AN ANALYTICAL HIERARCHY PROCESS APPROACH FOR A COVID-19 RISK ASSESSMENT STUDY AMID THE LATEST RE-OPEN AND UNLOCK PHASE IN INDIA

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ABSTRACT

The long duration of the COVID-19 pandemic has now compelled people to come out of their cells and begin engaging in various activities using different modes and in different places, which involves a high risk of being infected by COVID-19. This work aims to analyze the degree of the risk involved in such activities with the implementation of the latest re-open and unlock phase in India, the second most COVID-19 affected country. Seven important activities and the mode and place of conducting these activities are considered as the main criteria and sub-criteria of this study. The responses are formed with a pairwise comparison matrix, and an Analytical Hierarchy Process (AHP) approach is used to calculate the criteria/sub-criteria weights. An integrated AHP analysis output representation consisting of the degree of risk, grades, ranking, and major reasons of risk for each criterion and sub-criteria of this work is presented. This risk assessment study may help identify risky activities so that people can choose other available alternatives.

Keywords: COVID-19; AHP; risk assessment; MCDM; Decision-making

1. Introduction

The novel corona virus (COVID-19), or Syndrome Corona Virus-2 (SARS-CoV-2), originated in Wuhan City of Hubei province in China and has become a worldwide pandemic (Wang et al., 2020). The common symptoms of COVID-19 include dry cough, fever, malaise, and headache (Wang et al., 2020) which are normal symptoms of sickness as the seasons change which makes it tedious to verify unless a check-up for COVID-19 is done. The WHO has found that an infected person can transmit the virus to others who are within 6 feet. However, recent studies have found that possible virus transmission can occur over a distance of 2 meters (Setti et al., 2020). As of 10:10 GMT, October 10, 2020, Worldometer (2020) had reported over 37,155,642 confirmed cases including 1,073,338 deaths worldwide. According to the registered data, the United States of America, Brazil and India are most COVID-19 affected nations. To prevent a possibly

more critical situation, the government of India ordered a nationwide lockdown (2020) on March 24, 2020 which initially came into force for 21 days starting on March 25, 2020 (Lockdown implementation order, 2020). Due to the lockdown implementation, all important but non-essential activities such as traveling, gathering, use of delivery services, entertainment activities, and many other important activities from a financial point of view were stopped. In order to maintain social distancing, a series of unlock phases was soon started due to the financial and management requirements.

Phase 4 re-open and unlock was announced through the Ministry of Home Affairs website on August 29, 2020, which allows various activities to take place with some restrictions. The exponential increase in the number of cases and casualties has become a major concern for all the health bodies including the WHO and the Indian Council for Medical Research (ICMR) because for the last few days, India has continuously recorded more than 75,000 cases per day (Worldometer, 2020).

The easing of restrictions for conducting various essential activities that was issued in the latest phase of unlock guidelines are applicable to more than 1.38 billion citizens of India (Population of India, 2020) which potentially increases the COVID-19 risk. This situation has motivated the authors to conduct a risk assessment study for many important daily life activities. This study aims to calculate the risk involved in many activities that are likely to take place in this phase of unlock. In this work, the authors tried to list various activities, and the mode and place of conducting these activities with their relative risk of COVID-19 infection. The authors have applied the Analytical Hierarchy Process (AHP) with the row geometric mean method (Crawford and Williams, 1985) to calculate relative risk weights of the main criteria and sub-criteria. The activities and mode or place of conducting an activity are considered as criteria and sub-criteria, respectively in this study. The risk weight of the criteria/sub-criteria helps identify extremely risky activities.

2. Focus of the work

SARS-CoV-2 has become one of the worst healthcare emergencies that does not yet have a promising treatment or vaccination available, which makes a relative risk assessment of various activities and the places of conducting these activities very important to minimize the fatal growth rate of infections. This work highlights seven main activities that are necessary for normal living and likely to take place in response to the latest re-open and unlock phase. The seven activities include job, shopping, gathering, entertainment, traveling, residency, and utilizing delivery services and have been listed as our main criteria. The various modes and places of conducting these activities based on their expected strength and possibility of contact with different people are considered as the sub-criteria of this study. The main criteria and sub-criteria with their notations are listed in Table 1.

In this work, the standard layer hierarchy and the proper hierarchical structure representing all of the main criteria and sub-criteria of this study are respectively shown in Figures1 and 2. The analyzed risk of conducting the main activities are listed in Table 2 and the cumulative risk weight, ranking, and description as well as the major factors and reasons are discussed in Table 3. This work helps people understand the risk involved in the mode of conducting an activity at some particular place so that available

alternatives can be considered or the activity can be avoided. It is important to remain safe and clear during this pandemic period.

Table 1
Main criteria and their sub-criteria

Criteria	Sub-criteria
Job A_1	Hospital A_{11}, Government office A_{12}, Private office A_{13}
Shop A_2	Grocery store A_{21}, Vendor A_{22}, Shopping mall A_{23}
Gathering A_3	Marriage ceremony A_{31}, Cremation ceremony A_{32}, Conference and seminar A_{33}, Worship place A_{34}
Entertainment A_4	Stadium A_{41}, Movie hall A_{42}, Zoo and water park A_{43}
Traveling A_5	Personal vehicle A_{51}, Bus, Train and Taxi A_{52}, Airline and ship A_{53}
Residency A_6	Joint family A_{61}, Nuclear family A_{62}, Hosteller A_{63}
Utilizing delivery Services A_7	Food delivery A_{71}, E-commerce A_{72}

3. AHP solution

The Analytical Hierarchy Process (AHP), developed by Saaty (1977), is a highly practical procedure that helps solve complex multicriteria decision making (MCDM) problems. The AHP hierarchy structure is a three layer structure (Chaiyaphan and Ransikarbum, 2020) as shown in Figure 1, where the top, middle and final layer of the hierarchy structure are i) Goal or Target ii) Criteria, Sub-criteria (if any), and iii) Possible choice or solution to the problem, respectively.

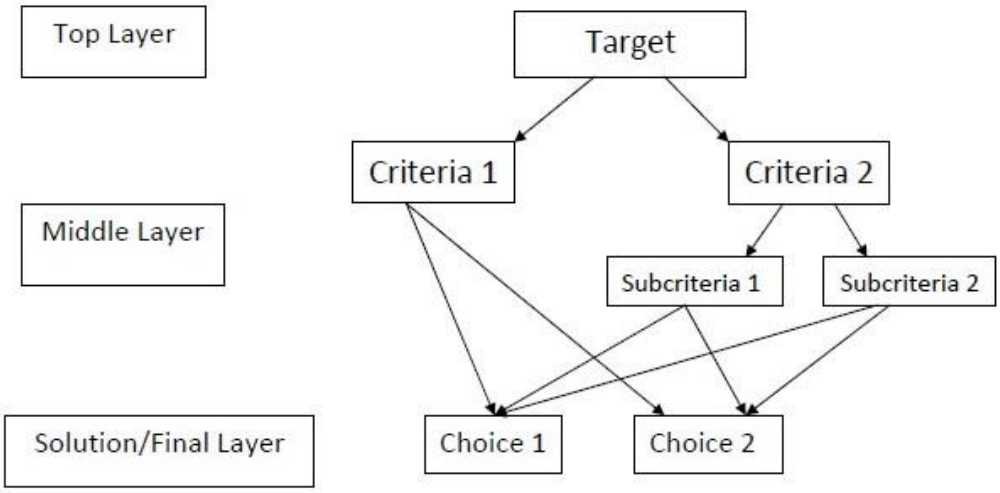

Figure 1 Hierarchy structure of AHP

The AHP has widely been used in healthcare, risk assessment, construction, supply chain, automotive, and many other fields by researchers and statisticians. Simon et al. (2019) applied the AHP model for priority analysis of various strategies for malaria control. Improta et al. (2019) applied the AHP for health technology assessment (HTA) of optoelectronic biosensors for oncology. Rajak and Shaw (2019) performed an AHP analysis for evaluation and selection on mobile health (mHealth) applications. Also, the AHP has been an impressive support system for researchers in risk assessment studies. Lyu et al. (2020) used Fuzzy AHP in the risk assessment of mega city infrastructure, and Rivera et al. (2020) applied the AHP to study the risk factors for the spread of COVID-19 in Peru.

The application of the AHP requires the sequential fulfillment of several major steps (Rosenbloom, 1997) listed below:

1. Break down the problem into a hierarchy of a finite number of decision elements.
2. Compute the pairwise comparison values for all possible pairs of criteria at every level of the hierarchy structure and construct a pairwise comparison matrix with tolerable inconsistency. According to Saaty (1977), the degree of inconsistency can be measured using the expressions given below:

$$CI = \frac{\lambda_{\max} - n}{n-1}$$
$$CR = \frac{CI}{RI}$$

where, CI is the consistency index; $\lambda_{\max}$ is the largest Eigen value; n is the number of criteria; CR is the consistency ratio, and a RI value 0.58, 0.9 and 1.32 for $n = 3,\ 4$ and 7 respectively, is the suggested random index value (Saaty, 1987). It is suggested that the CR value must be less than 0.1.

3. Compute the preference weight using the suitable AHP analysis. For a pairwise comparison matrix $A = \lfloor a_{ij} \rfloor$, i^{th} row geometric mean (Crawford and Williams, 1985) value is:

$$w_i = \left(\prod_{j=1}^{n} a_{ij} \right)^{1/n}$$

4. Rank the decision criteria after aggregating the relative weights.

Table 2
Pairwise comparison of main criteria, normalized weight and grade

Criteria	A_1	A_2	A_3	A_4	A_5	A_6	A_7	Criteria weights	Grades	Consistency check
Job A_1	1	3	1	2	2	6	5	0.2677	A	
Shopping A_2	0.33	1	0.5	1	0.33	3	3	0.1043	D	
Gathering A_3	1	2	1	4	2	5	4	0.2632	B	$CI = 0.0327$
Entertainment A_4	0.5	1	0.25	1	0.5	2	2	0.0947	E	$CR = 0.0242$
Travelling A_5	0.5	3	0.5	2	1	4	3	0.1745	C	$RI = 1.32$
Residency A_6	0.1667	0.33	0.2	0.5	0.25	1	0.5	0.0408	G	
Utilizing delivery services A_7	0.2	0.33	0.25	0.5	0.33	2	1	0.0548	F	

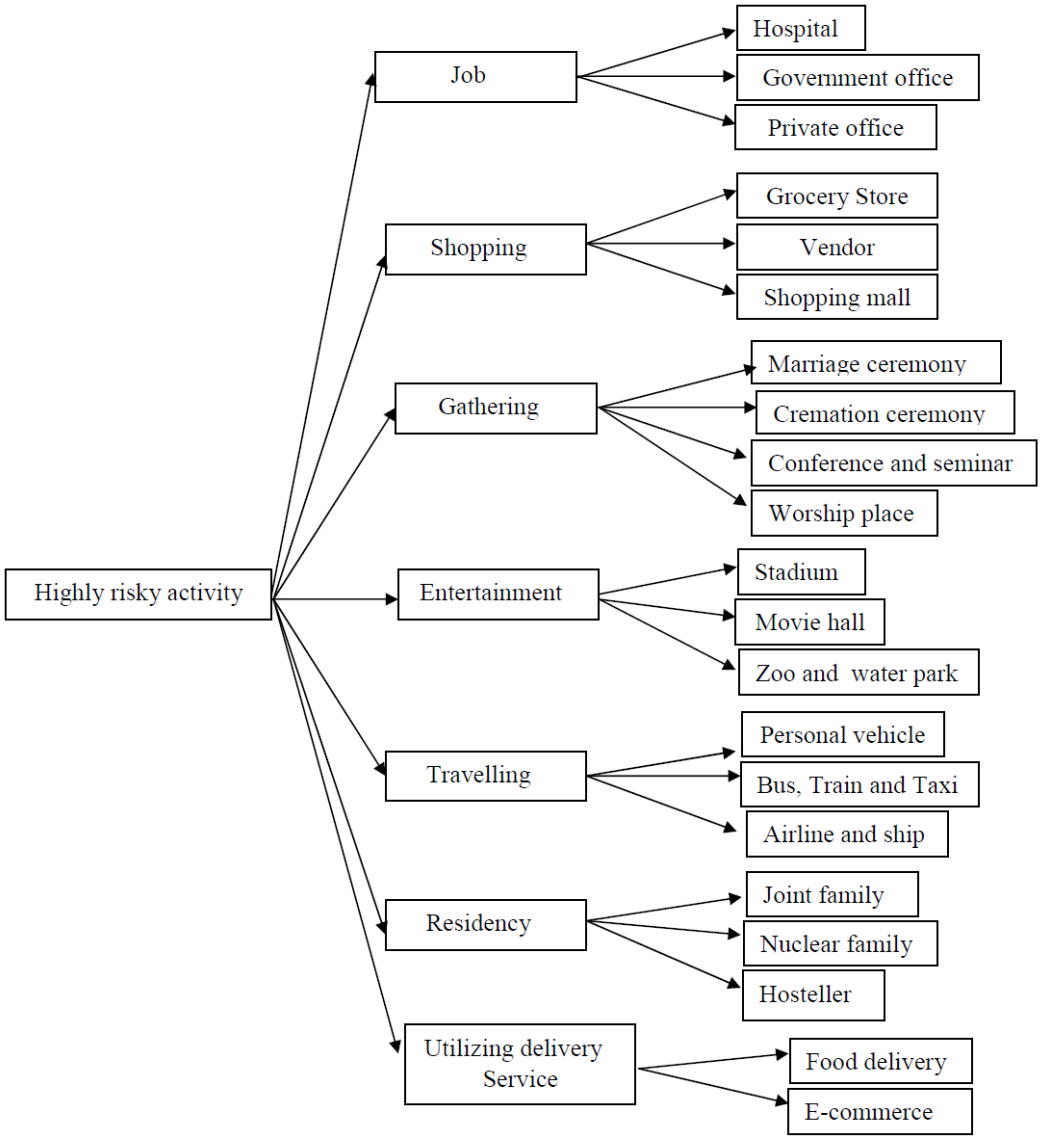

Figure 2 Hierarchy of activities and their respective places

4. Results and discussion

The authors have identified seven important activities as the main criteria of this risk assessment study. These activities were specifically chosen by considering the latest gathering restrictions in the Phase 4 re-open and unlock (2020) guidelines issued by the Ministry of Home Affairs. Also, the mode and place of conducting these selected activities have been identified as their sub-criteria and are shown in Table 1. Since the AHP is able to provide very reliable output for complex multicriteria decision making (MCDM) problems with little mathematical computation, the authors were able to perform all of the analysis manually using the row geometric mean method with precision (Crawford and Williams, 1985).

The authors observed that the opinions of different health experts regarding how safe/unsafe a location is are subject to the presence or absence of some pre-determined factors. Generally, medical experts/doctors would be the most likely people to provide responses for a healthcare study such as this; however, since they are required to perform their duties to every possible extent during this pandemic the authors have identified some major factors that are favorable to COVID-19 virus transmission as follows: i) A high population density or a large number of people present/involved in an activity, ii) Maintaining less than 6 feet of social-distancing, and iii) Physically close and frequent contact among people. Next, the pairwise comparison matrix was shaped by an expert data analyst and statistician based on their experience and understanding of the correlation of identified factors with the criteria and sub-criteria of this study. A consistency analysis was used to ensure that the PCM was tolerably inconsistent. The degree of risk involved in a criterion was calculated as criteria weight by applying the row geometric mean method. All of the criteria were assigned a grade from A to G based on their high to low degree of risk; this is shown in Table 2. Moreover, the pairwise comparison matrices, consistency-checks, and relative weights for all of the sub-criteria within the same level of the hierarchy are shown in Table 4.

This AHP analysis for a COVID-19 risk assessment presents an integrated outcome representation in Table 3. This representation includes all criteria and sub-criteria with their degree of COVID-19 risk in the form of criteria and sub-criteria weight, the cumulative sub-criteria weight derived by multiplication of local sub-criteria weight with their respective main criteria weight which leads to form a global sub-criteria weight and ranking. The authors have also expressed various expected reasons of risk involvement in this representation.

Table 3
Integrated outcome representation with expected major reasons of risk

S.NO	Criteria /Sub-criteria	Criteria weight	Sub-criteria weight	Cumulative normalized Sub-criteria weight	Grade and ranking	Expected major reasons of risk
A_1	Job	0.267682			A	Frequent contact with external objects makes it the most serious activity of the study
A_{11}	Hospital		0.745006	0.199425	1	Being in direct contact with virus infected patients, health care workers like doctors, nurses and others are at extreme risk of COVID-19
A_{12}	Government office		0.098552	0.026380	14	Need for continuous operational state for proper implementation of guidelines
A_{13}	Private office		0.156441	0.041876	9	The limited space available and lack of sanitization facilities in many private offices
A_2	Shopping	0.104275			D	The basic requirement of goods and other materials has resulted in shopping as a main criterion
A_{21}	Grocery store		0.196246	0.020463	17	The reach to a limited number of customers from a specific territory makes shopping at grocery stores less risky than shopping at vendors or the mall
A_{22}	Vendors		0.49223	0.051327	7	Covering a very large area of the city increases the risk of being in contact with the virus
A_{23}	Shopping mall		0.311522	0.032484	11	Finite, but sufficiently large customer capacity
A_3	Gathering	0.263216			B	A gathering is the second most risky activity because meeting with a large group of people

						proportionally increases the probability of COVID-19 infection
A_{31}	Marriage ceremony		0.222189	0.058483	4	Permission for 50 people gathering at a marriage ceremony
A_{32}	Cremation ceremony		0.119379	0.031422	12	Permission for at most 20 people gathering at a cremation ceremony
A_{33}	Conference and seminar		0.200771	0.052846	6	Large participation in a conference and seminar
A_{34}	Worship place		0.457659	0.120463	2	High visiting frequency and the non registering nature of a worship place
A_4	Entertainment	0.094716			E	Need for a healthy mood and good physical health are very essential at this time which demands that entertainment be one of the main criterion of this study
A_{41}	Stadium		0.196976	0.018656	18	The risk of coming in contact with sports equipment that may carry the virus, yet stadiums have sufficient space for maintaining distance from others
A_{42}	Movie hall		0.311239	0.029479	13	The density of the audience in a movie hall is very high and increases the risk
A_{43}	Zoo and water park		0.491783	0.046580	8	Possible infection through animals and contaminated water
A_5	Travelling	0.174485			C	A list of requirements demands that one travel by various modes of transportation, which makes it an essential criterion of this study
A_{51}	Personal vehicle		0.122542	0.021381	16	Traveling by personal vehicle eliminates many possibilities of infection, yet their maintenance requires visits to many public places
A_{52}	Bus, Train and Taxi		0.319130	0.0556835	5	Use of the same seats by many people and high capacity of commuters, categorizes use of a bus, train, and taxi as extremely risky
A_{53}	Airline and ship		0.558326	0.097419	3	Overseas origin of passengers from various countries and a very large capacity of these modes of transportations are the main reasons for the extreme risk.
A_6	Residency	0.040795			G	The residency area of an individual with a number of people is a major concern of this study; however, the AHP analysis finds that it has optimal risk involvement
A_{61}	Joint family		0.537895	0.021943	15	A large number of family members makes it slightly risky
A_{62}	Nuclear family		0.297788	0.012148	20	Small number of family members is the main reason for a nuclear family to have the second to last position in most risky sub-criteria
A_{63}	Hosteller		0.164315	0.006703	21	Being a hosteller is the last ranked sub-criteria with the minimum risk involved
A_7	Utilizing delivery services	0.054828			F	Utilization of various resources without going out is the main reason for inclusion of various delivery and online purchase facilities under the category of 'Utilizing delivery services' in this study
A_{71}	Food delivery		0.666666	0.036552	10	Involvement of many hands from cooking to delivery
A_{72}	E-commerce		0.333334	0.018276	19	Careful and standard measures, but the product visits many stations

Table 4
Pair wise comparison of sub-criteria with consistency check and weight

Criteria	Sub-criteria					Sub-criteria weight	Consistency check
A_1		A_{11}	A_{12}	A_{13}			
	A_{11}	1	6	6		0.745006	CI = 0.0268
	A_{12}	0.1667	1	0.5		0.098552	CR = 0.046
	A_{13}	0.1667	2	1		0.156441	
A_2		A_{21}	A_{22}	A_{23}			
	A_{21}	1	0.5	0.5		0.196246	CI = 0.0269
	A_{22}	2	1	2		0.492230	CR = 0.0464
	A_{23}	2	0.5	1		0.311522	
A_3		A_{31}	A_{32}	A_{33}	A_{34}		
	A_{31}	1	2	1	0.5	0.222189	
	A_{32}	0.5	1	0.5	0.33	0.119379	CI = 0.0136
	A_{33}	1	2	1	0.33	0.200771	*CR* = 0.0151
	A_{34}	2	3	3	1	0.457659	
A_4		A_{41}	A_{42}	A_{43}			
	A_{41}	1	0.5	0.5		0.196976	*CI* = 0.0268
	A_{42}	2	1	0.5		0.311239	*CR* = 0.0462
	A_{43}	2	2	1		0.491783	
A_5		A_{51}	A_{52}	A_{53}			
	A_{51}	1	0.33	0.25		0.122542	*CI* = 0.0077
	A_{52}	3	1	0.5		0.319130	*CR* = 0.0133
	A_{53}	4	2	1		0.558326	
A_6		A_{61}	A_{62}	A_{63}			
	A_{61}	1	2	3		0.537895	*CI* = 0.0027
	A_{62}	0.5	1	2		0.297788	*CR* = 0.0047
	A_{63}	0.33	0.5	1		0.164315	
A_7		A_{71}	A_{72}				
	A_{71}	1	2			0.666666	*CI* = 0
	A_{72}	0.5	1			0.333334	

5. Conclusions

COVID-19 is spreading exponentially and for a developing country like India with a population of 1.38 billion (Population of India, 2020) it has become an extremely tedious health care management problem. The government of India has promptly responded to the pandemic and imposed a nationwide lockdown (2020). Many restrictions have been eased in a sequence of re-open and unlock phases. In the latest Phase 4 re-open and unlock (2020) guidelines, the authors have observed that large gatherings, interstate transportation, utilization of various delivery services and many other activities are no longer under strict control which might be responsible for a sudden increase in COVID-19 cases. To analyze the degree of COVID-19 risk involved in many important activities through different modes and at different places, the authors conducted a COVID-19 risk assessment using a very popular MCDM technique, the Analytic Hierarchy Process (AHP).

A simple and structured application of the AHP has derived very significant outcomes. The risk assessment reflects that doing a job has the highest risk of COVID-19 infection among all seven listed activities because it requires frequent contact with external objects that may carry COVID-19. Moreover, gathering is an occasional event, but has the potential possibility of COVID-19 transmission to a large number of people coming from different places which makes it the second most risky activity of the study, followed by traveling, shopping, entertainment, utilizing delivery services and residency. The authors found that cumulative sub-criteria weights and global sub-criteria ranking were very helpful in identifying the most risky places to conduct the corresponding activity. Based on the rankings, the hospital is the most risky work station and healthcare workers such as doctors, nurses and other medical staff are at extreme risk of COVID-19 infection because they are in direct contact with COVID-19 patients. The absence of proper identification and record placement policies and the frequency of visiting are the expected reasons for a place of worship to be the second most risky sub-criteria of this study. All of the other sub-criteria and their global rankings and major reasons for risk are explained in Table 3. The authors also conclude that being a hosteller and living in a nuclear family are two of the least risky sub-criteria when compared to others.

In this COVID-19 risk assessment, the authors tried to express the real time suitability of the AHP approach. The authors suggest that many other healthcare management problems can be analyzed with a large number of different activities in future. This study can potentially help select a suitable alternative activity or mode and place of conducting an activity to avoid various risk factors involved with the parent activity.

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