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PRESERVATION OF HISTORIC HERITAGE IN ENERGY DEPENDENT ANTHROPOCENE: A CHALLENGE FOR CLIMATE COMPATIBLE DEVELOPMENT

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ABSTRACT

Climatic conditions have a strong relationship with human civilization since its beginning on planet Earth. The *Anthropocene* has transformed the world from nature-based ecosystem to energy dependent socio-ecological system of modern civilization where per capita carbon footprint has increased many folds. The human influence for the current state of global-scale anthropogenic imprint of climate change on historic heritages is context dependent. In the context, this qualitative research paper aimed to examine in depth the topic of priority interest i.e., the state of knowledge and conceptual understanding about the nexus and relationship of climate, energy, development and historic heritages in the *Anthropocene* by employing cause and effect modeling technique. Based on content analysis of the global state of the knowledge and three modeled scenarios including two case studies, this paper built very good arguments about the amplifying and triggering effects of GHG flux towards climatic extreme events and its cascading effects, having a complex nexus with historic heritage sites. The issues of climate vulnerability, adaptation, resilience and mitigation explored and clarified well. It deciphers the need to devise sustainable and climate compatible solutions of 'triple-win' strategies' for the protection and preservation of historic heritage sites worldwide, which is a challenge of 21st century. The general cause and effect model can be used for the purpose of future climate response strategies for different historic heritage sites, by developing case specific scenarios.

INTRODUCTION

Climatic conditions have a strong relationship with human civilization since its beginning on planet Earth (Abate, 1994). The overall aboriginal anthropogenic impact was negligible in the context of effectiveness of self-maintenance system in natural cyclic processes during early phase of human interaction with the environment (Goudie & Viles, 1997; Kohen, 1995). The human influence for the current state of global-scale anthropogenic imprint has been recognized since the 1800s and the period was informally and occasionally termed as *Anthropocene* on logical grounds over the last two decades; but it has not accepted formally yet (Steffen et al., 2011). The '*Anthropocene*' Working Group of the 'International Commission on Stratigraphy' (ICS) proposed the optimal beginning of *Anthropocene* from the middle of 20th century by linking it with quantum of accelerated and rapid industrialization, population growth and globalization; with a primary marker of nuclear bombing and tests from the early 1950s (Zalasiewicz et al., 2020). During *Anthropocene* the world has transformed from nature-based ecosystem to energy dependent socio-ecological system of modern civilization where per capita carbon footprint has increased many folds. The *Anthropocene* can be contextualized in two dimensions, one is the context of 'comfort' for humankind and second is its energy dependence, which interfered and influenced the natural balance of climatic system worldwide. There is a global consensus on the harsh reality of climate change (Eleftheriadis & Anagnostopoulou, 2017; Iqbal & Khan, 2018; Jiang et al., 2017), and cascading effects of climate related extreme events are cross-cutting to all sectoral economies (Garner et al., 2017; Islam et al., 2019; Roe et al., 2017). It includes significant impacts on historic heritage sites and the paleontological assets of the world (Phillips, 2015). Development of energy efficient mass transit systems in old metropolis contribute in mitigation of climate change impact with their low emission operation by pooling of mobility resources and minimizing energy losses. But at the same time, construction activities for development of such systems may affect the foundations of old historic building, while the vibrations during operation may also affect these heritages. There is another issue of energy loss as extra energy is required for old structures of historic heritages, which envisage climate mitigation strategies particularly for recreational activities at these places. On the other hand, heavy rains and flooding due to climatic extremes also pose threats to historic heritage sites, which need climate adaptation and resilience measures for their preservation.

The historic heritage sites are more vulnerable to an array of regional as well as global impacts of climate change due to their geographical locations in different climatic zones (Teruel Cano et al., 2019). There is a dire need to preserve these historical treasures by devising suitable strategies that work against the climate change. The climatic extreme events would likely to continue with similar trends, with an anticipated rise of 3.2 °C in global temperature by the year 2100. While, the annual global emissions reduction target is lagging behind about 7.6% in limiting the warming effect to 1.5°, and the natural resources' usage is considered unsustainable as the desired 3% target of energy efficiency has not been achieved worldwide (UN Statistics Division, 2020). Anthropogenic GHG flux is an essential climate variable and among the key driving forces having a very strong linkage with complex interdependence on fossil energy resources (I. Ali & Iqbal, 2017; Hassan et al., 2018; WMO, 2019). The response options are ‘context-dependent’ in order to have trade-offs for interlocking agenda of the SDGs (Blanchard et al., 2017) and preservation of historic heritage sites. The rapid consumption of fossil fuel in *Anthropocene* has not only threatened the available energy reserves but also contributing the largest share towards global GHG emissions. These emissions together with energy efficiency have linkages with the historic heritages viz-a-viz material damage and excessive use of energy during recreational activities at these sites, which need climate mitigation response worldwide. GHG flux also amplifies the effects of extreme climatic events in one way or the other, thus rendering the issue of climate vulnerability, adaptation and resilience measures towards sustainable and climate compatible solutions of ‘triple-win’ strategies’ (Mitchell & Maxwell, 2010) for the protection and preservation of historic heritage sites worldwide, which seems to be a big challenge of *Anthropocene* epoch.

In this backdrop, this paper aimed to examine in depth the topic of priority interest i.e., the state of knowledge and conceptual understanding about the nexus and relationship of climate, energy, development and historic heritages in the *Anthropocene*. Firstly, it takes into account a range of relevant stock of literature generated by professional experts as well as case studies of two historic heritages in Pakistan. Pakistan is a home to various significant cultural heritage resources from the Indus Valley and Gandhara civilization of Buddhist, pre- and post-Islamic, Mughal, Sikh and colonial periods that are valuable to history and science. These resources are at danger from the aforementioned climate threats and are in need of immediate protection. Secondly, it rationalizes the necessary elements of emerging sustainable and climate compatible development agenda for policies, processes and institutional measures for protection and preservation of historic heritage sites not only in Pakistan but also worldwide.

METHODOLOGY

This paper is an extended version of the issues identified regarding the nexus of climate, energy, development and historic heritages in the *Anthropocene*, in literature review as part of a broad Ph.D. research study undertaken by the first author. This qualitative study employed commonly used content analysis technique (Elo & Kyngäs, 2008; Lindgren et al., 2020) and clubbed with case studies method which is widely practiced in social inquiries and interpretation of surrounding as well as the development nexus and relationship between the variables involved (STAKE, 1978; Walsham, 1995). Initially, a range of relevant opinions and analysis were taken into account, generated by experts, and relevant documents for different peer reviewed publications. At the second stage, a general cause and effect model was developed for energy dependent *Anthropocene* and climate change scenario. Modeling was carried out through three consecutive consultation sessions with experts’ groups. It was built on the foundations of life cycle process approach. It was done on flip charts by exercising the widely practiced Problem Tree / Situational Analysis technique (Borgatti et al., 2009; Hovland, 2005; Wellman, 1983), prior to examine and deepen the understanding and drawing two more process flows for the case studies. It was meant to decipher the interlocking and relationship between climate, energy, development and historic heritages; due to a number of interdependent issues. At third stage, the paper has generated discussion based on cause-and-effect modeling and listing down the key issues with by employing thematic and content analysis technique. The content analysis was done for the explored relevant literature on the stock of account regarding impacts of climate change on historic heritage sites by reviewing the global dynamics and two case studies from Pakistan. One case study was comprised of Lahore Orange Line Mass Transit system by taking it as a development intervention for the 'comfort narrative', while the second case of Bhanbhore port city was examined by considering it as an ancient civilization located on climatically vulnerable coastal area of Pakistan.

RESULTS AND DISCUSSION

Cause And Effect Models

Figures 1 to 3 show three different novel models developed as part of this study. These models helped in developing conceptual understanding about the nexus and relationship of climate, energy, development and historic heritages in the *Anthropocene*. First model (Figure 1) provides a general picture about the scenario of energy dependent *Anthropocene* and climate change in the context of historic heritage sites. This model can be used for the purpose of future climate response strategies for different historic heritage sites, by developing case specific scenarios. The second model (Figure 2) was developed for the energy dependent *Anthropocene* scenario of Lahore Orange Line Mass Transit System and Climate Change for better understanding on pros and cons of development projects. The third model (Figure 3) showcases the scenario of ancient city Bhanbhore, which rationalizes required climate response strategies for such cases.

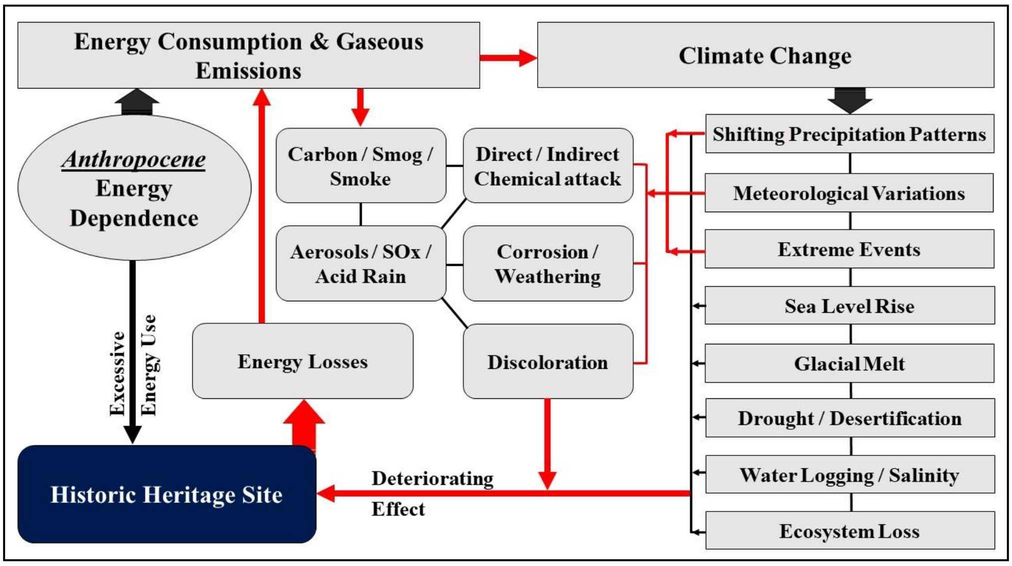

Figure 1: Cause & Effect Model for Energy Dependent Anthropocene And Climate Change Scenario

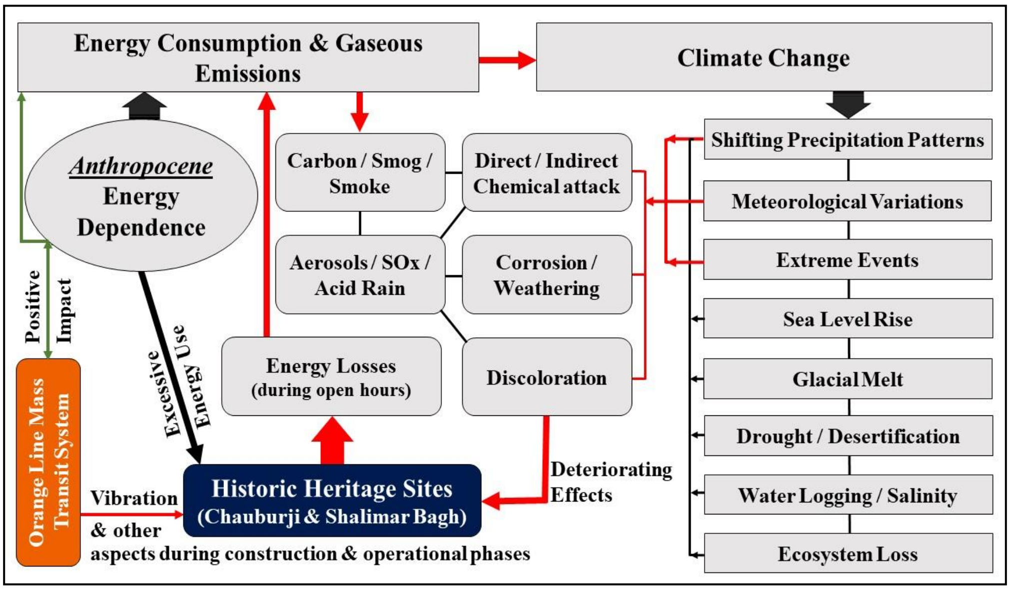

Figure 2: Energy Dependent Anthropocene Scenario of Lahore Orange Line and Climate Change

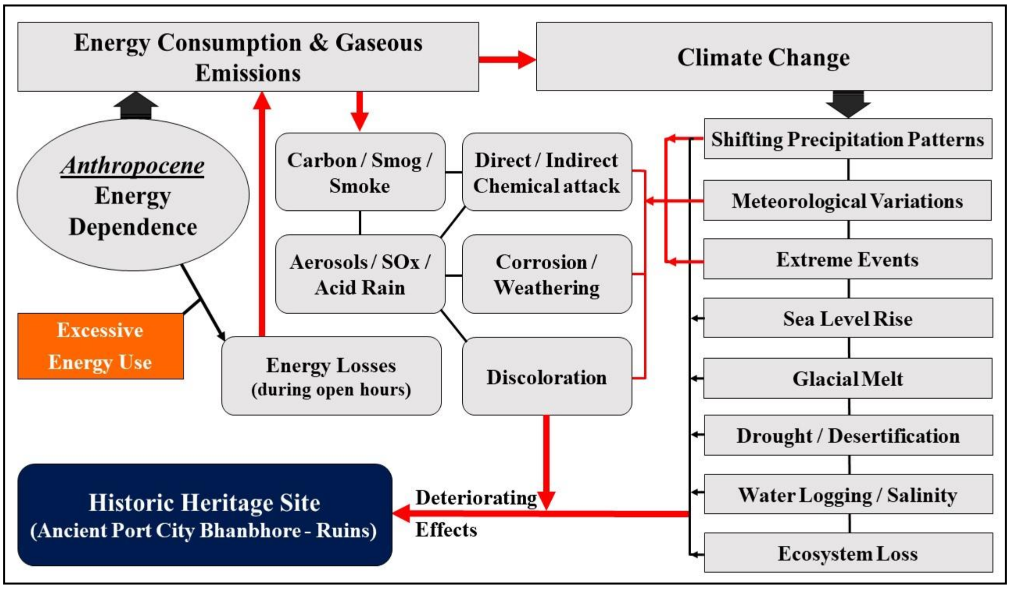

Figure 3: Energy Dependent Anthropocene Scenario of Bhanbhore City Ruins and Climate Change

Global Dynamics

Global climate change is evident through various observations and studies (Garner et al., 2017; Islam et al., 2019; Roe et al., 2017). The first cause and effect model (Figure 1) indicates a very complex nexus of energy dependent *Anthropocene* and the phenomenon of climate change in the context of historic heritage sites located worldwide. Globally, there is a consensus that these sites are vulnerable to an array of regional as well as global impacts of climate change (Phillips, 2015; Teruel Cano et al., 2019). Among these, the Polar regions have relatively higher risks to the disasters of climate change and global warming (Teruel Cano et al., 2019). The cold and wet climate of the arctic and alpine regions has led to the preservation of the archaeological sites and materials that offer an insight about the cultural and ecological history of our ancestors and their practices (Murray et al., 2011). Along with the warming at twice the rate of the global average since the 1980s, the arctic is now experiencing observable impacts of climate change including rising air temperatures, thawing permafrost and inconsistent precipitation pattern, and also contributing towards sea level rise (Fenger-Nielsen et al., 2020). Coastal erosion has been found to affect the Canadian and Alaskan shorelines and has resulted in the disappearance of three out of four known archaeological sites (Murray et al., 2011). Sea level rise, lengthened open water periods due to the decline in sea ice, and a predicted surge in the frequency of storms is expected to intensify coastal erosion in the Polar Regions (Romero & Emanuel, 2017; Screen et al., 2018). The thawing of permafrost is becoming increasingly common, which is expected to expose the organic archaeological materials. Climatic models show that the warming climate will decrease the extent and the depth of the active frozen layer which thaws during summers, and the increased depth of the active layer would result in the increased soil erosion and microbial activity (Pedersen et al., 2020). This is particularly devastating in case of archaeological wood and wooden structures as the increased temperature, drained water and increased oxygen availability triggers microbial degradation (Hollesen et al., 2018). Fungal decay is causing the loss of wooden artifacts in Greenland is expected to increase with increasing temperatures. A study on the organic archaeological resources in Norway predicts that an average 3 degree increase in air temperature could accelerate the overall decay by 50 percent (Murray et al., 2011). Similarly, bone degradation and the loss of historical burial sites are expected (Maldonado-Erazo et al., 2021). Moreover, the 'greening' of the *Tundra* due to the warming effect will result in the archaeological sites overgrown and eventually hidden, while the roots would destroy the foundations and the organic archaeological materials. Northern Europe is a home to numerous historical sites that are perpetually or partially frozen (Perry, 2011). The porous nature of the stones in these structures is at risk of degradation due to the increased frequency of freeze-thaw phenomena. Along with the frost damage, these remains could also experience damage to the foundation structures and induce landslides which could destroy these vulnerable heritage sites (P. Brimblecombe et al., 2011).

In a similar manner, the tangible and intangible implications of climate variability are expected to impact other regions of the world as well (Hall et al., 2016). The historic coastal areas of Europe, Asia and Africa are prone to the sea-level rise, resulting in permanent submersion of low-lying areas, population migration and ultimately, loss of culture (Sabbioni et al., 2008). Moreover, variations in humidity, temperature, precipitation patterns and water availability may result in the degradation of built structures through thermal stress, water logging, dissolution of salts and crystallization formation on archaeology, wall paintings and decorated surfaces; and biological attack by fungi, algae, molds and invasive species such as termites (Brooks et al., 2020; Pedersen et al., 2020). Natural and ecologically-sensitive heritage sites could experience a change in landscape, specie loss, and trigger ecosystem loss, calling for a dire need to study the past and current phenomena in order to devise adaptation and mitigation strategies for these sites before they perish (Maldonado-Erazo et al., 2021).

With the evolution of understanding of climate variability and its impacts in the *Holocene*, it has become evident that the major climatic events of the past coincided with the archaeological evidences of social and cultural change, indicating that the rise and fall of the ancient societies was greatly influenced by climate change (Douglas et al., 2016; Wang et al., 2016). Various research studies have identified that the climatic events such as severe droughts, aridification, extreme precipitation patterns, flooding and climate-driven plagues were the common reasons of the tragic end of some of the great civilizations of the old world (Wiener, 2014). Ancient Maya civilization, Mesopotamian, Indus Valley Civilization and numerous Egyptian, North American, African and Oriental Societies migrated. They fought within themselves or with the foreign invaders over receding resources, or succumbed to the plagues that wiped out their magnificent existence (Anzidei et al., 2020; Cookson et al., 2019; Momeni et al., 2015; Tan et al., 2015; Wang et al., 2016; Welc & Marks, 2014; Wiener, 2014).

The frequency of extreme meteorological events has increased over time due to the climatic variations (Dinan, 2017). Coupled with the sea level rise and ocean warming, hurricanes and storms have intensified and the integrity of the coastal zones and the cultural and archaeological sites has become grim. Barbuda, Puerto Rico, Malaysia, Indonesia and other Caribbean and Pacific nations have been severely affected by tropical disasters such as Hurricane Irma and Maria as a huge loss of indigenous ecosystems, heritage and cultural knowledge has ensued (Dunnavant et al., 2018). Similarly, the destruction by the Hurricane Harvey and Hurricane Sandy in the USA has caused colossal damage to the sites of importance from the native-American era (Johnson et al., 2015; Reeder-Myers & McCoy, 2019). According to the projections, climate change driven sea level rise is expected to inundate 136 sites of the UNESCO’s cultural relevance by 2100 (Perez-Alvaro, 2016). Growing body of research suggests that 1m of sea level rise is expected in this century and with 5m or more in the upcoming centuries. It would result in significant damage to the shoreline and coastal settlements which account for 40 percent of the global human population (Anderson et al., 2017). Landmarks of national and international significance along the coast are therefore threatened across the world (Anderson et al., 2017; García Sánchez et al., 2020; Reimann et al., 2018). Underwater resources such as shipwrecks, coral reefs are also of great cultural, scientific, ecological and economic importance. It is estimated that 86 percent of the World Heritage Reefs (25 out of the 29) will experience severe bleaching by 2040, and four of these sites will experience frequent severe heat stress by 2025 (Beyer et al., 2018; Cheal et al., 2017; Heron et al., 2017).

Apart from the impacts of climate change discussed above, historical structures and heritage sites are also prone to devastation by the exposure of air-borne pollution and emissions originating from various sources (Daly, 2011; Phillips, 2015) in energy dependent context. The level and severity of pollutants have increased many folds during the *Anthropocene*. Built structures tend to disintegrate naturally over time, but numerous anthropogenic factors accelerate this process. Along with the loss of invaluable archaeological resources of cultural and scientific significance, the deterioration of these heritage sites and materials has an annual cost of around 3 percent of the global GDP (Daly, 2011). This deterioration by external environmental factors is a multi-dimensional interaction of chemical, biological, climatic processes, consequences of the influences of anthropogenic contaminants and natural features of the surroundings. Since the industrial revolution, a significant increase in the deterioration of the buildings has been observed (Auras et al., 2013). The presence and atmospheric transport of pollutants, such as the Oxides of Nitrogen and Sulphur, Carbon Monoxide, Particulate Matter, Aerosols and Ozone, damages the built environments by abrasion, deposition and removal, direct/indirect chemical attack and corrosion, resulting in discoloration, material loss, structure falling and soiling (Peter Brimblecombe & Grossi, 2007; Watt et al., 2009).

There have been several studies to assess the impacts of prevalent pollutants originating from industrial and vehicular emissions on various kinds of historical structures. The *'first European Risk Assessment of UNESCO's Cultural Heritage Material at European Level'* study evaluated the impacts of air pollution on the cultural materials, surface recessions and mass loss of Copper, Bronze and Limestone from 1980 to 2010 (Spezzano, 2021). The findings indicated a decrease in the degradation of the structures as a result of the implementation of pollution reduction policies in the European Union. The Alhambra, a UNESCO's World Heritage Site and a Hispano-Islamic structure of cultural and religious prominence, is being exposed to the impacts of nanoparticle weathering originating from vehicular emissions, and losing the inscriptions and art of cultural significance (Oliveira et al., 2019). Despite the reduction of industrial emissions in Europe, the urban centers still boast a high level of air pollution due to the vehicular emissions. (Auras et al., 2013) found out that buildings in the historical urban cities of Munich and Mainz were heavily exposed to the soiling by the vehicular particulate matter (PM_{10}) and deposition of NOx from exhaust emissions, and the stone structures are prone to weathering coupled with the factor of climate change (Auras et al., 2013).

The famous Taj Mahal has also suffered degradation by the vehicular and industrial emissions ($PM_{2.5}$) which has caused the white marble structure to blacken over the years (Lal et al., 2016). A similar research assessed the impacts of various urban emissions on the medieval stone structures, particularly the Cologne cathedral. Despite the reduction in the emissions in Europe during the past three decade, this building was found to have developed massive gypsum crusts, indicating that the past emission concentrations need to be considered along with the contemporary ones for the preservation measures (Graue et al., 2013).

Based on the global state of knowledge and the modeled scenario of energy dependent *Anthropocene* and climate change, the above discussion is quite successful in building good arguments about the amplifying and triggering effects of GHG flux towards climatic extreme events and its cascading effects, having a complex nexus with historic heritage sites. The issues of climate vulnerability, adaptation, resilience and mitigation understood well. Further, it helped in exploring the interlocking and relationship between climate, energy, development and historic heritages; due to a number of interdependent issues. It is sufficient for deciphering and rationalizing the need to devise sustainable and climate compatible solutions of 'triple-win' strategies' for the protection and preservation of historic heritage sites worldwide.

Case Studies From Pakistan

Pakistan is among the least contributors towards global GHG emissions but acutely vulnerable to the effects of climate change and there are increasing trends in temperature, precipitation and seasonal variations (Iqbal & Khan, 2018; Teruel Cano et al., 2019). The frequency of climate-driven extreme events such as flash floods, storms and droughts has seen a rapid surge (Rasul et al., 2012). These effects are unfavorable and disastrous for the cultural heritage and archaeological resources of the country (Farooq & Maknoon, 2020). Remains and artifacts from the Indus Valley and Gandhara civilization, pre- and post-Islamic, Buddhist, Mughal, Sikh and colonial periods are an indication of the glorious history of this region. But these historic heritages are suffering with an ill fate due to the anthropogenic activities, pollution and climate-driven changes (Hamid Akbar et al., 2020; Magrini & Franco, 2016; Mahnaz Hassan, 2009; Sabry & Dwidar, 2018; Sarkar et al., 2016).

Industrial and transportation sector of Pakistan is still largely dependent on non-renewable energy sources and fossil fuels for their operation (R. Ali et al., 2019; Sajid, 2020). Along with the harmful emissions from fossil fuel burning, toxic smoke and tailpipe emissions from the aforementioned sources are also contributing towards the air pollution. Atmospherically transported SO_x, NO_x, and particulate matter originating from these sources are harmful for the aesthetics and the structural integrity of the cultural heritage (Farooq & Maknoon, 2020). Climate change driven fluctuations in humidity, temperature and precipitations, combined with the air pollution greatly affects these structures (Peter Brimblecombe & Grossi, 2007). Increased localized events of acid rain, pH imbalance of soil, and water logging has historically resulted in the degradation of marble and clay structures in Mohenjodaro and Harappa (Gulzar et al., 2014). Coupled with the ramifications of the climate change, the increasing air pollution and emissions from industries and vehicles are contributing towards the degradation of the invaluable heritage resources (Brooks et al., 2020; Carmichael et al., 2018; Ciantelli et al., 2018; Gulzar et al., 2014; Momeni et al., 2015; Patrón et al., 2017; Rovella et al., 2021; Spezzano, 2021).

Another implication of climate change is that there is a deviation (rise is most cases) in the energy requirement, which has increased the use of nonrenewable resources and fossil fuels to fulfill the demand, resulting in hazardous emissions (Adhikari et al., 2012; Kass et al., 2015). Energy sector is a major contributor to climate change. In Pakistan, energy sector is the largest contributor with 46 percent of the total national GHG emissions (Khan et al., 2016). Pakistan's Nationally Determined Contribution (NDC) Statement 2016 committed to curtail its present 46% GHG to a target of 26 % with an estimated abatement cost of 40 billion US$, which otherwise would become 56% by 2030 in business-as-usual scenario. Rising demand of air conditioning and heating is expected to increase the energy demand, and consequently the GHG emissions (Cabeza et al., 2018). To cut emissions and preserve energy, various practices have been applied globally with a special focus on energy-efficient infrastructure (Pacchiega & Fausti, 2017). Historical buildings are traditionally vast structures and the energy consumption to illuminate and heat/cool the buildings is enormous (Cabeza et al., 2018). Moreover, ineffective insulation of these buildings results in energy loss. Lack of effective ventilation results in an additional energy requirement to cool the buildings, along with an increased risk of CO_2 production and suffocation (Magrini & Franco, 2016). Suitable technological interventions could be incorporated in the historic infrastructures to minimize energy loss without compromising the structure and originality of these heritage sites (Burattini et al., 2015). Where climate change has resulted in altered patterns of precipitation, increasingly long summers and shifting weather has led to the glacial melting, which has resulted in the inundation of the Indus river basin, devastating of the resources that come in its way (Maldonado-Erazo et al., 2021). Similarly, sea level rise and seawater intrusion, storms, droughts, and ecosystem loss are the threats that Pakistan's cultural and archaeological assets are facing (Farooq & Maknoon, 2020). While many of these climatic disasters are inevitable, there is a dire need to incorporate appropriate adaptation, resilience and mitigation measures.

In this context, the Orange Line Mass Transit of Lahore is a prominent development case in the *Anthropocene* context-dependent case of energy and climate change, which has linkage with the cultural heritage sites, due to its environmental aspects of construction and operational phases. This 27 km long metro train service was built in collaboration with China under the Belt and Road Initiative, bringing the three hour long commute to a mere one hour journey, making day-to-day traveling easier for the people of Lahore (*Orange Line Metro Train Project*, 2016). Along with providing inexpensive and comfortable commute, this service has contributed towards curbing the emissions from personal vehicles as approximately 250,000 people utilize this mode of mass transit on a daily basis (*Punjab Masstransit Authority*, 2016). On the other hand, this mega project faced political and civil resistance before and during the course of its planning and construction due to the ambiguity regarding the land acquisition, compensation, and lack of civic engagement (Imran et al., 2018). The most controversial were the issues of the rights to culture and its reconciliation with the rights to development (*Human Rights Review Vol. IV*, 2018). Due to the design and proximity of the project, 25 landmarks of colonial and Mughal period were affected. Pakistan's Antiquities Act 1975 states that no construction should be undertaken within 200 meters of the boundary limit of a heritage site. Shalimar Bagh, Gulabi Bagh, Buddhu ka Awa, Mauj Darya Darbar, Chauburji, General Post Office, Lahore Cathedral, Shah Chiragh Garden, St. Andrews Church, the Supreme Court Registry, Shah Chiragh Din building and Lakshmi building were in the close proximity (less than 200m) of the project's construction site. These are listed under Antiquities Act, Punjab Special Premises Act and UNESCO's World Heritage Sites (Shahid et al., 2020). The ground vibrations generated from various construction activities and the operation of heavy machinery in close vicinity of the aforementioned and countless other heritage sites were bound to have devastating effects on the foundation and the structural integrity of the already deteriorating buildings (Ullah et al., 2019). Additionally, the inadequately performed feasibility studies of the project failed to account for the environmental impact on historic heritage sites, during construction phase (Shahid et al., 2020).

Another climate vulnerable archaeological site of immense cultural significance is the ruins of the ancient port city of Bhanbhore that is located 65 kilometers East of Karachi and on the northern bank of Gharo Creek. This city dates back to first century BC to thirteen century AD (*UNESCO World Heritage Centre*, 2018). Along with being famous for hosting an important medieval port as a gateway to the south Asia to being a major ivory market of the world, Bhanbhore is often said to be the city of Debal where the Muslim invasion of the Indian-sub continent took place (Morelle et al., 2014). Buddhist, Islamic and Hindu artifacts and architecture explored in the city are of great value in studying the various cultures and invaders who utilized this port city to access the sub-continent (Felici, 2018). It is also important for the promotion of maritime tourism in Pakistan. Nature had its part in ending the role of this port city when Indus River shifted its course in the eleventh century, leaving the creek silted (Rasul et al., 2012). In the present day, the relics of the city are vulnerable to the ramifications of climate change especially due to the proximity to the sea. Recently, tropical cyclones have significantly increased in the northern Arabian Sea instead of the Bay of Bengal, and due to this favorable thermal regime, cyclones hit Oman and Pakistan with an increased frequency and intensity (Salik et al., 2015). The tidal landscape of Sindh is flatter than the best of the coastline of Pakistan, which makes it more vulnerable to future sea level rise, flooding and sediment loss. Similarly, an average sea level rise of 1.1 mm in the past century has caused coastal erosion higher than ever with 173 mm in the Indus stream system and 1 mm sediment loss per annum. High inflow of water in the Indus River delta is expected to cause a loss of 2.73 percent of the delta's area till 2050 (Hussain et al., 2020). Water logging and salinity of the structure due to seawater intrusion and inundation of deltaic zone is also a threat to the integrity of the already deteriorating heritage site. As a coastal site exposed to the climate-driven sea level rise, these particular ruins of cultural importance are at an additional danger along with extreme meteorological events on land. The third cause and effect analysis model (Figure 3) illustrates the relationship between climate, energy and Bhanbhore city ruins. Hence, there is a need to protect and preserve these ruins from climatic impacts by devising adaptation and resilience strategies.

CONCLUSION

Within the ecosphere of the planet Earth, changes in atmosphere (air), lithosphere (land) and hydrosphere (water) affected the biosphere (life on Earth). However, ethnosphere (human ingenuity thoughts, intuitions, ideas and inspirations) modified a part of ecosphere as anthroposphere (also referred as technosphere) to fulfill its needs. Hence, a relationship of climatic conditions with evolution of human civilization and culture has been established in Earth's history, which transformed the ecosphere. The *Anthropocene* demarcates the evolution of anthroposphere to an energy dependent technosphere to fulfill the needs of socio-economic system of modern civilization where per capita carbon footprint has increased many folds. The human influence on the current state of global-scale anthropogenic imprint of climate change on historic heritages is 'context dependent'. Three different novel models developed as part of this study may help in developing conceptual understanding of the argument. First model provides a general picture about the scenario of energy dependent *Anthropocene* and climate change in the context of historic heritage sites. This model may be used for devising future climate response strategies for different historic heritage sites, by developing case specific scenarios. The second model illustrates the energy dependent *Anthropocene* scenario of Mass Transit System (e.g., Lahore Orange Line Train) and climate change for better understanding of pros and cons of development projects. The third model showcases the scenario of the ancient port city Bhanbhore which rationalizes required climate response strategies for such cases. It is found that GHG flux has amplifying and triggering effects towards climatic extreme events and its cascading effects, having a complex nexus with historic heritage sites. The issues of climate vulnerability, adaptation, resilience and mitigation have quite a complex nexus which is understood well during the course of this study. It is deciphered that climate change is a major challenge of 21^{st} century for energy dependent context in *Anthropocene* and the case of historic heritage sites. There is a need to devise sustainable and climate compatible solutions of 'triple-win' strategies' for the protection and preservation of historic heritage sites worldwide.

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