and Control of World Heritage Sites.

### 7.3.4 Documentation and Research

The first step was creating a database for the site, a complete documentation of the pyramid was done, and a database of information was established at the Supreme Council of Antiquities and the Culture Centre at the Library of Alexandria containing maps of the area, pictures and slides, and many microfilms of the area were preserved. A full survey of all the monuments and methods to sign the places, danger and places of loss to come up with a map of the dangers of the Saqqara region and clarify the places of pressure, followed by analysing land uses and studies of tourist flow rates. Sensors to monitor climatic changes, pollution rates, temperatures, and human influences, especially due to the high levels of pollution.

### 7.3.5 Funding

The Egyptian government is the main financier of the pyramids area through the Ministry of Culture and the Supreme Council of Antiquities, and there are some technically and financially directed missions from governments of some countries, such as the Italian government for the Saqqara region, and many American missions on the pyramid plateau.

### 7.3.6 Considerations

The management system has taken several precautions to follow-up the urban sprawl, which led to building security fences and gates to control the paths of tourists and tight security from the tourism police with an integrated administrative structure which is based in King Farouk's rest house, and many public awareness raising programs were made to reduce any negative effects on the region.

### 7.3.7 Operational Scale

In 1990, UNESCO raised its level of interest in the area of the pyramids and placed a plan to protect and manage the area, which relied on a team of British architects presented reports aimed at preserving the excavations in the area and stopping the deterioration in the area as a result of pollution, in addition to controlling the entrances to the area and limiting the construction of modern facilities, as indicated by UNESCO.

### 7.3.8 Programming for Conservation Projects

The project came out with total outputs that covered a risk analysis and a complete survey of the area, but they were not reflected on the special administration of the area as a world heritage**.** The project has developed indicators for measurement of pollution, tourism rates, climate change, cracks, **c**olour loss rates, presence of microorganisms on the walls.

### 7.3.9 Monitoring and Reporting

The effects of risks and vulnerabilities are as follows: lost in original material and graffiti tints**,**

salts are behind the outer layers installed on the walls, which led to cracks and separation of these layers from the walls**,** salts and powders were found on the surface of stone walls**,** dissolution in layers of stone surfaces**,** erosion of roofs and stones**,** parts of the walls fell due to human pressure from visitors**,** destruction caused by human activities**,** change of colours.

The Risk scenario of occurrence of the risk is due to two basic types: the physical environment, and the human pressure

- The first type: includes risk factors related to environmental factors such as climate, biological factors, air quality, and others.
- The second type: human pressure can lead to the deterioration of the site in addition to the urban settlements surrounding the residential and productive (agricultural and industrial) site, which represent a potential danger to the site and the resulting pollutants and material damage.

### 7.3.10 Preventive Measures and Special Considerations

Table 3. Prevention and mitigation measures to address the site's weaknesses and risks

| Factors of weakness | Prevention and Mitigation Measures |
|---|---|
| **The state of preservation of tomb walls has deteriorated as a result of various pollutants** | Develop a database to monitor the state of preservation and give quantitative and qualitative data through which to take conservation measures and deal with risk cases |
| **High levels of pollution** | Setting up a monitoring and control system on the site through sensors to monitor climate changes, pollution rates, temperatures and human influences |
| **Human violations** | Enact and enforce strict laws in case of external violations |
| **Blasting activities in excavations and the military area adjacent to the site** | The distance from the site should be determined in accordance with international codes that recommend the least distance in which these activities can be held near archaeological areas |
| **High rates of tourist flow** | Linking the tourist flow database with the data on vulnerability analysis and preservation to formulate on-site tourism management plans |

## 7.4 Comparative Analysis of the Three Case Studies

The following table (Table 4) is a comparison analysis of the three case studies according to the stages of management strategies. The checklist presents the management strategies applied in each case study.

Table 4. Comparative analysis for case studies

| Points of comparison | | | | Case Study | | |
|---|---|---|---|---|---|---|
| | | | | Taj Mahal | CULT-STRAT | Saqqara |
| Introductory Information | | | Operational scale | ✓ | ✓ | ✓ |
| | | | Scope of plan | ✓ | ✓ | ✓ |
| | | | Relationship with any other relevant plans | | | ✓ |
| | | | Limitations and Impact of national context and development plan | | | |
| | | | Identifying stakeholders | ✓ | ✓ | ✓ |
| | | | The lead organization(s) | ✓ | ✓ | ✓ |
| | | | The project team and its responsibilities | ✓ | ✓ | ✓ |
| Collecting Data / Status Analysis, Diagnosis & assessment/ Prioritization | | | Identifying site values and originality | ✓ | ✓ | ✓ |
| | | | Site condition | ✓ | ✓ | ✓ |
| | | | Building's condition | ✓ | ✓ | ✓ |
| | | | Diagnosing the current condition | ✓ | ✓ | ✓ |
| | | | Risk assessment and stock at risk | ✓ | ✓ | ✓ |
| | | | Prioritization | | | |
| Planning | | | Objectives and vision | ✓ | ✓ | ✓ |
| | | | Development of management and action plans | ✓ | ✓ | ✓ |
| | | | Allocation of resources and management needs and inputs | | | ✓ |
| | | | Cost analysis including cost of interventions | | ✓ | ✓ |
| | | | Timeframe & time between interventions | | ✓ | |
| Therapy/Management plan implementation | On building/site scale | Maintenance | Means to avoid the causes of the unwanted effect | ✓ | ✓ | ✓ |
| | | | Mapping and modelling pollution impacts | | ✓ | |
| | | | Monitoring pollution | ✓ | ✓ | ✓ |
| | | | Plans for pollution reduction to tolerable thresholds | ✓ | ✓ | ✓ |
| | | | Buildings regular inspection and maintenance | ✓ | ✓ | |
| | | | BIM | | | |
| | | Conservation/Preservation | Monitoring systems and early detection of the symptoms of the unwanted effects | | ✓ | ✓ |
| | | | Using non-invasive inspection technologies | ✓ | ✓ | ✓ |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | Cyclic preventive maintenance | | ✓ | |
| | | | Testing and sampling for early detected damages | ✓ | ✓ | ✓ |
| | | | Repairing detected damage | ✓ | ✓ | |
| | | **Renovation** | Repair the damages using appropriate restoration techniques | ✓ | | ✓ |
| | | | Regular inspection and maintenance | | | |
| | | | Mitigation strategies to prevent further damage | ✓ | ✓ | ✓ |
| | **On Buffer zone scale** | | Preventing damaging activities | ✓ | ✓ | ✓ |
| | | | Creating workplaces | | | ✓ |
| | | | Providing Services | ✓ | | ✓ |
| **Control/ Work & Site Output Indicators** | | | Evaluation of monitoring indicators | ✓ | ✓ | ✓ |
| **Outcome's assessment** | | | Review of management effectiveness assessment results | ✓ | ✓ | |

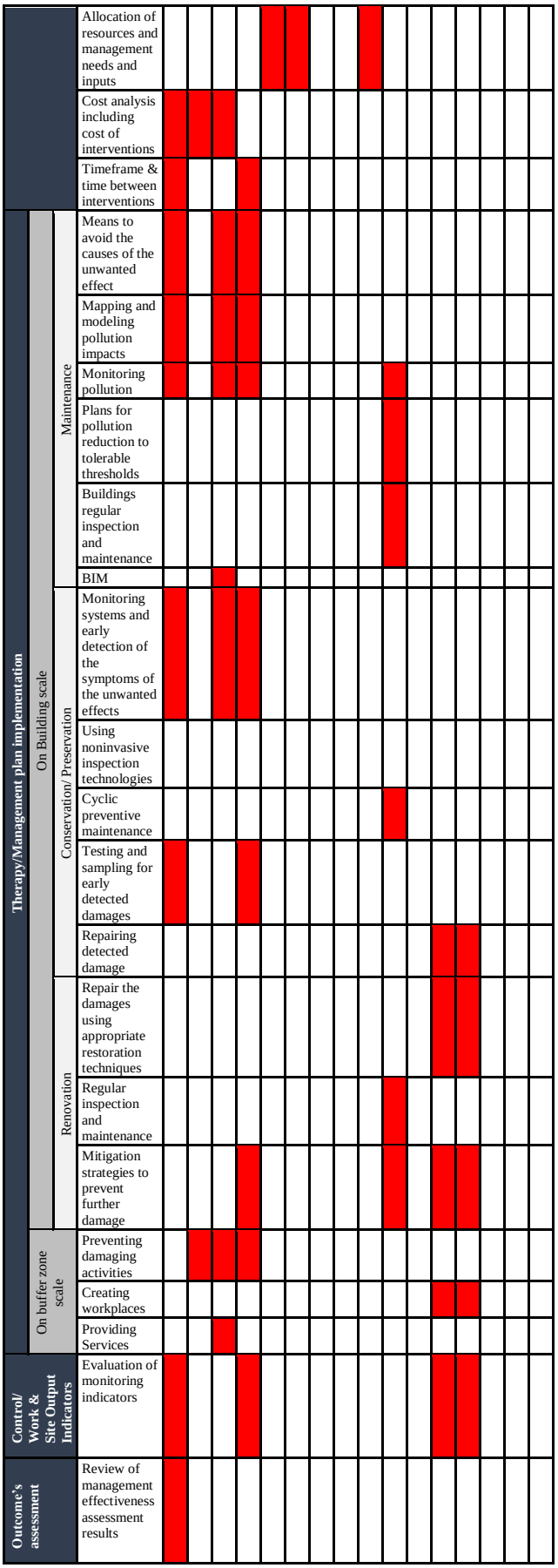
## 8 Stakeholders and Actors involved

The following table (Table 5) determine the role of the Egyptian administrative bodies whether stakeholders or actors in the process of applying management strategies on historic buildings. The table demonstrates the relation between each administrative body and their involvement in the steps of the management process applied in Egypt, where some are involved in more than one action. These actions are also co-related and overlapping through the whole process.

Table 5. Role of administrative bodies through the stages of management strategies in Egypt

| ADMINISTRATIVE BODIES | | Minister office | | | | | | General Secretariat | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Scientific office | Legal office | Technical office | Risk and disaster administration | Administrative affairs | Administrative office | Financial and administrative | General dep. of financial affairs | General dep. of Administrative Affairs | General Administration of employees' affairs | General dep. of Maintenance, movement and transportation | General dep of gardens, beautification and landscaping | Egyptian and Greece-roman antiquities sector | Central administration of antiquities of Cairo and Giza | Islamic, Coptic and Jewish antiquities sector | Central administration of antiquities of Cairo and Giza | NGOs | Private sectors | Funding agencies |
| **Introductory information** | Operational scale | | | ■ | | | | | | ■ | | | | | | | | |
| | Scope of plan | | | ■ | | | | | | ■ | | | | | | | | |
| | Relationship with any other relevant plans | | | | | ■ | | | | ■ | | | | | | | | |
| | Limitations and Impact of national context and development plan | ■ | | | | | | | | | | | | | | | | |
| | Identifying stakeholders | | ■ | ■ | | | | | | | | | | | | | | |
| | The lead organization(s) | | ■ | ■ | | | | | | | | | | | | | | |
| | The project team and its responsibilities | | | | | ■ | ■ | | ■ | | | | | | | | | |
| **Collecting Data / Status Analysis, Diagnosis & assessment/ Prioritization** | Identifying site values and originality | ■ | | ■ | | | | | | | | | | | | | | |
| | Site condition | ■ | | ■ | | | | | | | | | | | | | | |
| | Building's condition | ■ | | ■ | | | | | | | | | | | | | | |
| | Diagnosing the current condition | ■ | | ■ | ■ | | | | | | | | | | | | | |
| | Risk assessment and stock at risk | ■ | | ■ | ■ | | | | | | | | | | | | | |
| | Prioritization | ■ | ■ | ■ | ■ | ■ | | | | | | | | | | | | |
| **Planning** | Objectives and vision | ■ | | | | | | | | | | | | | | | | |
| | Development of management and action plans | ■ | | | | | | | | | | | | | | | | |

Gehan Nagy, Khalid Dewidar,
Mona Azouz, Marian Nessim, Dina Salem,
Yasmine Sabry, Fayrouz Ashraf




# 9 Results

After analysing the management process applied along the three case studies, and the role of administrative bodies in decision making, it is concluded that the developed framework of management strategies for preservation of historic buildings are as follows (Fig. 3) divided into five stages to result in an outcomes assessment to fulfil the management strategy applied.

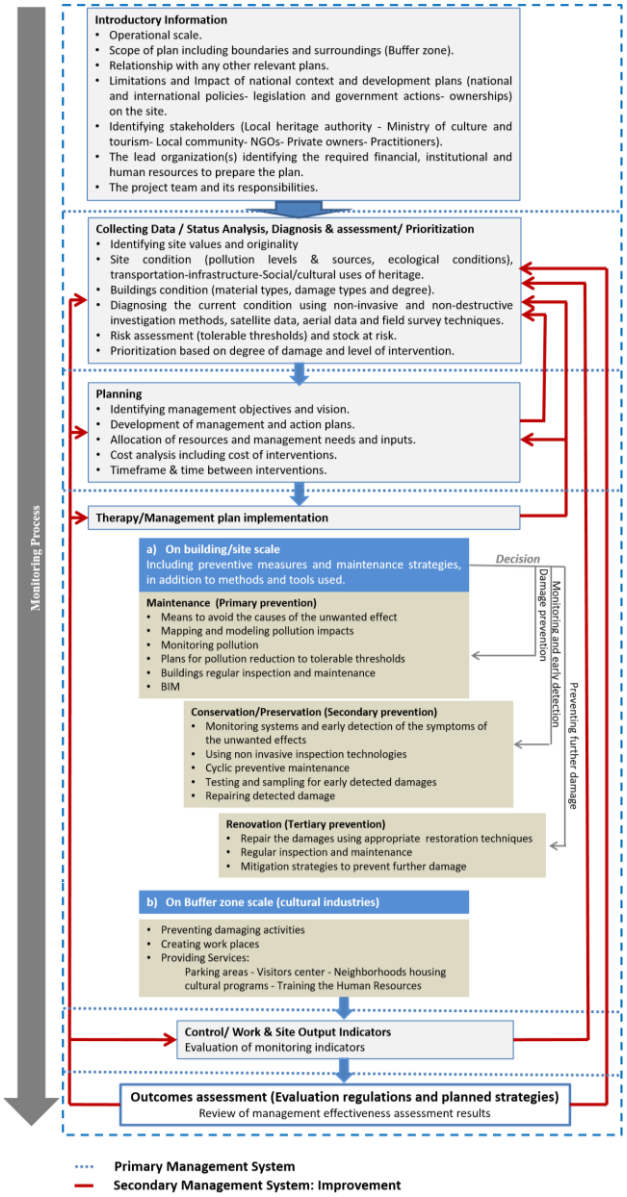


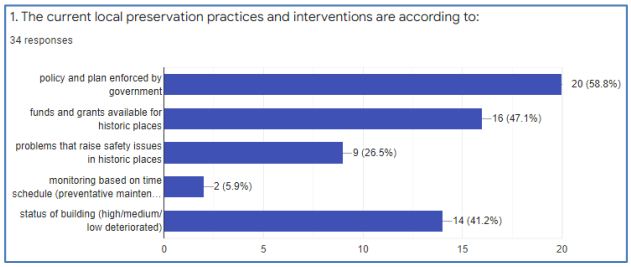

Fig. 3: Proposed management strategies framework for preservation of historic buildings.

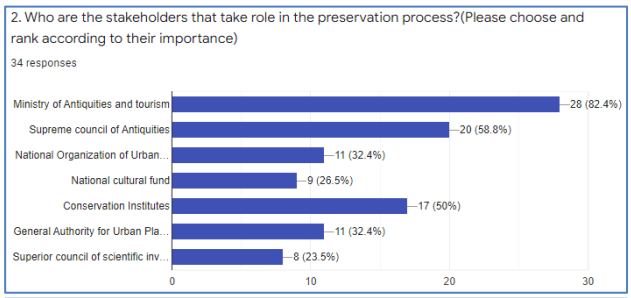
The framework is proposed from the analysis of the management strategies applied on the case studies for preservation of historic buildings. The strategies followed are a flow of steps to be taken in the management plan of historic buildings including

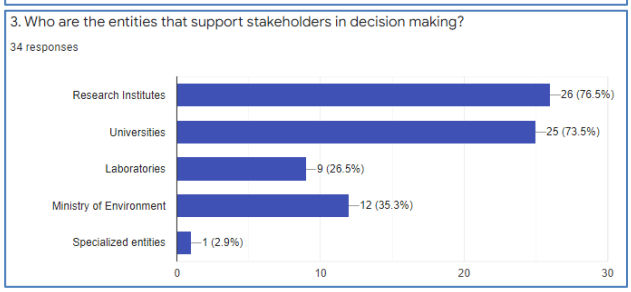
primary and secondary systems. The monitoring process aimed in assessing the building through data collection, analysis, planning and implementation and these lead to outcome assessment and a complete review of the management strategies effectiveness.

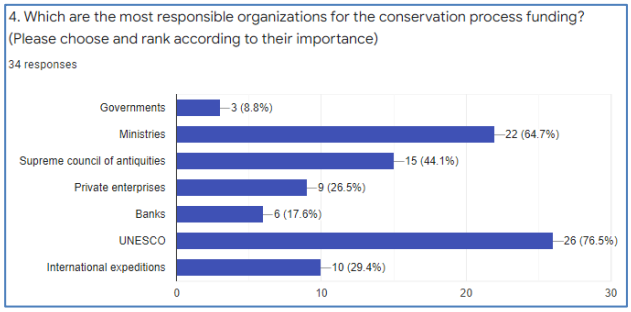
## 10 Questionnaire Output

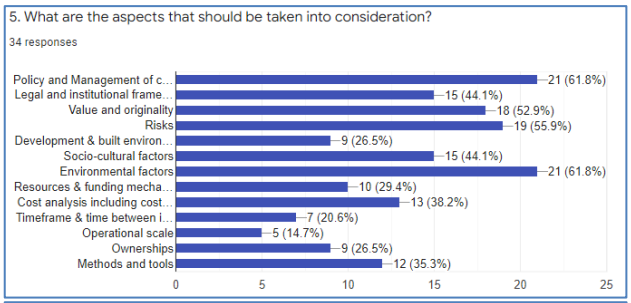
To validate the framework generated, a survey was answered by 34 experts in different fields through a workshop titled "Air pollution and heritage buildings deterioration: potentials for management and prevention". The results were as follows:

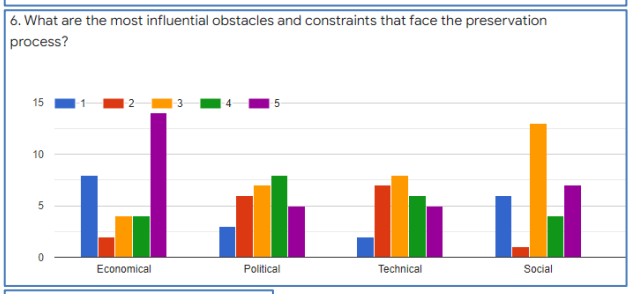


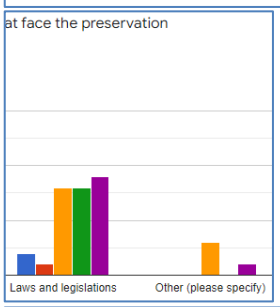



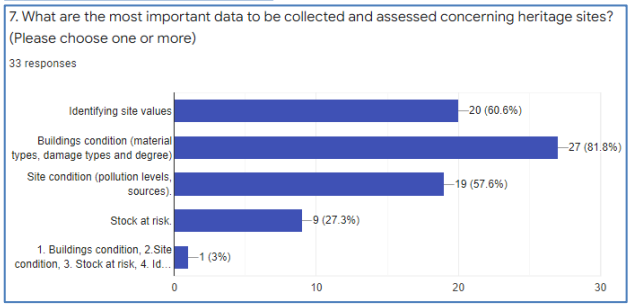



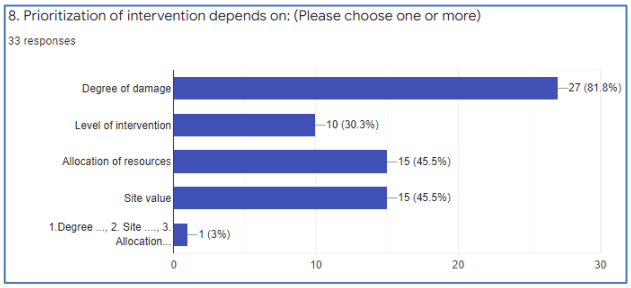



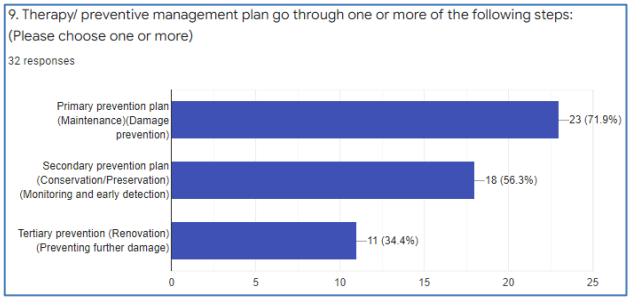



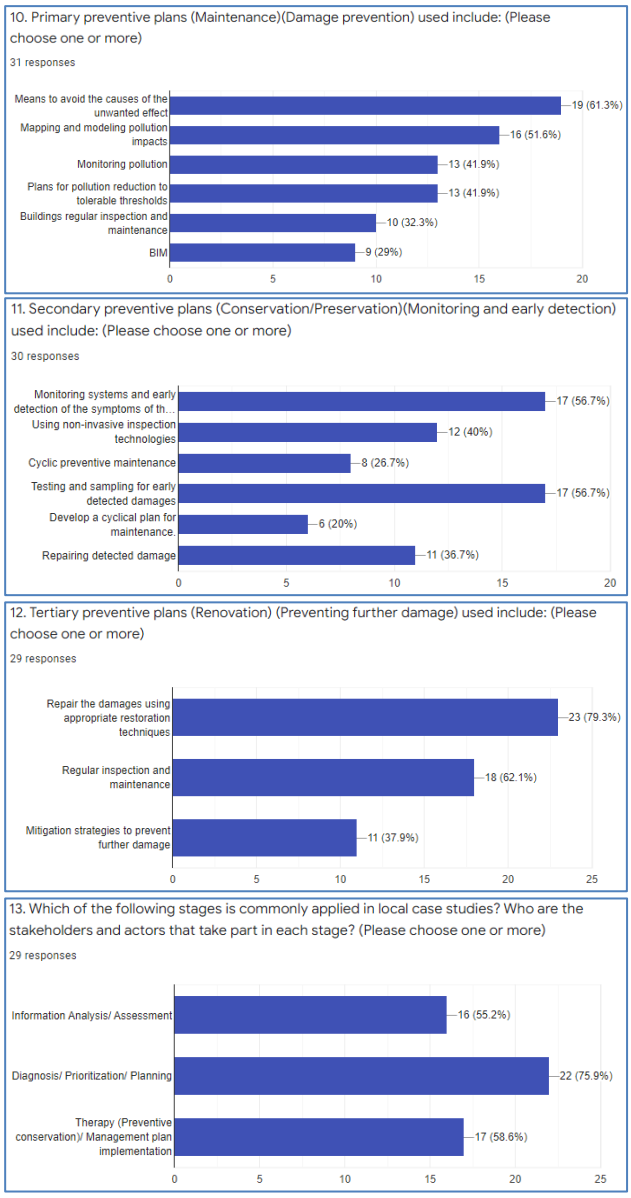






## 11 Conclusion & Recommendations

The aim of the paper was to minimize the deterioration of historic buildings caused by air pollution through the development of a framework for local management preservation strategies. The outline of the paper went first through theoretical part on air pollution impacts on historic buildings, the types and measures of preventive conservation, the common maintenance and management strategies used and the systems of heritage management. The proposed stages of management strategies were applied in the analysis of three case studies: two international and one national. The role of administrative bodies in the management process of Egyptian historic buildings was determined in accordance with the proposed stages of management strategies. The paper concluded a developed framework of management strategies for preservation of historic buildings on the local scale for Egyptian sites.

The paper developed a framework of the management strategies for preservation of historic buildings. Below are ( Table 6) factors recommended to be highlighted for further research on the elements of management strategies:

Table 6. Recommendations for further research

| Management strategies process | To be kept | To be enhanced | To be developed |
|---|---|---|---|
| Introductory Information | Determining the scope of plan, the identification of stakeholders and assigning responsibilities for the project team | The need to enhance the relationship of the management plan with any other relevant plans | The need to set a development plan for any limitations of the national context |
| Collecting Data / Status Analysis, Diagnosis & assessment/ Prioritization | Diagnosing the current condition for the site and the building along with risk assessment. | | Prioritization of necessary actions through the management plan |
| Planning | Development of management and action plans along with cost analysis and setting the timeframe of the plan | Allocation of resources and management needs and inputs | |
| Therapy/Management plan implementation | Mapping and modeling of pollution impacts and including monitoring the pollution. Setting plans for pollution reduction and regular inspection and maintenance of the building | Regular inspection and maintenance should be added in the process | The integration of BIM in the management plan implementation |

| | | | |
|---|---|---|---|
| Control/ Work & Site Output Indicators | Evaluation of monitoring indicators | - | - |
| Outcome's assessment | - | Review of management effectiveness assessment results | - |

*References:*

[1]. P. Kumar and B. Imam, "Footprints of air pollution and changing environment on the sustainability of built infrastructure," in *Science of the total environment*, vol. 444, 2013, pp. 85-101.

[2]. UNECE, "UNECE," 2015. [Online]. Available: https://www.unece.org/info/media/news/environment/2015/air-pollution-puts-cultural-heritage-at-risk/air-pollution-puts-cultural-heritage-at-risk.html#:~:text=Air%20pollution%20is%20a%20key,is%20enormous%20and%20often%20irreversible.

[3]. J. Watt, J. Tidblad, V. Kucera and R. Hamilton, The Effects of Air Pollution on Cultural Heritage, Springer, 2009.

[4]. S. D. Torre, "Learning and Unlearning in Heritage Enhancement Processes," in *ESA Research Network Socilogy of Culture Midterm Conference: Culture and the Making of Worlds*, 2010.

[5]. E. H. Al-Allaf, "PREVENTIVE CONSERVATION AS A PROCEDURE FOR SAFEGUARDING MOSUL BUILT HERITAGE," *Diyala Journal of Engineering Sciences*, vol. 07, no. 02, pp. 98-129, June 2014.

[6]. PRECOMOS, 2016-2019. [Online]. Available: https://set.kuleuven.be/rlicc/research/precomos.

[7]. G. Wijesuriya, J. Thompson and C. Young, "World Heritage Resource Manual," UNESCO, Paris, 2013.

[8]. TMCC, "RMA Architects," RMA architects, 2003. [Online]. Available: https://rmaarchitects.com/collaboration/taj-mahal-conservation-collaborative/. [Accessed 2022].

[9]. UNESCO, 2004. [Online]. Available: https://whc.unesco.org.

**Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)**

-Gehan Nagy, Khalid Dewidar has executed and organized the workshop.
-Mona Azouz, Marian Nessim, Dina Salem was responsible of the first and second case studies analysis and the development of the framework.
-Yasmine Sabry carried out the stakeholders and actors' part
-Fayrouz Ashraf was responsible for the data collection of literature review, third case study analysis and the questionnaire output.

**Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself**

This paper is part of a funded project by the STDF (Science and Technology Development Fund) ID 41601. The project is a collaboration between three institutions: The British University in Egypt (BUE), Housing & Building National Research centre (HBRC), and the Zagazig University.