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Development of a Risk Assessment and Management Model for UNESCO World Heritage Site

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Abstract: Historical Location propose wide range of risks that can impact reptation, assets, or people that can have major impact. There for Risk management plans was improved in At-Turaif to cope with hazards. The objective of the study is to develop a risk assessment and find which building has the highest priority. The rank will be conducted using MCDM (Multi-Criteria Decision-Making) using five criteria (1) Risk rate, (2) Heritage value, (3) Important, (4) maximum occupancy, and (5) Traffic. These five criteria were applied through AHP-TOPSIS to find the highest rank building. The result of the risk assessments indicates there are electric, physical, fire, environmental, and security hazards. Risk assessment also propose control plan for each hazard. Based on AHP-TOPSIS results. All 28 buildings were rank according to the five criteria with Salwa palace, traditional homes, Omar palace, and Beit Almal need to be prioritized due to their important according to TOPSIS results. Some souks and Clusters fall in the lower section of the rank due to it risk rate and heritage value. The study recommends conducting further research on mud buildings and heritage sites in Saudi Arabia, as it is unique for the country, and recommends plans to eliminates the main hazards such as mud damages by spraying walls with protective coating. And develop new SOP (Standard operation procedures) for the worker to follow. Additionally, the study recommends improving the hazards control strategy and implement new action for hazards

Keywords: Risk Assessment, UNESCO, At-Turaif, TOPSIS, Delphi, MCDM

I. INTRODUCTION

At-Turaif District is a UNISCO world heritage site located in Addiriyah city in Saudi Arabia. It was the capital of the first Saudi state dates to the 1700s. At-Turaif District has heritage and cultural value with buildings dates to the 1700s and some valuable artifacts, the site consists of 5 museums, visitor reception center, 5 palaces, and 11 traditional homes. As the site will be open for the public and VIPs in November of 2022, it will be a must visit place in Riyadh city for Saudis, residents, and tourists.

Each of the buildings has its own challenges, hazards, importance, and heritage value. Furthermore, it is expected that the number of visitors will increase. Therefore, the impact of any hazard could be more severe with the expected crowd. Few studies are found about At-Turaif District, but not related to safety, such as Aljahani (2019). Based on these, there is urgent need for establishing a risk assessment and management plan to avoid any human, reputation, or asset loss.

Risk assessment in heritage sites is found in limited number of studies in the literature. Pedersoli et al. (2016) proposed that fire, water, pests, pollutants, light, UV, abnormal temperature, abnormal RH, dissociation, physical forces, and criminals are important factors to be considered in risk assessment of the heritage sites. The visitors themselves have impact on the deterioration of material (Barlett, 2019). These risks caused damage to many historic sites, and the aspect of risk management is necessary to determine what options to evaluate in such cases (Jigyasu, 2005). Salleh (2009) covered the fire factor in his study and contributing factors like, weak structures, poor safety awareness, and large number of visitors. The author proposed some improvements of fire safety in heritage site based on his study. López, (2016) most risk assessment in cultural focus on armed conflict and natural hazards and does not have the concept of "culture of assessment" and how to implement international standard of risk management. Rausand & Haugen, (2020) introduce a complete risk assessments and risk analysis of accidents that occur in technical or sociotechnical. And it gave guidelines for any organizations to standardize the risk analysis terminology. Enrico (2018), future of risk assessments and how capable the available data and computational power to use simulation for scenarios, with the new emerging hazards such as cyber security and climate change.

The aim of this paper is to develop a risk assessment and management model based on multicriteria decision making (MCDM) techniques. The study aim is achieved through the following objectives:

1) Identifying all types of hazards that create safety risk of human or property loss,
2) Analyzing the risks in terms of likelihood and severity of impact on human, property and environment,
3) Determination of the important criteria that have significant effect on decision making regarding risk management, and
4) Providing management prioritization model using MCDM techniques such as Analytic Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS).

II. METHODOLOGY

A list of all important buildings in Al-Turaif District was decided to be included in the risk assessment mode. Using the Delphi method, the decision criteria and their pairwise comparisons were generated. The decision criteria were:

1) Risk rate
2) Heritage value
3) Importance
4) Maximum occupancy

Each building was evaluated via these criteria either objectively when data is available, or subjectively using a 5-point Likert scale when quantitative data is not applicable. For instance, heritage value and importance were evaluated using a 5-point Likert scale by a sample of experienced employees in At-Turaif. On the other hand, criteria such as occupancy was quantitatively calculated by dividing the gross building area by the occupant load factor. The pairwise comparisons of the criteria were used in AHP to calculate the weight of the criteria. These weights along with buildings evaluations with respect to each criterion were used in TOPSIS technique to rank the buildings and prioritize them for risk management. The following is a brief description of the AHP and TOPSIS methods used.

A. Analytical Hierarchy Process (AHP):

AHP is a process used to analyze and organize complex decisions. It was developed by (Saaty, 1994). AHP is used to help compare between criteria and the weight of each criterion. 5 criteria and 28 buildings were evaluated. the goal of this study is to find which building we should prioritize based on the 5 criteria. The criteria weight was determent using pair wise comparison and survey was handed to the engineers in At-Turaif consists of a scale form 1-9,

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Table 1: Verbal judgments of preferences

Rating	*Verbal judgments of preferences*
9	Extremely preferred
8	Very strongly to extremely preferred
7	Very strongly preferred
6	Strongly to very strongly preferred
5	Strongly preferred
4	Moderately to strongly preferred
3	Moderately preferred
2	Equally to moderately preferred
1	Equally preferred

Table 2: pair wise comparison

Criteria	*Left side scale*									*Right side scale*								*Criteria*
C1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C2
C1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C3
C1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C4

After collecting the survey each quantified judgment is Divided to the sum of its performance factor quantified

$$A = (x_{ij})_{m\times m} = \begin{matrix} C_1 \\ C_2 \\ \vdots \\ C_m \end{matrix} \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mm} \end{bmatrix} \quad [1]$$

Next step is to calculate normalized matrix and priority vector to find the weight of each of the five criteria to be used in the TOPSIS calculations. The Pair-wise comparison matrix, $A = (x_{ij})_{m\times m}$, is normalized by using the equation below

$$x_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad [2]$$

Then the weight will be calculating by used the following equation

$$w_i = \frac{\sum_{j=1}^{m} x_{ij}^{*}}{m} \quad [3]$$

The λ_{max} is calculated using

$$\lambda_{max} = \frac{W\ Sum}{w_i} \quad [4]$$

Then we find consistency ratio (CR) the consistency index (CI). Finally, we use (RI) random consistency index (ALONSO & LAMATA, 2006). If CR is calculated ⩽ 0.1 then the pair-wise comparison is considered to have an acceptable consistency.
To find the consistency ratio (CR) the consistency index (CI)
Needs to be calculated for each matrix

$$CI = \frac{\lambda_{max} - m}{m - 1} \quad [5]$$

CR can be calculated using

$$CR = \frac{CI}{RI} \quad [6]$$

If CR is calculated ≤ 0.1 then the pair-wise comparison is considered to have an acceptable consistency.

Table 3: random consistency index (ALONSO & LAMATA, 2006)

Size of matrix	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
RI	0.525	0.882	1.109	1.248	1.342	1.406	1.450	1.485

B. The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)

TOPSIS was developed by (Hwang & Yoon, 1981) to solve multiple attribute decision making problem. It is based on that the chosen alternative should have the shortest distance from PIS (the positive ideal solution) and the farthest from NID (Negative ideal solution), using TOPSIS to find which building we should prioritize based on the 5 criteria were PIS is the building we should prioritize, and NIS is lest prioritized building. To calculate TOPSIS first we are creating decision matrix where each building is listed with each criterion.

$$D = \begin{array}{c} \\ B_1 \\ B_2 \\ \vdots \\ B_n \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_m \end{array} \\ \begin{bmatrix} Y_{11} & Y_{12} & \cdots & Y_{1m} \\ Y_{21} & Y_{22} & \cdots & Y_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ Y_{n1} & Y_{n2} & \cdots & Y_{nm} \end{bmatrix} \end{array} \quad [7]$$

Then we find Normalized decision matrix as R = [rij] and Weighted normalized decision matrix as W = [Wij].

Finding the Normalized decision matrix as R = [rij]

$$r_{ij} = \frac{Y_{ij}}{\sqrt{\sum_{j=1}^{m} Y_{ij}^2}} \quad [8]$$

Calculating the Weighted normalized decision matrix as $W = [W_{ij}]$

$$W_{ij} = w_j \times r_{ij} \quad [9]$$

The next step is to find the PIS (A+) and the NIS (A–). And the separation distance of each building PIS (A+) and the NIS (A–).

$$A_i^+ = \sqrt{\sum_{j=1}^{m}(W_{ij} - W_j^+)^2}\ , \qquad i = 1,2, \dots n \qquad [10]$$

$$A_i^- = \sqrt{\sum_{j=1}^{m}(W_{ij} - W_j^-)^2}\ , \qquad i = 1,2, \dots n \qquad [11]$$

the last step is to find relative closeness (Ci*), solution has a value between 0 and 1. And we rank building based on Ci*.

$$C_i^* = \frac{D_i^-}{D_i^+ + D_i^-} \qquad [12]$$

III. RESULTS AND DISCUSSION

A. *Listing all important buildings in At-Turaif District:*

There are 35 buildings in At-Tarif most of the are not in used or were not rebuild or repaired only 28 buildings out of 35. All the 28 buildings were inspected and reviewed to identify hazards associated with. Based on the research it shows that there are 130 physical hazards in At-Turaif buildings ranging from physical damages of wall caused by heavy trucks, equipment's, and golf carts. To damage to wood structure caused by water use and white ants. Physical damages are the main hazards in At-Turaif as almost all buildings are made using mud which can be easily damaged. 2nd most causes of hazards are environmental hazards at 102 hazards such as damages caused by animal, Water, weather, or insects. Also, there are number of hazards that can affect the museums artifacts such as high temperature, high humidity, and spotlights. For mechanical hazards out of 39 hazards most of them are caused by HVAC pipes that might be damage inside wall caused water to damage wall inside At-Turaif. Also Tempering with AC controls can damage several units that's connected together VRV (Variable refrigerant flow). Which can cause downtime for the effected buildings. Electrical hazards mostly caused by spraying white ants' treatment without considering light or electrical plugs which can cause short-circuit. Also, one of the Electrical hazards are that events contractor does not consider electrical load on the sockets. For Security hazards is mainly cause by trespassing into the site and causing damages to buildings. Also, some electrical and server rooms access door dose not function properly making the door easily open without access. Since At-Turaif buildings are all the same made from mud most buildings have common hazards between them.

B. *Identifying each building heritage value, important, Maximum occupancy, and Traffic*

i. *Buildings heritage values, important*

Each Building heritage value and important were calculated using as survey that was handed to Engineers and management in At-Turaif. Survey was made in Google forms. All calculated average score of all data from each building. shown in Table 4.5.

Base on the data on gathered from the survey in table 4.5 shows that all buildings have historical value with the highest being Salwa palace at 4.892 out of five, also we can find that other palaces range from 4.676 in Omar palace to 3.973 in Nasser palace, in museums however are in lower Historical value averaging around 3.844 with Military and Daily life museum being the same Historic Value. Souks and Clusters on the other hand has lower value averaging around 3.518 with cluster 1-9 3.054 out of 5, that might be because cluster 1-6 being the least accessed building to the public. The building with lowest Historical value is the VRC at 2.892 out of 5 which has high value despite being a newly constructed building.

For the buildings importance it depends on multiple factors what the building is used for, how Historically important that building. Salwa palace also has the highest Importance value between all buildings at 4.919 out of 5. The VRC ranked in the 2nd place at 4.486 out of 5, VRC is used for events at weekly bases, and it is the first building that visitor enter in At-Turaif. That why based on survey it has high score.

ii. Buildings Maximum occupancy

Buildings Maximum occupancy were calculated using the equation in Methodology Taking into consideration that each building has its own usage.

iii. Traffic

This criterion will rank each building based on its useability how often this building being used

C. Using AHP (Analytic hierarchy process) to find the critical weight of each factor

First part of the AHP is to do a pair wise comparison. It was handed to 10 engineers in At-Turiaf. To find each comparison After Pair wise comparison survey results. AHP Priority Vector based on equations.
Historic value has the highest weight of 38%, risk rate weighted at 28.5% building importance at 21.7%, and 6.2%, and 5.5% for Building occupancy and Traffic respectively. most engineers prioritize building based on its historical vale due to the nature of the location but, we can find risk in buildings is highly considered in their response.

Table 4: Pairwise comparison of the main criteria

Main Criteria	*Priority Vector*
Historic Value	0.380
Importance	0.217
Risk Rate	0.285
Building occupancy	0.062
Traffic	0.055
CR	0.052

D. *Using Using TOPSIS (The Technique for Order of Preference by Similarity to Ideal Solution) technique for prioritizing:*

After inputting the criteria values into TOPSIS The final rank Based on TOPSIS ranking Result below.

Table 5: Final TOPSIS Rank

Rank	*Building*	*Rank*	*Building*
1	Salwa Palace	15	Ibrahim palace
2	Traditional Homes	16	Nasser Palace
3	Omar Palace	17	VRC
4	Beit Almal	18	Fahad Palace
5	Daily Life Museum	19	Souk 26
6	Military Museum	20	Ardah Dance House
7	Horse Museum	21	Souk 23
8	Architecture Museum	22	Souk 31
9	Cluster 1-9 (Stores & Data Center)	23	Cluster 1-3 (Farmer House)
10	Saad Palace	24	Souk 25
11	Souk 24	25	Cluster 1-7
12	Moudi Sabala	26	Souk 27
13	Guest Palace	27	Cluster 1-6
14	Thunayyan Saud palace	28	Cluster 1-5

IV. CONCLUSIONS

The results of buildings risk assessment shows that even though At-Turaif buildings looks similar each building has it challenges and hazards some buildings are more easily to eliminate or minimize the hazard and others might not be possible to solve. There are buildings are rarely used for example Cluster 1-5 or cluster 1-3.

MCDM (Multi-Criteria Decision-Making) is used for complex decisions, and we use these five criteria (1) Risk rate, (2) Heritage value, (3) Important, (4) maximum occupancy, and (5) Traffic. Using Delphi method, the weight of each criterion will be scored by a group of At-Turaif Engineers.

Most of the hazards in At-Turaif are physical hazards either form people or vehicles. made by daily PPM by a main contractor or event contractor, also water can also cause physical damage to wooden structures and mud walls. Other than physical damage there is environmental damage caused by animals, weather, or insects for museum artifacts there are several environmental hazards such as high humidity, high temperature, or spotlight as spotlight can damage fabric inside the museums. For electrical hazards it's mostly caused by spraying white ants' treatment without considering lights or Electrical sockets that can cause short circuits, also for events some contractor does not consider the load for the sockets Used by them.

Based on AHP-TOPSIS results. All 28 buildings were rank according to the five criteria with Salwa pace, traditional homes, Omar palace, and Beit Almal need to be prioritized due to their important according to TOPSIS results. Some souks and Clusters fall in the lower section of the rank due to it risk rate and heritage value.

From the risk assessments of all buildings in Appendix A. damages to mud walls is the most common hazards in all building's either from physical or water damage there for a plan must be developed to eliminate or minimize these hazards. One of the plans is to coat wall s with a spray that will protect mud wall from water damage. Or prevent large vehicles from entering At-Turaif. And close narrow turns to prevent damage by golf carts. Also, water damages caused by HVAC pipes that damages internal walls a plan must be developed to identify the source of the leak and eliminate the hazard. Most of the hazards caused by workers who were not informed about the At-Turaif and it important. There must be a guide developed in multiple languages and be handed over to workers explaining the importance of the location. There are multiple hazards that are specify for one building for example cluster 1-9 which house data center, RO, and the stores. And a plan must be developed to minimize these hazards even though they are not present in other buildings. Another example is to develop a plan for event contractors and filming crews to minimize hazard caused by them.

Management should develop a plan to minimize these hazards starting with salwa palace hazards as it has the highest priority and needs multiple approves to work or develop any part of the palace. Then working on palaces and the tour route as these buildings are the most common buildings the visitors will see and enter. Lastly plans to work on buildings at least priority based on table 4.16.

V. RECOMMENDATIONS

Based on the study results, these are recommendations to be considered in the future:

- This study recommends instructing any worker or contractor to be instructed how to work in At-Turaif as not many buildings are made from mud, also Due to DGDA guidelines there are SOP (Standard operation procedures) to be followed for working in At-Turaif.
- Also, the study recommends on conducting further research on mud buildings and heritage sites in Saudi Arabia, as it is unique for the country.
- It recommends plans to eliminates the main hazards such as mud damages by spraying walls with protective coating. And develop new SOP (Standard operation procedures) for the worker to follow.
- Additionally, the study recommends improving the hazards control strategy and implement new action for hazards in Appendix A.

Conflict of interest: We declare that we have no conflict of interest.

Ethical statement: we declare that they have followed ethical responsibilities.

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