Ranking Major Problems and Vulnerable Pilgrims in Hajj

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ABSTRACT

Even though existing research studies explored problems and affected pilgrims of Hajj pilgrimage in isolation, successful pilgrimage management demands ranking the major problems and vulnerable groups of pilgrims in an aggregated manner as well as revealing mutual associations over them. To do so, we survey pilgrims (n=900) from diverse demographics and perform quantitative analyses (e.g., statistical analysis, network analysis, and ranking analysis) over the problems and demographics of the pilgrims. Our analyses reveal that transportation, finding camps, and hygienic washrooms are the most important problems faced by the Hajj pilgrims. On the other hand, pilgrims having less education, poor skill in speaking English, and less expertise in using smart communication devices present the most vulnerable groups.

1. Introduction

Tourism for religious purposes is one of the earliest forms of its kind in the history of mankind (Rinschede, 1992). Such tourism includes pilgrimage, religious festivals, religious conferences, etc. Due to religious tourism's immensity and diversity, researchers are studying many aspects of such tourism including motivating factors, economic aspects, roles of stakeholders, etc., (Leppäkari, 2008; Lin, 2021; Terzidou, Scarles, & Saunders, 2018; Zamani-Farahani & Eid, 2016). Among different forms of the religious tourism, Islamic pilgrimage in general and Hajj in specific have drawn a great attention to researchers in recent years (Almuhrzi & Alsawafi, 2017; Islam, 2021; Nisha & Cheung, 2022; Salim et al., 2021).

The annual Hajj pilgrimage takes place in Saudi Arabia over five to six days during the last Islamic calendar month Dhu Al-Hijjah. It is obligatory for every adult Muslim, who have the physical and financial capabilities to perform the rituals. Hajj pilgrimage takes place in multiple locations of Saudi Arabia covering Mecca, Mina, Arafah, and Muzdalifah. Pilgrims from all around the world perform Hajj every year resulting in huge crowds near the pilgrimage locations. For having such huge crowds, ensuring safe and comfortable pilgrimage for all the pilgrims is always considered to be a great challenge. This happens as the pilgrims often experience different types of crowd-related problems (e.g., health, accommodation, transportation, food services, etc.) while performing rituals such as stone-throwing in Jamarat, Tawaf through circling around the holy mosque, etc., (Alasmari, Edwards, Assiri, Behrens, & Bustinduy, 2020; Ali et al., 2020; Hoang et al., 2021; Masud, Bakar, & Yussof, 2016; Taibah, Arlikatti, Andrew, Maghelal, & DelGrosso, 2020).

To understand the characteristics of such crowd-related problems and to mitigate those problems, many research studies were conducted. A significant portion of those studies focused on public health sectors covering infectious diseases, respiratory diseases, skin infections, heat injury, etc., (M. A. Alshehri et al., 2021; Gardner, Chughtai, & MacIntyre, 2016; Masud et al., 2016). A few studies also explored the management-level dissatisfaction among the pilgrims covering air services, food, accommodation, and transportation (Bianchi, 2017; Islam, 2021). Some other studies found pilgrims' ethnicity and person-specific factors as major determinants in experiencing the problems (Alsolami, Embi, & Enegbuma, 2016; Sharaf et al., 2021).

Although these existing studies explore the problems in isolation, an overall analysis covering all the different types of problems presents a great significance in road to identifying the most salient ones. Besides, it is an important fact that a huge number of pilgrims come from several developing countries such as Bangladesh, India, Pakistan, etc. Pilgrims from these countries also experience a number of crowd-related problems with no exception. However, even being more vulnerable to the problems, the pilgrims from the developing countries generally lack in drawing focus in the literature. Therefore, in this study, we investigate the crowd-related problems during the Hajj pilgrimage from a developing country (Bangladesh, to be specific) perspective. To do so, first, we design a survey questionnaire to explore the problems experienced by the pilgrims. Subsequently, we analyze the responses through quantitative analysis (e.g., statistical analysis, network analysis, centrality, and ranking). In the process of our study, we focus on a set of research questions.

ORCID(s):

1.1. Our research questions

In this study, we focus on the following set of research questions.

- **RQ1:** How do the problems faced by the Muslim pilgrims vary with respect to various baseline factors such as the mode of pilgrimage (Hajj or Umrah) and previous pilgrimage experience?
- **RQ2:** How are the different problems associated among themselves - specially for the first-timer Hajj pilgrims from Bangladesh? How far can we rank the problems?
- **RQ3:** How do the problems and the demographics of pilgrims get associated among themselves? How far can we rank the problems and demographics from a bipartite point of view?

1.2. Our contributions

In road to answering these research questions, we make the following set of contributions in this study.

- We design a comprehensive survey questionnaire to know about pilgrims' demographic information and their experiences about problems faced during pilgrimage. By disseminating the survey questionnaire both online and in-person, we collect responses of pilgrims (n=900) from many countries (mostly from Bangladesh, which represents a developing highly-populated Muslim-majority country).
- We perform exploratory analyses on the collected responses and reveal that pilgrims' experiences significantly vary with different baseline factors such as the mode of pilgrimage (Hajj or Umrah) and previous pilgrimage experiences.
- We perform statistical tests on the collected responses to investigate potential associations between different problems. Besides, we explore associations between the problems and the demographics of the experiencing pilgrims. Based on the analyses, we formulate two graph networks namely - 1) Problem Association Network (PANet) and 2) Demography-Problem Association Network (DPANet).
- We analyze PANet in-depth by applying relevant graph network-based algorithms to determine different graph-centric measures such as clique and centrality. Through determining these measures, we find out clusters of problems that are more associated among themselves.
- Further, based on the scores of centrality (e.g., degree centrality, closeness centrality, etc.) and other relevant measures (e.g., HITS, CoHITS, and BiRank), we rank both the problems and demographics in the PANet as well as DPANet.

1.3. Organization of this study

We organize the remaining of this paper as follows. In the following section, we present the related studies done so far. Next, we demonstrate the design of our survey questionnaire and data collection. Then, we present our exploratory analysis. Afterwords, we discuss on the statistical and graph network analyses that we conduct on our collected data. After that, we discuss on findings of this study in detail and compare those findings with that of other existing studies. We also analyze the applicability of this study. Finally, we conclude this work through shedding some light on potential future work. We present a high-level flow diagram of our steps performed in this study in Figure 1.

2. Literature Review

This section reviews the previous studies on problems during Hajj pilgrimage, demographics of the affected pilgrims, associations between problems and demographics, ranking major problems and vulnerable groups, etc.

2.1. Problems during Hajj pilgrimage

Pilgrims face multitudes of problems during Hajj pilgrimage. The problems include the following.

2.1.1. Difficulty in conversation

During Hajj pilgrimage, pilgrims face difficulties in conversation when communicating with different other stakeholders (e.g., fellow pilgrims, airport officials, Hajj authorities, and management personnel) (Owaidah, 2015). Among those stakeholders, the management personnel of Hajj pilgrimage have to facilitate many public services including healthcare, accommodation, security, pilgrimage-related information, etc., (Taibi, 2014). To ensure such services, there is a necessity of having communication at different levels - between pilgrims and service providers, between authorities and service providers, and between authorities and pilgrims (Taibi, 2014). As a significant number of pilgrims come from non-Arab countries (Owaidah, 2015), ensuring smooth communication at each of these levels is challenging.

2.1.2. Hygienic sanitation

During Hajj, pilgrims face different hygienic issues (e.g., scarcity of hand rub, limited access to washrooms, scarcity of clean toilet, etc.) (Mahdi et al., 2020). Moreover, the availability of good hygienic facilities depends upon the travel agencies and the packages. Pilgrims have to choose a package from available packages, which include economical, deluxe, and super deluxe (Mahdi et al., 2020). Good packages require good amount of money to be paid. As many pilgrims from developing countries cannot pay enough money for the better packages, the hygienic issues faced by those pilgrims are worse. A case study conducted upon pilgrims from four countries (New Zealand, Pakistan, Bangladesh, and Myanmar) revealed similar findings where Pakistani pilgrims mentioned that the management of cleanliness in washrooms was poor, and they found garbage and litter all around the washrooms (J. Rahman, Thu, Arshad, & Putten, 2017).

2.1.3. Finding camps at Mina

Mina is a valley located five miles near Mecca having 160,000 tents for housing of pilgrims (Shambour & Khan, 2022). During the five days of Hajj, pilgrims spend most of the days in the tents of Mina. During their stay, pilgrims have to go out and get back to the tent to perform other rituals of pilgrimage. In doing so, pilgrims sometimes face difficulties in locating their specific tents due to having other similar-looking tents (Alkharoubi, 2020). Although authorities deploy many tent-locating infrastructures (e.g., specific signs, numbers, written instructions, etc.) above the tents, pilgrims find those infrastructures identical and challenging to distinguish (Alkharoubi, 2020). Therefore, many pilgrims use landmark signs, such as mosques, restaurants, etc., to locate themselves and find their tents (Alkharoubi, 2020).

2.1.4. Lack of transportation

Hajj pilgrimage is a series of spatio-temporal events where millions of pilgrims have to travel Mecca and its neighboring locations (e.g., Mina, Mujdalifah, Arafah, etc.). Therefore, ensuring a secure and sustainable travel experience is a big challenge for such a heavy crowd. On the other hand, existing infrastructures of the city has been improved gradually, perhaps not in a planned manner. Many roads are too narrow and some residents have no direct access to roads (Anisurrahman & Alshuwaikhat, 2019). Existing transportation services in those locations include walking facilities, buses, and metros (Hussain, Felemban, & Rehman, 2021). However, these services are not sufficient for an annual gathering of around 2.5 million pilgrims (Anisurrahman & Alshuwaikhat, 2019).

2.1.5. Lost pilgrims

Besides transportation issues, Hajj often causes getting lost of pilgrims especially of elderly ones and children (S. Alshehri, 2015). Studies show that 50% of the pilgrims fear becoming lost (S. Alshehri, 2015). The exist many reasons behind pilgrims' getting lost including lack of knowledge about Hajj ritual places (e.g., entrance and exit gates), language barrier, similar looking clothing, etc., (Alshalani, Alnaghaimshi, & Eljack, 2020; A. Rahman, Hassanain, & Hossain, 2017). The consequences of getting lost of a pilgrim are troublesome for both the pilgrim's group and the organizers (S. Alshehri, 2015).

2.1.6. Understanding road direction signs

During Hajj pilgrimage, pilgrims need necessary directional information regarding exact places of Hajj rituals. Though organizers employ volunteers on the streets, they are not available all the time. Besides, language barrier between the pilgrims and the volunteers make the conversation difficult (Owaidah, 2015). Therefore, static directional signs on the streets have been deployed by authorities. However, pilgrims often find those signs inadequate and hard to understand (Owaidah, 2015).

2.1.7. Major problems

From the above problems, ranking major problems is very important for organizers and authorities, as they can take precautionary measures to eradicate or reduce the extent of the most salient problems. However, this aspect of analysis

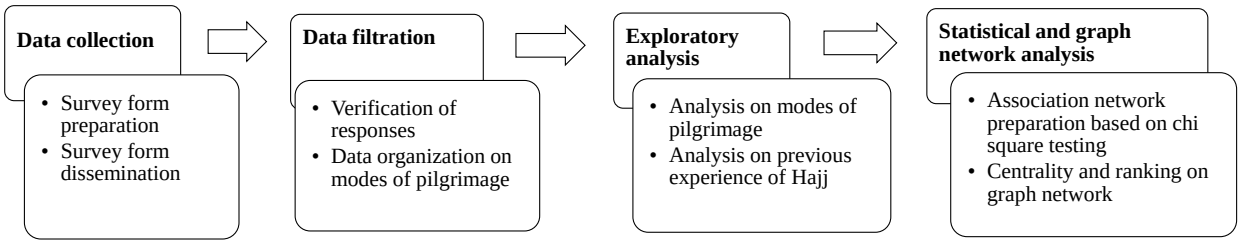


Figure 1: Methodology of our study in stages as follows: data collection, data filtration, exploratory analysis, statistical analysis, and network analysis.

is very little explored in the literature. In the literature, we find a study conducted on 236 pilgrims from Bangladesh where pilgrims had high dissatisfaction on several pilgrimage services, which include transportation, accommodation, and hajj-training (Islam, 2021). However, problems during pilgrimage are not related to only services provided by authorities.

2.2. Demographics of affected pilgrims

Pilgrims' demographics influence the problems during the Hajj pilgrimage (Alsolami et al., 2016). According to (Bianchi, 2017), pilgrims having specific demographics are more susceptible to deaths leading to higher mortality rates. In the literature, such pilgrims are identified as vulnerable groups or high-risk groups. Those groups include aged pilgrims, women, children, foreign workers, refugees, and illegal migrants living in Saudi Arabia (Bianchi, 2017).

Apart from mortality rates, studies showed that pilgrims' ethnicity, age, and gender had impact on the health conditions (e.g., accident, burn, infection, allergy, eczema, etc.,) of them (Sharaf et al., 2021). Results showed that Asian and African pilgrims were affected by skin problems and older pilgrims were more prone to infections during pilgrimage. However, there was no significant difference between male and female pilgrims in all categories of health conditions.

2.3. Avenues for improvement

Prior work on problems during Hajj pilgrimage mainly focused on identifying a specific problem and exploring various reasons and possible solutions for the problem. However, prioritizing the major problems according to different ranking metrics is little explored in the literature to the best of our knowledge. Besides, existing studies on demographics of pilgrims considered mostly health-related problems to identify vulnerable groups of pilgrims. However, pilgrimage is associated with varying problems (e.g., language barriers, hygienic sanitation, transportation, getting lost, understandable road direction signs, etc.). The associations between those problems and pilgrims' demographics are yet to be explored in the literature to the best of our knowledge. Furthermore, from the associations, there are possibilities to prioritize vulnerable groups of pilgrims and major problems, which are yet to be taken into consideration in the existing literture.

3. Dataset preparation

In this section, we demonstrate the preparation of the survey questionnaire, data collection, data filtration, and participants' demographics. In the process of our dataset preparation, we first develop a survey questionnaire consisting of 49 questions in 12 sections. We provide the prepared questionnaire as a supplimentary document. We organize the questionnaire in a self-report form in which participant pilgrims read each question and select responses by themselves without any outside interference. In the first section, we ask about the pilgrim's demographic information (e.g., age, gender, education, language proficiency, etc.). In the remaining sections, we ask about specific problems (e.g., transportation, getting lost, washroom, food, drinking water, etc.). Regarding the conduction of the survey, we take approval from the ethics committee of the authors' institution.

We recruited data collectors from different universities in Bangladesh to collect data for us. Besides, the authors of this paper participated in the data collection in both Bangladesh and Saudi Arabia. To reach pilgrims from other countries, we sent the survey questionnaire through email and Facebook. During the dissemination of the survey form, each participant provided informed consent. At the end of 6 months-long data collection, we were able to collect 988 responses.

Table 1
Demographics of the participant pilgrims

Basic information	Distribution	Number of participants	Percentage (%)
Gender	Male	601	66.8
	Female	297	33
	Do not disclose	2	0.2
Age	Youth (1-14)	7	0.8
	Young adulthood (15-24)	110	12.2
	Middle adulthood (25-44)	298	33.1
	Older adulthood (45-64)	434	48.2
	Retirement (65+)	51	5.7
Education	Below 10th grade	183	20.3
	10th grade	105	11.7
	12th grade	120	13.3
	Above 12th grade	102	11.3
	Undergraduate or above	390	43.3
Country of living	Bangladesh	772	85.8
	Saudi Arabia	37	4.1
	Malaysia	13	1.4
	India	12	1.3
	Pakistan	9	1
	United States	8	0.9
	Algeria	7	0.8
	Others	42	4.7
Language	Bengali	827	91.9
	English	463	51.4
	Hindi	126	14
	Arabic	120	13.3
	Urdu	106	11.8
	Others	60	6.7
Communication medium	Smart device	569	63.2
	Feature phone	272	30.2
	No device	59	6.6

During the in-person survey, we formulate some terms and conditions for the data collectors. The data collectors, who did not follow the terms and conditions (checked after the survey conduction), are identified as not reliable and ignored for further analysis in our study. At the end of data filtration, we get 900 credible responses.

We provide a highlight of the demographics of the selected 900 participant pilgrims in Table 1. Here, participants are mostly from Bangladesh, 85.8% (n=772) and others are from 21 different countries including Saudi Arabia, Kuwait, Qatar, Malaysia, India, Pakistan, Algeria, United States, Australia, Nigeria, Egypt, Germany, Indonesia, Ireland, etc. The ages of the pilgrims while performing Hajj is ranged from 6 years to 82 years (average 47 years). 66.8% (n=601) of the pilgrims self-reported as male, 33% (n=297) as female, and 0.2%(n=2) did not want to disclose. 20.3% of participants' literacy level is below 10th grade and 43.3% participants are undergraduate or above.

4. Exploratory analysis

We perform a set exploratory analyses on the collected data. Here, our goal is to understand the problems the pilgrims faced as well as the different types of pilgrims among our participants.

4.1. Experience of problems

During the survey, participant pilgrims mentioned several problems. They shared their experiences of mismanagement, poor accommodations, getting lost, and other negative experiences.

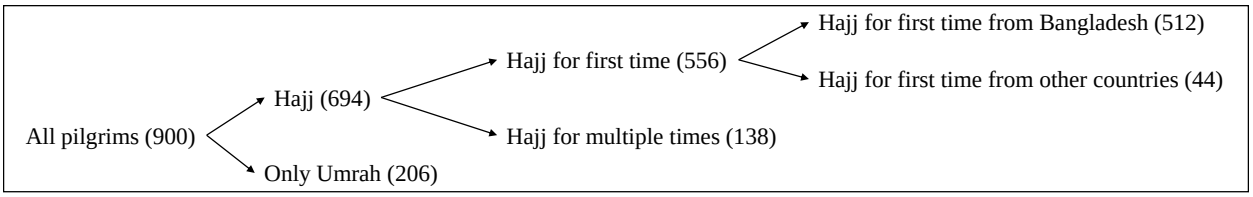


Figure 2: Hierarchy of different types of pilgrims and corresponding count

Table 2
Abbreviations of problems explored in this study

Abbreviation	Problem	Abbreviation	Problem
Conv	Difficulty in conversation	*Food*	Getting food
Harm	Entering into Masjid al-Haram	*Wat*	Getting drinking water
Wash	Finding washrooms	*Lost*	Getting lost
Hyg	Finding hygienic washrooms	*Arf*	Hurdles in Arafah
MC	Finding camps at Mina	*Sign*	Understanding road direction signs
Trans	Finding transport		

"A serious problem is when the crowd increases in Masjid al-Haram, volunteers keep closing the gates one after another. Then a pilgrim has to run from one gate to another to enter the mosque and often can't enter."

- A 48-year-old male pilgrim

"I was standing right there where I got lost so that when someone comes back looking for me, he or she can find me easily. I had no device or wristband or id card with me then and was unable to speak to the volunteers because of language barrier."

- A 79-year-old female pilgrim

"Camp was so much overloaded and cheap rated. As the Moallem and Hajj agencies were dishonest so they rented low-rated and long-distance tents. Therefore, pilgrims, almost every time quarreled with the Muallems (the agency's representatives). As I face these types of problems, I didn't stay in the tent. I stayed those times under a tree with my wife."

- A 43-year-old male pilgrim

"It would be better, if there were more space for females to pray inside the Masjid an-Nabawi And importantly time for females to visit Riadh ul Jannah should be fixed and declared."

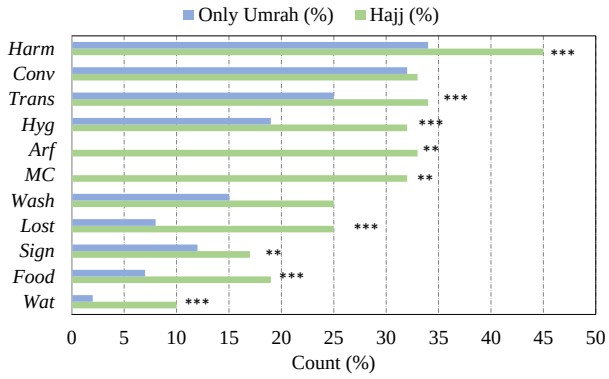
- A 46-year-old female pilgrim

From the responses of pilgrims, we identify 11 problems as the most common in nature. We list those problems in Table 2 with abbreviation for each. In the remaining of the paper, we address those problems by their abbreviations in italic font.

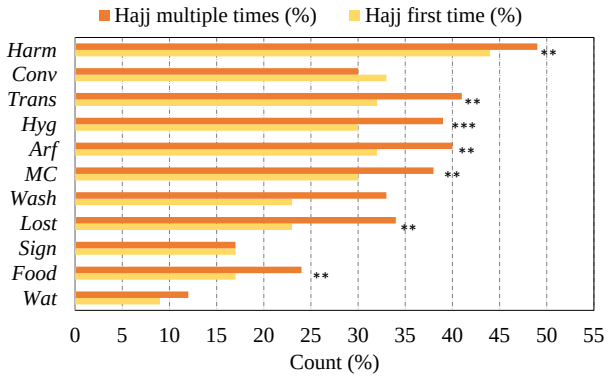
4.2. Pilgrims of different types

We divide all the participant pilgrims (n=900) into multiple categories according to several criteria. As shown in Figure 2, among 900 participant pilgrims, 694 participants performed Hajj and 206 participants performed only Umrah. Among the Hajj (n=694) pilgrims, 556 participants performed Hajj for the first time, whereas 138 participants performed Hajj multiple times. Finally, of the first-time Hajj pilgrims, 512 participants are from Bangladesh and 44 participants are from other countries. Then, we perform a pair-wise comparison between different categories of pilgrims.

We perform z-test (Montgomery & Runger, 2010) to statistically test if the population percentages of two categories (i.e., Hajj and Umrah) are significantly different. We illustrate the result of z-test in Figure 3a where problems with



(a) Comparison among experience of Hajj and Umrah pilgrims in facing different problems



(b) Comparison among pilgrims who performed Hajj for the first time and pilgrims who performed Hajj multiple times on their experience in facing different problems

Figure 3: Different types of pilgrims and differences in their experience of facing problems. Statistically significant difference between two sub-groups is marked by asterisks (** indicates $p < 0.01$, *** indicates $p < 0.001$)

significant p-value are illustrated as asterisks (*). The difference in the percentages is statistically sound with nine problems showing statistically significant ($p < 0.01$) difference. For example, for problem *Harm* which stands for 'Entering into Masjid al-Haram', 45% Hajj pilgrims (blue colored bar) faced this problem compared to 34% Umrah pilgrims (green colored bar) and the difference is statistically significant having p-value < 0.001 (***).

In parallel, we perform z-test for pilgrims who performed Hajj for the first time and multiple times. The result of that analysis is shown in Figure 3b. Pilgrims who performed Hajj multiple times reported more percentage of response for a problem (orange colored bar) compared to pilgrims who performed Hajj for the first time (yellow colored bar). The obvious reason behind this is that those who have multiple experiences faced proportionately multiple problems with varying degrees.

From the above tests on different categories of pilgrims, this is evident that pilgrimage experiences vary significantly with modes of pilgrimage. Therefore, we choose a specific category of pilgrims for further studying the different problems and demographics. As substantial pilgrims in our study are from Bangladesh, we select pilgrims from Bangladesh who performed Hajj for the first time (n=512) to conduct the subsequent analyses of this study.

5. Statistical analysis

We perform a set of statistical analyses over the collected data. In the subsequent part of this section, we present our approach and findings from the statistical analyses.

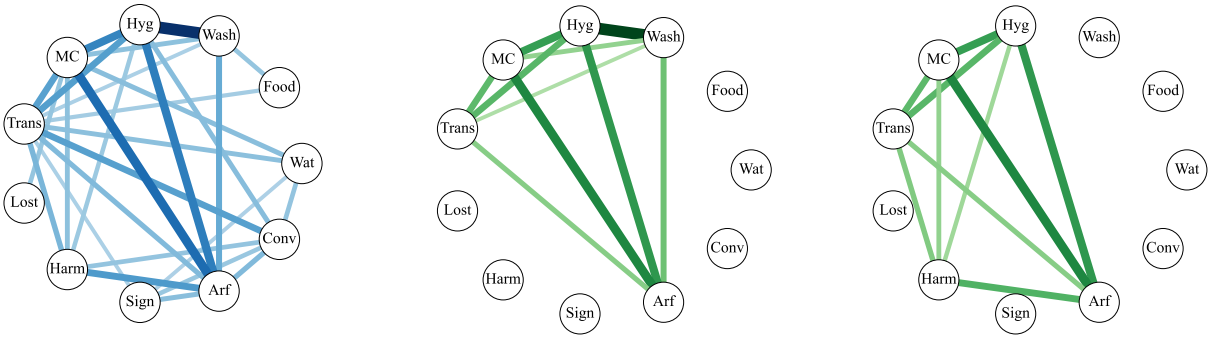
5.1. Approach

We perform multiple hypothesis tests on the collected responses to unveil different perspectives and interpretations of the responses.

1. To identify whether the problems (e.g., getting drinking water, finding washrooms, understanding road direction signs, etc.) have any association among themselves, we develop a graphical model using NetworkX library(NetworkX, 2022). We use the chi-squared test in scipy.stats package (SciPy, 2022) with Cramer's V test to measure the goodness of association. From Cramer's V as the edge-weights of PANet, we search for statistically strong association (Cramer's V >= 0.15 and P < 0.05) between problems.
2. To identify whether the demographics (e.g., age, gender, education, employment, usage of smart devices, etc.) have any association with the problems, we develop a bipartite graphical model using the NetworkX library (NetworkX, 2022). We use the chi-squared test in scipy.stats package (SciPy, 2022) with Cramer's V test to measure the goodness of association. From Cramer's V as the edge-weights of DPAnet, we search for a statistically strong (Cramer's V >= 0.15 and P < 0.05) association between the demographics of participants and the problems (Akoglu, 2018).

Table 3
Cramer's V association among problems. Asterisks represent Yates' corrected (Yates, 1934) statistically significant association between two problems (* indicates P < 0.05; ** indicates P < 0.01; *** indicates P < 0.001).

Problem	*Wat*	*Food*	*Wash*	*Hyg*	*MC*	*Trans*	*Lost*	*Harm*	*Sign*	*Arf*	*Conv*
Wat											
Food	0.13**										
Wash	0.13**	0.18***									
Hyg	0.13**	0.07	0.46***								
MC	0.2***	0.11**	0.19***	0.31***							
Trans	0.19***	0.17***	0.15***	0.26***	0.26***						
Lost	0	0	0	0	0.18***	0.04					
Harm	0.14**	0.03	0.03	0.18***	0.19***	0.21***	0				
Sign	0.15**	0.14**	0.08	0.1*	0.14**	0.15**	0	0.13**			
Arf	0.14**	0.09*	0.24***	0.32***	0.35***	0.21***	0	0.27***	0.2***		
Conv	0.18***	0.14***	0.11**	0.2***	0.14***	0.26***	0	0.18***	0.18***	0.21***	



(a) Problem Association Network (PANet)

(b) A maximum clique in PANet

(c) A maximum clique in PANet

Figure 4: Problem Association Network (PANet) based on strong association (Cramer's V >= 0.15 and P < 0.05) between two problems is shown in Figure (a). The green-colored networks in Figure (b) and (c) represent the maximum cliques of PANet. Note: Cramer's V > 0.25 = Very strong association; Cramer's V > 0.15 = Strong association; Cramer's V > 0.10 = Moderate association (Akoglu, 2018).

5.2. Findings

The first statistical test to find association between different problems results in an association matrix as shown in Table 3. Here, both rows and columns represent problems. Each cell represents Cramer's V association coefficient which ranges from 0 to 1 (i.e., larger the coefficient, stronger the association). From the association matrix, we develop an association graph network which we name as Problem Association Network (PANet) as shown in Figure 4a. The vertices of this graph represent the problems. The edges represent the association between two problems.

Our second statistical test results in an association matrix of problems and demographics which is illustrated in Table 5. Here, rows and columns of the matrix represents demographics of pilgrims and problems encountered respectively. As like first test, each cell represents Cramer's V association coefficient which ranges from 0 to 1 (i.e., larger the coefficient, stronger the association). Using the association matrix, we develop a bipartite association network as shown in Figure 6. The left and right vertices of this network represent the demographics of Hajj pilgrims and problems encountered during Hajj pilgrimage respectively.

In both PANet and DPANet, the width and darkness of the edges represent the strength of association, i.e., the wider and darker an edge, more strong the association.

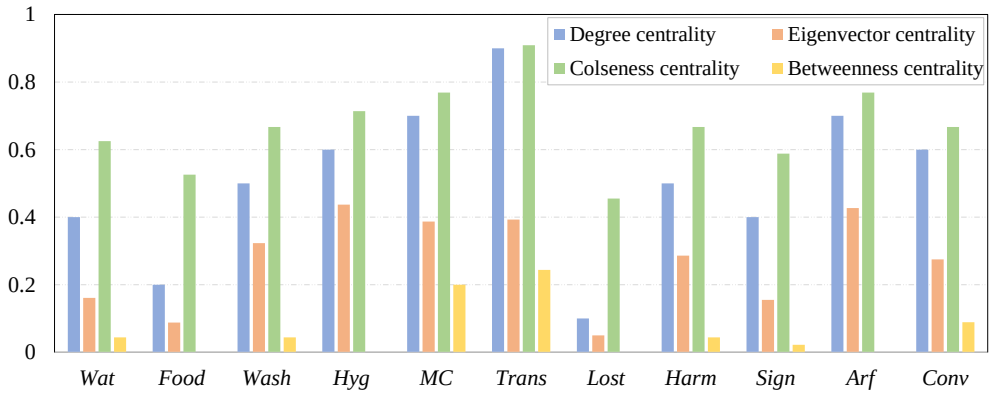


Figure 5: Measure of different types of centrality for problems in Problem Association Network (PANet)

Table 4
Ranking of problems on different centrality metrics. Higher rank signifies more important problem.

Centrality measure	*Wat*	*Food*	*Wash*	*Hyg*	*MC*	*Trans*	*Lost*	*Harm*	*Sign*	*Arf*	*Conv*
Degree centrality	3	2	5	7	**9**	**11**	1	5	3	**9**	7
Eigenvector centrality	4	2	7	**11**	8	9	1	6	3	**10**	5
Colseness centrality	4	2	5	8	**9**	**11**	1	5	3	**9**	5
Betweenness centrality	6	1	6	1	**10**	**11**	1	6	5	1	**9**

6. Graph network analysis

According to research questions 2 and 3, we need to rank the problems and demographics of pilgrims so that administrative and management personnel can identify the most salient problems and vulnerable groups of pilgrims. A recent research study has shown that graph network analysis methodologies, such as cliques and centrality can help to identify important nodes in the network (Shahid et al., 2019). Therefore, we perform several graph network analysis methodologies on the Problem Association Network (PANet) and Demography-Problem Association Network (DPANet) to rank important problems and demographics.

6.1. Problem Association Network (PANet)

Here, we describe the findings of graph network analysis. We present the findings from two different perspectives: clique and centrality.

6.1.1. Clique

We extract the maximal cliques from PANet to know about how a subset of problems associate among themselves. We find eight maximal cliques among which three are maximum cliques. Among the three maximum cliques, we demonstrate two maximum cliques in Figure 4b and 4c.The maximum cliques are completely interconnected, i.e., each node of a maximum clique is connected with every other node. For example, in Figure 4b, five problems namely 'finding transport' (*Trans*), 'finding camp at Mina' (*MC*), 'finding hygienic washrooms' (*Hyg*), 'finding washrooms' (*Wash*), and 'hurdles in Arafah' (*Arf*) are completely connected among themselves. The maximum cliques represent the largest possible chain of interactions among problems. Moreover, it is evident from the maximum cliques in Figure 4 that they contain some of the strongly associated vertex-pairs in the network, such as {'finding a washroom' (*Wash*), 'finding hygienic washrooms' (*Hyg*)}, {'finding camp at Mina' (*MC*), 'hurdles in Arafah' (*Arf*)}, {'finding hygienic washrooms' (*Hyg*) 'hurdles in Arafah' (*Arf*)}, etc. Therefore, we hope that these maximum cliques will help us to understand the importance of certain problems during the Hajj pilgrimage.

6.1.2. Centrality

We evaluate different centrality measuring algorithms to get an insight into the connectivity, closeness, and betweenness centrality of different nodes in the PANet. We compute those measures using degree_centrality(),

Table 5
Cramer's V association between demographics of pilgrims and problems they faced. Asterisks represent Yates' corrected (Yates, 1934) statistically significant association between two problems (* indicates P < 0.05; ** indicates P < 0.01; *** indicates P < 0.001).

Demography	*Wat*	*Food*	*Wash*	*Hyg*	*MC*	*Trans*	*Lost*	*Harm*	*Sign*	*Arf*	*Conv*
Gender	0	0.04	0	0.09	0	0.06	0	0	0.13**	0	0.04
Skill in speaking Arabic	0	0	0	0.05	0.08	0	0	0	0.16***	0.06	0.03
Skill in speaking Urdu/Hindi	0.02	0	0.05	0.08	0	0	0	0	0.16***	0	0
Skill in speaking English	0	0	0.05	0.17***	0.17***	0	0.03	0.11*	0.23***	0.19*	0.01
Education	0.07	0	0.12	0.21***	0.2***	0.08	0.14*	0.16*	0.19***	0.21*	0
Employment	0	0.02	0	0.11	0.08	0.14	0.03	0.16*	0.18***	0.1	0.05
Usage of smart communication device	0	0	0.06	0.21***	0.09	0.09	0.1	0.04	0.21***	0.11*	0
Age of performing Hajj	0	0	0	0.08	0	0.12	0.16*	0	0.12**	0.07	0

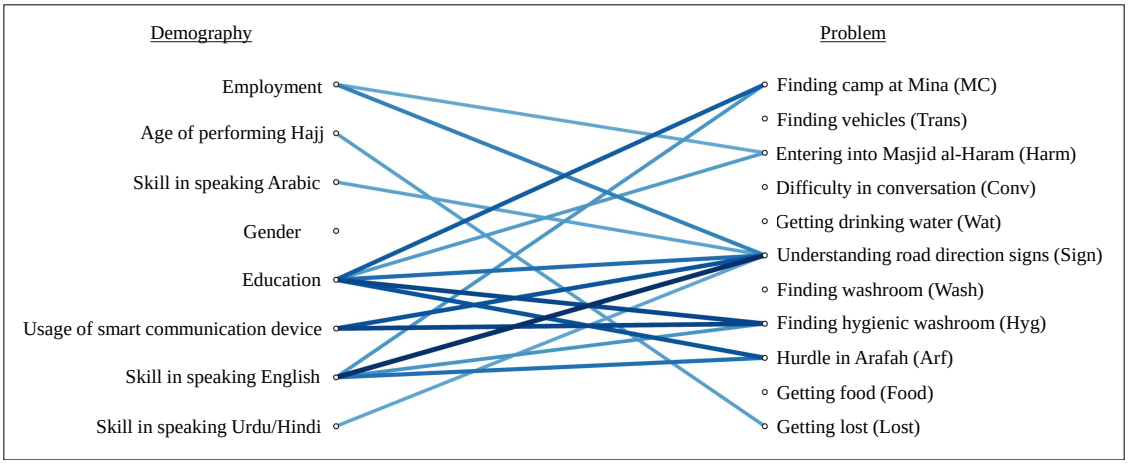


Figure 6: Demography-Problem Association Network (DPANet). Edges are shown only for strong associations (Cramer's V >= 0.15 and P < 0.05). Note: Cramer's V > 0.25 = Very strong association; Cramer's V > 0.15 = Strong association; Cramer's V > 0.10 = Moderate association (Akoglu, 2018).

eigenvector_centrality(), closeness_centrality(), and betweenness_centrality() functions available in Networkx library (NetworkX, 2022).

Degree centrality: The degree centrality of a node is simply the degree the node has, i.e., the higher the degree of the node, the more central the node is. Figure 5 illustrates the results where blue colored bars indicate degree centrality score. Here, we can see that 'finding transport' (*Trans*) has the highest and 'getting food' (*Food*) has the lowest degree centrality. This signifies that the problem 'finding transport' (*Trans*) is associated with maximum number of other problems. Whereas, 'getting food' (*Food*) is associated with minimum number of problems.

Eigenvector centrality: Eigenvector centrality is a centrality measure based on the centrality of a node's neighbors (Bonacich, 1987). Figure 5 illustrates the eigenvector centrality scores for each problem with orange colored bars. Here, we can see that 'finding hygienic washrooms' (*Hyg*) has the highest and 'getting lost' (*Lost*) has the lowest eigenvector centrality.

Closeness centrality: Closeness centrality generally measures how fast a node can share information with other nodes. Closeness centrality of a node can be inferred as the relative importance of the node in the network (Freeman, 1978). Here, higher values of closeness indicate higher centrality. Figure 5 illustrates the result with green colored bars. Here, we can see that 'finding transport' (*Trans*) has the highest and 'getting lost' (*Lost*) has the lowest closeness centrality.

Betweenness centrality: Betweenness centrality of a node dictates the influence of the node on the flow of information in the network (Brandes, 2001). Figure 5 illustrates the results with yellow colored bars. Here, we can

Table 6
Ranking of problems in bipartite graph based ranking algorithms. Higher rank signifies more important problem.

Ranking algorithm	*Wat*	*Food*	*Wash*	*Hyg*	*MC*	*Trans*	*Lost*	*Harm*	*Arf*	*Conv*	*Sign*
HITS	3	1	4	**10**	**8**	5	6	7	**9**	2	**11**
CoHITS	2	1	4	**10**	**8**	7	5	6	**9**	3	**11**
BiRank	2	1	4	**10**	**8**	7	5	5	**9**	3	**11**

Table 7
Ranking of demography in bipartite graph-based ranking algorithms. Higher rank signifies more important demography.

Ranking algorithm	Gender	Skill in speaking Arabic	Skill in speaking Urdu/Hindi	Skill in speaking English	Education	Employment	Usage of smart communication device	Age of performing Hajj
HITS	1	3	2	**7**	**8**	5	**6**	4
CoHITS	3	2	1	**7**	**8**	**6**	5	4
BiRank	3	2	1	**7**	**8**	**5**	**5**	4

see that 'finding transport' (*Trans*) has the highest and 'getting food' (*Food*), 'finding hygienic washrooms' (*Hyg*), 'getting lost' (*Lost*), and 'hurdles in Arafah' (*Arf*) has the lowest betweenness centrality.

The ranking scores of problems based on different centrality metrics are shown in Table 4. From the ranking scores, 'finding hygienic washrooms' (*Hyg*), 'finding camp at Mina' (*MC*), 'finding transport' (*Trans*), 'hurdles in Arafah' (*Arf*), and 'difficulty in conversation (*Conv*)' have the higher centrality rankings among all other problems. This implies that these problems are among the major problems in Hajj pilgrimage.

6.2. Demography-Problem Association Network (DPANet)

In DPANet, we perform some bipartite graph-specific ranking algorithms (e.g., HITS, CoHITS, BiRank) to rank the problems and demographics of pilgrims. We present the findings of the analysis below.

6.2.1. Ranking of problems

The ranking scores of problems after performing the bipartite graph-specific ranking algorithms are shown in Table 6. Here, the larger value represents a higher ranking which implies higher importance to be given when handling those problems during Hajj. The top four ranking problems are highlighted in Table 6 which are as follows: 'understanding road direction signs' (*Sign*), 'finding hygienic washrooms' (*Hyg*), 'hurdles in Arafah' (*Arf*), and 'finding camp at Mina' (*MC*).

6.2.2. Ranking of demography

During the conduction of the survey, we observed that human demographics (e.g., age, gender, education, language, etc.) often influence specific problems for the pilgrims. Our bipartite graph-specific ranking also reveals such reflection which is shown in Table 7. Here, a higher value for demography represents a higher ranking which signifies authorities should be more careful and kind towards pilgrims having such demography during the events of Hajj pilgrimage. In Table 7, we highlight the top three ranking demographics for each ranking algorithmic which are as follows: 'education', 'skill in speaking English', and 'employment'.

7. Discussion

In this section, we demonstrate how our findings answer the research questions set in this study. Besides, we discuss how our findings address the gaps in the literature. We also discuss how Hajj authorities can get benefited from our findings and what are the future implications of this study.

7.1. Variation in experiencing problems by the pilgrims

Hajj and Umrah pilgrimages are the most well-known forms of religious as well as tourism activities (Saidovna, 2021). Pilgrims have to perform Hajj at a specific time in the month of Dhu al-Hijjah in the Islamic calendar, whereas, pilgrims can perform Umrah at any time in the whole year. Besides, there are fewer rituals in Umrah than Hajj pilgrimage. Therefore, in Figure 3, we find fewer people who experienced the listed problems during the Umrah pilgrimage than that in the Hajj pilgrimage. Moreover, at Arafah and Mina, there are no rituals for Umrah pilgrimage (Saidovna, 2021). Therefore, there is no mention of problems there from Umrah pilgrims.

Alongside the mode of pilgrimage, the experiences of pilgrims who performed pilgrimage for the first time and who performed pilgrimage multiple times also differ in each problem, which is vividly depicted in Figure 3b. Here, we find that the extents of problems faced by the pilgrims who performed pilgrimage multiple times are mostly higher than that faced by the pilgrims who performed pilgrimage for the first time. The reason behind such a difference is that, even though previous pilgrimage experience of performing the rituals helps pilgrims overcoming the problems better in subsequent appearances, each year the number of pilgrims performing pilgrimage varies and new infrastructures as well as management policies emerge in the places of rituals leading to new problems for the pilgrims (of Statistics, 2019).

7.2. Associations between problems

From the experience of Bangladeshi pilgrims who performed Hajj pilgrimage for the first time, we prepare a Problem Association Network (PANet) as shown in Figure 4a. The PANet presents strong associations between different problems. Here, we reveal that experiencing 'hurdles in Arafah' (*Arf*) and 'finding hygienic washrooms' (*Hyg*) have a strong association. This strong association implies that those who faced problems in Arafah, also faced problems in finding hygienic washrooms during the pilgrimage.

From the PANet, we also measure the centrality of each problem for different centrality measures to identify the important problems in the network. Accordingly, as shown in Table 4, 'finding hygienic washrooms' (*Hyg*), 'finding camp at Mina' (*MC*), 'finding transport' (*Trans*), 'experiencing hurdles in Arafah' (*Arf*), and 'difficulty in conversation' (*Conv*) have the higher ranks among all the problems. This finding signifies that these problems are more important and need more attention from administrative and management authorities. Among these more important problems, lack of transportation during Hajj pilgrimage got significant attention in some prior work (M. A. Alshehri et al., 2021; Gardner et al., 2016; Islam, 2021; Masud et al., 2016; J. Rahman, Thu, Arshad, & Van der Putten, 2017) too.

7.3. Association between demographics and problems

Ranking of problems as shown in Table 6 highlights the more salient problems in our DPANet. This ranking is different from the ranking obtained from the PANet. This happens as we consider associations only between the problems in the PANet, whereas, we consider associations between demography and problems in the DPANet.

As per the ranking obtained from the DPANet, we find that 'understanding road direction signs' (*Sign*), 'finding hygienic washrooms' (*Hyg*), 'experiencing hurdles in Arafah' (*Arf*), and 'finding camp at Mina' (*MC*) have the higher ranks among the 11 problems. Among these, 'understanding road direction signs' (*Sign*) is the top-ranked problem, as this problem is associated with many demographics of the pilgrims.

Besides, from the bipartite representation of DPANet as shown in Figure 6, we observe several associations between the demographics of pilgrims and the problems faced by the pilgrims. Additionally, from the ranking of demographics as shown in Table 7, we find that 'education', 'English speaking proficiency', and 'usage of smart communication devices' are associated with many problems. Rationale behind this finding is the fact that the importance of 'education' and 'English language proficiency' is highly significant, as many instructions (e.g., road direction signs, instructions in smartphone applications, etc.) observed during Hajj pilgrimage are written in English (Abdellah & Ibrahim, 2013; Felemban et al., 2020). Besides, there exist many smart device-based platforms for knowledge sharing and navigation that are designed and developed to ease the experiences of pilgrims (Alam, Hadi, & Najam, 2022; Mohandes, 2015; Sharma, Bhondekar, Shukla, & Ghanshyam, 2018). Pilgrims who are used to smart devices may take benefit from these sources of information.

7.4. Comparison with other existing studies

In this study, we explore different types of problems experienced by the pilgrims. Besides, we consider pilgrims of different demographics (e.g., gender, age, literacy, country of living, language of speaking, etc.). Then, we reveal strong associations between different demographics and problems (through PANet and DPANet) as mentioned earlier. Leveraging the association networks, we identify major problems and vulnerable groups of pilgrims.

Prior research studies also attempted to identify major problems and vulnerable groups of pilgrims in pilgrimages of different religion. For example, the study in (Joseph et al., 2016) conducted a survey over 46 doctors operating in Sabrimala pilgrimage located in India. This study revealed that human stampedes and person-to-person communicable diseases have the highest rank. Another study (Islam, 2021) conducted a survey over 236 Bangladeshi pilgrims to identify service gaps and satisfaction of pilgrims. Their study revealed that air services, food, accommodation, and transportation services had satisfaction rates of 94.9%, 75.8%, 61.9%, and 43.2% respectively. However, none of these

Table 8
Comparison (area of focus, data acquisition, and contributions) of our study with existing literature. '✓' denotes that a contribution has been made and '-' denotes that a contribution has not been made.

Research study	Area of focus	Data acquisition	Associate problems and demographics	Identify major problems	Identify vulnerable pilgrims
(Taibah et al., 2020)	Hajj pilgrimage	Survey (n=245)	-	-	-
(Ali et al., 2020)	Hajj pilgrimage	Secondary sources	-	-	-
(Dauda Goni et al., 2019)	Hajj pilgrimage	Survey (n=225)	-	-	-
(Sharaf et al., 2021)	Hajj pilgrimage	Survey (n=550)	-	-	-
(Alsolami et al., 2016)	Hajj pilgrimage	Survey (n=156)	-	-	-
(Lin, 2021)	Dajia Mazu pilgrimage	Expert opinions	-	-	-
(Joseph, Babu, Dev, & Pradeepkumar, 2016)	Sabarimala pilgrimage	Survey (n=46)	-	✓	-
(Islam, 2021)	Hajj pilgrimage	Survey (n=236)	-	✓	-
(Bianchi, 2017)	Hajj pilgrimage	Secondary sources	-	-	✓
[Our study]	Hajj pilgrimage	Survey (n=900)	✓	✓	✓

studies identified vulnerable groups of pilgrims. Besides, association between problems and demographics was not focused in these studies.

Besides, another study (Bianchi, 2017) explored historical data of the Ministry of Health in Saudi Arabia and other scholarly articles to identify most vulnerable pilgrims in light of death rates during Hajj and Umrah pilgrimage. Their study identified poor people, women, and children from Asia and Africa as the most vulnerable groups of pilgrims. However, this study did not provide any information suggesting such pilgrims are vulnerable to which kind of daily life problems other than death.

Other research work (Ali et al., 2020; Alsolami et al., 2016; Dauda Goni et al., 2019; Lin, 2021; Taibah et al., 2020) also studied pilgrimages in different contexts. However, none of these studies explored any association between problems and demographics. Besides, none of these studies identified any important problem faced by the pilgrims or any important demographics of the pilgrims.

7.5. Implications

Ranking of problems is important for Hajj organizers and administrations, as they need to first identify the most salient problems in the event to take preventive measures for those problems on a priority basis. However, existing research studies still lack in this area, as the existing studies explore the problems in isolation. For example, the studies in (Islam, 2021; Joseph et al., 2016) explored only some specific problems (e.g., health and service gaps). Based on the findings of these existing studies, organizers and administrations can focus only on a few specific problems without knowing their overall importance. However, as Hajj pilgrimage is a multi-stakeholder event, pilgrims face multitudes of problems in reality. To this context, for the first time in the literature to the best of our knowledge, our study in this paper identifies the major problems and prioritize them in a comprehensive manner. Utilizing the findings of our study, organizers and administrations can take measures to alleviate the major problems first in a systematic manner.

Besides, ranking of demographics can provide important information about pilgrims who are more vulnerable to experiencing problems. In this regard, prior studies (Bianchi, 2017; Sharaf et al., 2021) only identified vulnerable groups of pilgrims focusing only on health conditions. Based on the findings of such existing studies, authorities can take care of the vulnerable groups of pilgrims on the basis of health conditions only. However, as diverse problems occur during Hajj pilgrimage, our study deals with multitudes of the problems as well as demographics of the pilgrims altogether. Thus, our findings on associations between problems and demographics (DPANet) can help authorities in a more robust manner, as we can find which problems are associated with which demographics from the DPANet. Accordingly, based on our study, authorities now can provide special care for vulnerable pilgrims having specific demographics to enable them perform their pilgrimage safely and successfully.

8. Conclusion

Islamic Hajj pilgrimage is one of the largest annual mass gathering events and the most popular religious tourism attraction for Muslims around the globe. Pilgrims face multitudes of problems during the five days long pilgrimage while performing this event. Prior research studies have focused on various problems in Hajj pilgrimage in isolation. Although they can identify possible reasons for a problem and affected stakeholders, they are unable to determine the importance of problems and identify pilgrims who are more vulnerable to those problems. Therefore, for the first time in the literature to the best of our knowledge, this study identifies the most salient problems during Hajj. We do so

through leveraging graph network based analyses. Besides, our study identifies pilgrims who are more vulnerable to a specific problem based on demographics of the pilgrims.

Following our network analysis over the problems faced by the pilgrims, we build a Problem Association Network (PANet). In the PANet, we identify 'transportation' (*Trans*), 'finding camp at Mina' (*MC*), and 'finding hygienic washrooms' (*Hyg*) as the most important problems. Therefore, to ease experiences of the pilgrims and to manage the pilgrims efficiently, organizers and administrations should prioritize taking necessary measures to first solve the most important problems. Besides, we have prepared a bipartite graph, called Demography-Problem Association Network (DPANet), following network analysis over demographics of pilgrims and problems they faced. In the DPANet, we find that pilgrims having less education, poor skill in speaking English, and less expertise in using smart communication devices are the most vulnerable groups of pilgrims with the possibility of facing problems during the pilgrimage.

Understanding the importance of problems and ranking vulnerable groups of pilgrims, as revealed in this study, are important not only to organizers and administration but also to the researchers of religious tourism. Although this study provides new insights into religious tourism in general and Hajj pilgrimage in specific, it has some avenues for further improvement. For example, in this study, pilgrims from Bangladesh cover around 85% (n=772) of the total participants. Thus, our study may not reflect the global perspective of Hajj pilgrimage rather it might portray the situation of pilgrims mostly from a developing country. Though many religious tourism destinations endure some of the problems mentioned in this study (e.g., scarcity of washrooms, transportation, food, and drinking water), the importance of problems may vary across different religious tourism activities. Therefore, to explore other religious tourism activities, future researchers can follow the same assessment strategies described in this study. Finally, in this study, comparatively fewer female pilgrims participated compared to male pilgrims (601 male and 297 female). The reason behind this happening is that we have conducted surveys in many rural places of Bangladesh where female populations reside in a very conservative environment and they are less likely to participate in such surveys.

Finally, ensuring a successful pilgrimage experience for all pilgrims always remains a major concern for organizers and administrations of the host country of Hajj. This requires prioritizing the major problems in different pilgrimage locations and understanding pilgrims' demographics. To this extent, this study examines Hajj pilgrims (mostly from Bangladesh) with a systematic assessment criterion through enlisting important problems and vulnerable groups of pilgrims. In the future, we plan to scale up our survey covering more pilgrims from many different other countries. Besides, according to our findings in this study, we plan to prepare a comprehensive work plan for organizers and administration to facilitate their tasks in ensuring a more successful and efficient management of Hajj pilgrimage.

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