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Invited ViewPoint

COVID-19 Risk Assessment Tool: Dual application of risk communication and risk governance

Ranit Chatterjee [a,b], Sukhreet Bajwa [a], Disha Dwivedi [a], Repaul Kanji [c], Moniruddin Ahammed [d], Rajib Shaw [a,e,*]

[a] Resilience Innovation Knowledge Academy (RIKA), India
[b] Kyoto University, Japan
[c] Gujarat Institute of Disaster Management, India
[d] Amazon Web Service, India
[e] Keio University, Japan

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ABSTRACT

Risk awareness is the best way to prevent and slow-down the transmission of the COVID-19 pandemic. Risk awareness is achieved through communication of risk assessment. Effective risk communication is an important measure to control the infodemic. Most risk assessment tools focus on either tracking the affected patients or diagnosing a probable health condition through symptoms. RIKA India introduces an innovative Risk Assessment Tool which goes beyond the symptom detection and patient tracking. It includes four factors in assessment of risk: Health, Behaviour, Exposure and Social Policy. Each of these four factors have sub-factors which help to assess the overall risk in a more comprehensive way and also present it to the user in a simplified way. The paper discusses the importance of the Risk Assessment Tool for awareness generation and decision making. Further, the datasets generated through the tool have been analysed to understand the key intervention areas for COVID-19 response and management.

1. Introduction

The coronavirus pandemic has yet again shown that we as a global society are not fully resilient to a health emergency of such a scale. The world has previously seen global health emergencies of Ebola virus in 2014, H1N1 (Swine Flu) in 2009 and SARS in 2003. Having faced such serious outbreaks, there are many lessons for the affected countries and the rest of the world to adapt to, and come out of this as a resilient society. The Novel Coronavirus (2019-nCoV) later named as COVID-19 disease, began as an outbreak in Wuhan province of China, before making its way around-the world in a matter of months and becoming a pandemic. As per Shaw et al. [1] this pandemic is characterised by: i) rapid spread, ii) aged and low immune people are more vulnerable and iii) differential recovery rate. As currently there is no vaccine for COVID-19, neither is there any confirmed treatment, therefore, the best way to prevent and slow down the transmission is to be well informed about its causes and how it spreads. WHO declared COVID-19 as a Public Health Emergency of International Concern (PHEIC) on the 30th of January 2020. This declaration means that the disease outbreak concerns more than one country and thus requires a coordinated international response [2]. While writing this paper the latest data of number of affected people of COVID-19 stands more than 4 million people with number of mortalities at 300,000 [3].

COVID-19 pandemic, as a public health emergency, has brought into light many challenges in our lives and livelihoods. It has brought into picture the need for a trans-disciplinary view of the current crises through various angles of global governance, technology and risk communication [4]. COVID-19 has posed not only health but economic and geo-political crises too. It is thereby a humanitarian challenge [5]. While health organisations and governments advise many preventive measures like social distancing and personal hygiene, one of the foremost strategies remains risk communication and awareness generation to break the chain of spread. Awareness and understanding of the risk at the community level goes a long way in enhancing prevention. In this regard, various risk assessment tools in the form of mobile applications or online surveys are being actively used. Such tools are intended to analyze the probable risk of the respondents based on information provided on current health status. Most of the tools majorly focus on the health diagnostics aspect of the risk wherein the observed symptoms are assessed to assign a category of risk with some platforms providing GIS based analysis of the geospatial risk based on current location of the confirmed cases. This leaves the understanding of risk limited to medical conditions. However, Cheng and Kwang [6] points out at the role of many inter-connecting factors such as social behaviour and exposure which contribute to the risk of contracting the disease as observed in the case of SARS. In case of COVID19 also, observing personal hygiene like

* Corrresponding author at: Resilience Innovation Knowledge Academy (RIKA), India.
E-mail address: shaw@sfc.keio.ac.jp. (R. Shaw).

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avoiding to touch face, wearing masks, frequent washing of hands as well as social/physical distancing is prescribed. All these factors essentially are part of community and social behaviour and become part of the governance. As per Shaw et al. [1] citizen compliance and behaviour resulted in containment of the spread in China and other countries.

Amidst the management and response to the COVID-19 pandemic, this paper has two specific objectives. One is to explores the use of innovation and technology in assessing the people's behaviour in pandemic response. Two to see how four parameters (health, exposure, Behaviour and Social Policy) are linked. The paper introduces Covid19 Risk Assessment Tool developed by RIKA India (Indian based social entrepreneurship start up, which works on disaster risk reduction, environmental management and sustainable development) as an innovative strategy for risk assessment, communication, decision-making and awareness. The first part explores the risk assessment and risk communication in the context of emergencies and specifically for COVID-19 pandemic. It undertakes a review of existing risk assessment and information tools available online in the form of apps and surveys. The second part concentrates on key features of RIKA's COVID19 Risk Assessment Tool and discusses the methodology used for development of the tool. The third part focusses on data analysis based on the responses of the Risk Assessment Tool. The data analysis uses Pearson's correlation coefficient to understand if there exists any linear relation between two variables and also to identify the strength of such relationship, if it exists. The analysis is followed by key inferences and conclusion.

2. Overview of existing COVID-19 related tools

Risk assessment is an important step in disaster risk reduction where it enhances the understanding of risk and allows information to decide on adequate preventive and mitigation measures. Core methodologies for disaster risk assessment include hazard, exposure and vulnerability assessment. Risk assessment is also widely used in the context of health, safety and environment. It involves evaluation of existing conditions of vulnerability, the impending hazard, existing exposure and current capacities for prevention. Risk models specify the factors which are needed to assess risk and the relationship among those factors, producing a sort of template for risk assessors to use in their assessments. Health risk assessment tools have been developed to assess individual risk for particular diseases.

Shaw et al. [1] points out the need to have a proper risk assessment including factors of health risk, governance, exposure and citizen behaviour. To strengthen the community level response, a coordinated approach of disaster risk governance from Sendai Framework point of view is needed to manage this public health emergency. In the case of China, emerging technologies like Artificial Intelligence (AI), Big Data, 5G technologies, drones, automated vehicles, robotics etc. were used to track, monitor and support logistics in management of Covid19 [ibid]. Technological risk assessment models can quickly analyze irregular symptoms and other similar red flags and thus alarm the community and the healthcare authorities. This helps to improve the planning, and awareness activities for patients on an evidence-based model. Further it helps to provide faster decision making, which is cost-effective. Such tools can help analyze the extent of infection spread by this virus by identifying the clusters and hot spots and can successfully do the contact tracing and monitor of the individuals [7].

COVID-19 is as much a pandemic as it is an infodemic [5]. WHO Information Network for Epidemics (EPI-WIN) [8] was launched as a new information platform to share customized information with specific target groups. The data on COVID-19 is dynamic and changing at a fast pace. COVID-19 hotspots (areas with affected cases of COVID19) are changing dynamically. This makes a control of information difficult. Social media in this regard tends to be flooded with messages many of which are not verified. As per Hua and Shaw [5], the media use for information access for the COVID-19 increased tremendously. However, the right information is the key to success in mitigation measures. The Chinese and Singapore government in this regard have checked the fake news and kept control on rumour spreading.

Risk assessment generally remains in the domain of science and technology, academia and policy makers. Providing public access to the risk assessment is done through risk communication. Community based activism such as aggressively finding suspected cases and supporting vulnerable groups was a successful advantage of South Korea to overcome the crises [36]. Japan's 26 national resilience working groups includes a high-level "STOP Pandemics 2020 Strategy Committee" which made many recommendations including on risk-communication so as to have a better integration of pandemic risks into all-hazard national resilience [9].

Risk Communication is the effective and accurate exchange of information about health risks and hazards often during an emergency [10]. The aim of risk communication is to advance risk awareness and understanding and to promote health-protective behaviour among individuals, communities, and institutions. The ultimate purpose of risk communication is to enable people at risk to take informed decisions to protect themselves and their loved ones. Risk communication is an essential part of the risk mitigation measures since it drives the public understanding, trust, acceptance and compliance with the measures. Risk mitigation is an interdisciplinary decision-making process based on information from risk and exposure assessment [11]. Risk Communication involves stakeholders like risk assessors, managers, news media, volunteer groups and the community. Risk communication uses many communications techniques ranging from media and social media communications, mass communications and community engagement. It requires a sound understanding of people's perceptions, concerns and beliefs as well as their knowledge and practices. As per Barry [12], if people had accurate information about the risks faced and the knowledge of prevention, they often performed heroically and increase the compliance to public safety advisory of the government. Risk communication, specifically, mass communication of public health information, can however have limitations of cultural issues as well as linguistic barriers, especially for the migrant communities.

In March 2020, WHO setup a 'WhatsApp' group for providing information and risk mitigation instructions [11]. Various countries also launched national communication measures structured in news and information websites/platforms jointly combatting fake news, aiming to encourage awareness, understanding and compliance towards restrictions. As part of such risk communication strategies, the mobile apps have come up as a means for risk communication. A summary of some of the available risk assessment tools and apps in the market is given in the Table 1.

The above-mentioned risk assessment tools are mostly based on the premise of either tracking the affected patients or diagnosing a probable condition through symptoms. These tools and apps help the government as well as the community in knowing if they have been in contact with an affected person. Amidst the concerns for privacy, many private apps have come up to aid in individual assessment of risk and contact tracing.

The RIKA's COVID-19 Risk Assessment Tool goes beyond the symptom detection and patient tracking. It intends to provide information on social behaviour and also assesses the people's compliance for the government advisory. The risk assessment score also includes the exposure of people through the type of residence, the behaviour of hand-washing and wearing mask as well as the current implementation status of restricted movement guidelines of the government.

In comparison to the Arogya Setu App by Government of India, the COVID-19 Risk assessment tool, provides awareness information in the form of questions which are also used to assess the risk based on behaviour and social compliance. Further, the COVID-19 Risk Assessment Tool generates information on anxiety levels to understand the need for psycho-social care as part of overall response. The inclusion of smoking as a risk behaviour is also not considered in Arogya Setu app or any other Risk Assessment Tool available in Asia or in the other continents. Another unique feature is the assessment of exposure based on residential type which is again missed in other available applications and tools.

3. Key features of COVID-19 risk assessment tool

The COVID-19 Risk Assessment Tool is a simple online tool which can be used to assess the risk based on multiple linked factors. The main features of the tool are that it is simple and free to use. The simplicity of the

Table 1
Summary of online risk assessment tools.

S. no.	Name of the tool	Main features
1.	Infermedica [13]	Identifies coronavirus symptoms and provides further information regarding COVID-19 concerns.
2.	Health Engine [14]	It asks questions on following parameters and provides analysis of risk: • Travel History • Corona Positive patient contact history • Symptoms of Fever etc.
3.	Henryford [15]	It asks questions on symptoms, with travel history and contact to provide risk analysis
4.	Docsapp	It is an online doctor consultation app to provide information on symptoms and whether to consult a doctor.
5.	WHO Mass Gathering Religious Addendum Risk Assessment Tool in the context of COVID-19	• It is an offline Risk Assessment Tool for organisers and planners • It Includes Mitigation Checklist for planning mass gatherings and events.
6.	Humandx.org [16]	It asks questions on age, travel history, symptoms, being in healthcare profession and co-morbidities. The assessment summary provides information on preventive steps, the need to visit doctor, get tested etc.
7.	Arogya Setu [17]	The app verifies symptoms and notifies the users if they are in vicinity of a diagnosed positive patient. Tracking is done via Bluetooth and a location-generated graph that charts proximity with anyone infected. The app also provides self-quarantine instructions.
8.	TraceTogether [17]	It is a contact tracing app that uses Bluetooth to track infected people and notify those who were in close proximity to them during the past 15 days.
9.	CovidWatch [17]	It uses Bluetooth signals to detect users when they are in proximity to each other and alerts them anonymously if they were in contact with someone who has tested positive. One unique feature of the app is that any third party, including the government does not have access to the data of who was exposed by whom.
10.	HaMagen [17]	This is launched by the Health Ministry of Israel. It uses contact tracing to contain the spread of the deadly contagion. The app allows users to know if in the past 15 days they were close to anyone who has been diagnosed with the virus.
11.	The Corona DataSpende [17]	It is a German smartwatch app which monitors the spread of coronavirus by collecting symptoms like pulse rate, body temperature, sleep patterns to detect any early signs of warning. It is done through wearing a smartwatch or a fitness tracker.
12.	PeduliLindungi [17]	It is developed by the Indonesian government. It enables users to compile data related to the spread of COVID-19 in the community and helps confirmed and suspected cases. It cross-references data stored on mobile device through Bluetooth. It enables an anonymous exchange of identities when in vicinity of another positive patient.
13.	COVID Safe	The Australian app helps state and territory health officials to quickly contact people who may have been exposed to COVID-19. The COVID Safe app speeds up the current manual process of finding people who have been in close contact with someone with COVID-19.

app lies in the fact that there is minimal data entry. The tool prominently includes questions related to awareness behaviour of the user in order to inculcate awareness. Key questions on whether social distancing is being maintained reiterate the importance of such measures. The tool ensures the implementation of risk communication to the end users. Further, the tool presents the analysis of risk in a visual format which is more appealing to the people. The tool assesses the prevalence of co-morbidities in the users which might increase their risk. As per Yang et al. [18], underlying diseases (Comorbidities), including hypertension, respiratory system disease and cardiovascular disease could be the risk factors for severe patients compared with non-severe patients of COVID-19.

Shaw et al. [1] notes that pandemic is global but its response is local. It is also pointed out that a major part of the response depends upon the culture and citizen behaviour [19]. [ibid], also notes that in Japan, people with colds, flu, or allergic, wear surgical masks as a cultural norm to prevent others from getting sick. The Japanese do not have emotional resistance to wearing masks, whereas people in other countries need to be informed on the need of wearing mask to prevent themselves as well as others. The survey assessment tool assesses the people's behaviour in wearing masks and can help overcome emotional resistance to adhering to government guidelines on restricted movements and sanitation practices. The study of Cheng and Kwang [6] demonstrated that although knowledge is important for performing SARS-preventive behaviours, social norm is also an important factor.

The assessment tool allows the users to take adequate measures with respect to the risk outcomes of high, moderate and low. The assessment tool also allows the measurement of risk perception through the level of anxiety shown by the user in the current scenario. The Risk Assessment Tool fights the infodemic. It shares the personalized risk assessment information. The data analysis can also provide insights into how many people are taking hand-washing seriously. It can detect the need for mental health risk assessment through anxiety level. The tool is a low-cost technology-based solution to provide assessment of individual risk as well as increase community awareness. The tool is customizable in various languages and is currently available in seven languages. The tool also adheres to the privacy norm by not collecting any personal information of the user like phone number or email ID.

3.1. Methodology for tool development

The COVID-19 Risk Assessment Tool is broadly based on four major factors of health, exposure, behaviour and social policy. Each of these factors have sub-factors which are based on findings from studies conducted in China and Italy [27]. The various parameters used to develop the assessment tool can be categorised as shown in Table 2 below.

Each of the parameters are assigned linear weights based on the responses in the given options (Annex-1 for details). The given weights for each parameter except for health are summed up and then average is calculated. The calculation is listed in Table 3 below.

The basic premise for calculation is that age and health is the inherent individual vulnerability that is being exacerbated due to individual exposures and individual behavioural elements. Gender has also been found to be a prevalent determiner of risk to COVID-19. The behaviour factor be5 and be6 are not scored for calculation of risk. Based on the above weightage the risk is calculated as:

$$\text{Risk} = (\text{HR} * 0.5) + (\text{Be} * 0.2) + (\text{Ex} * 0.2) + (\text{SP} * 0.1)$$

The output based on the above calculation gives us three different scenarios of risk as depicted at the end of the assessment: low, moderate and high risk along-with a general information advisory (Fig. 1 below).

This application has been deployed on Amazon Web Services (AWS). AWS Simple Storage Solution (S3) is used to host the user interface (web site). The user interface has been developed using AngularJS and Responsive Web Design. To distribute the web site content AWS CloudFront (Content Distribution Network, CDN) is used so that customers across the world can access it with low latency and high transfer speed. Survey Data is submitted from https://www.covid19risk.net web site to AWS API Gateway,

Table 2
Factors of risk assessment.

Health (HR)	Behaviour (Be)	Exposure (Ex)	Social policy (SP)
Age(A)	Use of Mask (Be1)	Residential Type (Ex1)	Effectiveness of Lockdown (SP1)
Co-Morbidities (Cm)	Hand-washing (Be2)	Occupation (Ex2)	Community Compliance of social distancing and mask use (SP2)
Gender(G)	Sanitizing before touching face (Be3)	Travel History and Mass Gatherings (Ex3)	
Smoking Habit (Sm)	Practicing Social-distancing norm (Be4)		
	Anxiety based on current situation (Be5)		
	Trust in government's measures (Be6)		

Table 3
Calculation for risk assessment factors.

Factor	Calculation	Weightage
Health Risk (HR)	Summation of A, Cm, G and Sm	50%
Behaviour (Be)	Summation of four Be(s) and then divide by 4[a]	20%
Exposure (Ex)	Summation of all Ex(s) and then divide by 3	10%
Social Policy (SP)	Summation of all SP(s) and then divide by 2	10%

[a] For behaviour factor, Be1, Be2, Be3 and Be4 are only considered to calculate risk. Be5 and Be6 are not calculated owing to their dynamic and qualitative nature.

which internally calls AWS Lambda function to store the survey data into Amazon DynamoDB Database. Entire application is serverless and it scales out and scales in automatically based on the usage. The cost associated with this kind of architecture is very minimal. Further, the geotagged locations for each respondent are plotted on a map to show the respondents the probable risk around that location and also the pre-identified hotspots by the government.

3.2. Methodology for data analysis

The COVID-19 Risk Assessment Tool was launched in India on 11th April 2020. Between 11th April and 4th May 2020, a total of 2216 responses were recorded. Of these, the data of test users and users with identified repetition was excluded to have unique response. This was done by application of filters in the data set using SPSS software. Two filters: IP address and Names were used to exclude the duplicate entries. As a result, a total of 1293 respondents' data is used to analyze the emerging trends and patterns.

The Statistical analysis used SPSS software (IBM Statistics 20) to sort the data and understand relationship between variables using percentages, graphs and Pearson Correlation. The Pearson correlation analysis was used so as to understand the linearity between variables. As observed in [22], the Pearson Correlation can provide understanding on the relationship between variables. The assessment measured the variables of behaviour across different age groups, between variables of behaviour with each other, between social policy and behaviour, between behaviour and exposure, between co-morbidities and age and other different

(a) Low Risk Output

(b) Moderate Risk Output

(c) High Risk Output

(d) General Advisory

Fig. 1. (a) Low risk output, (b) moderate risk output, (c) high risk output, and (d) general advisory.

combinations to understand and quantify the relationship of variables. Pearson's correlation coefficient was calculated to compare quantitatively the similarity between tow variables and to indicate quantitative discrepancies in the similarity. Pearson's correlation coefficient (ranging from −1 to +1) is a measure of the strength of the association between the two variables. A value of +1 is the result of a perfect positive relationship between these variables. Annexure-2 presents a summary of the results obtained from applying the correlation coefficient for different variables. The correlation coefficient is studied as per [24]. If the coefficient value lies between ±0.50 and ± 1, then it is said to be a strong correlation. If the value lies between ±0.30 and ±0.49, then it is said to be a moderate correlation. When the value lies below ±0.29, then it is said to be a weak correlation. There is no correlation when the value is zero.

3.3. Data collection strategy

A spoke and wheel propagation strategy were adopted for disseminating the tool. The tool was shared with various groups through WhatsApp, Facebook and through personal networks over email. Further, it was requested for the users to share it further within their own networks. The featuring of the tool on International Science Council and GDFRR Newsletter gave it wider audience and credibility.

3.4. Limitations

The limitations of the study pertain to limited sample size of analysis with 1293 samples. Further, the data from the survey tool may not be equally represented from each state, thus giving partial spatial analysis. The study uses the weighted variable to understand trends and patterns in place of absolute numbers. This is because the tool is meant to categorise risk based on the information and not for the survey as a primary objective.

4. COVID-19 risk assessment tool in India and key findings

The COVID-19 Risk Assessment Tool has been promoted and widely used in India. India, the second most populous country, currently has 90,000 active cases of the COVID-19 as on May 15, 2020 [20]. The string of measures taken by the Indian government have so far proved successful in containing the spread of the disease. A timeline series analysis of the measures and increase in cases is as given in Fig. 2 below. As observed, despite the strict measures, the cases of affected patients are still on a rise.

A total of 2216 respondents used the tool across various States in India between its launch and 4th of May 2020. A majority of the respondents fall in the age group of 10–39 followed by 40–49. This is possibly due to the access to mobile phone usage being especially high among the youth and young professionals (Table 4).

It is observed that 93% entries filled for the COVID-19 Risk Assessment Tool have been done by using mobile phone device. This is mainly attributed to ease of use of mobile phone and circulation of the Risk Assessment Tool through social media messages. As per Telecom statistics report of TRAI (Telecom Regulatory Authority of India), India's active mobile users reached 1026.37 million in 2018 [25,26].

Further, it suggests that the tool can thus be possibly enhanced as a mobile based application owing to the vast use of mobile phone devices. The mobile based application and a greater number of users would aid to crowd-sourcing of vital details to map the high-risk areas. The number of entries from foreign countries is 12.5%. This implies that the Tool has wide application where one can use it not only in India but also by Non-Resident Indians (NRIs) keen to check on the status of their friends and families in India. In addition, the tool can be used to take multiple surveys for family members who stay distantly. This is applicable to aged population who are not technology savvy and would need assistance of their children or other family members to fill up the survey.

As per ECDC [27], there is an increased mortality rate among males in comparison to females as have been observed among the COVID-19 patients. From the analysis of the data, only 12 people among the respondents featured in high risk and 11 of them are male, and one being the other gender. The findings are consistent with immune system variance among male, female and other gender [35]. The other gender has high risk due to compromised immune system. Further, 585 respondents fall within the medium risk category. Within this category also, the total constitution of men and other gender stands at 91%. The third category i.e. low risk has 696 of the respondents. Within this category the percentage of men stands at 68%. Thus, it re-establishes that females are comparatively at lower risk as they do not feature in high-risk category and in moderate risk also their percentage is only 9%.

Within the high-risk category, all the respondents are found to be above the age of 60 years. As per [ibid], the risk increases with an increase in age as observed in cases from China and South Korea. For Germany, Italy and Spain, the crude-case fatality increases particularly after the age of 60 years. However, there is an exception, where there are three cases in the age-group of 0–9 who fall under the medium risk. This is largely due to their residential type of an informal settlement and low compliance on behaviour factor of wearing mask, handwashing and sanitizing hands before touching face. Further, there are three cases of individuals aged 80 years and above falling in medium risk. This is attributed to higher compliance of behavioural factors and low co-morbidity score.

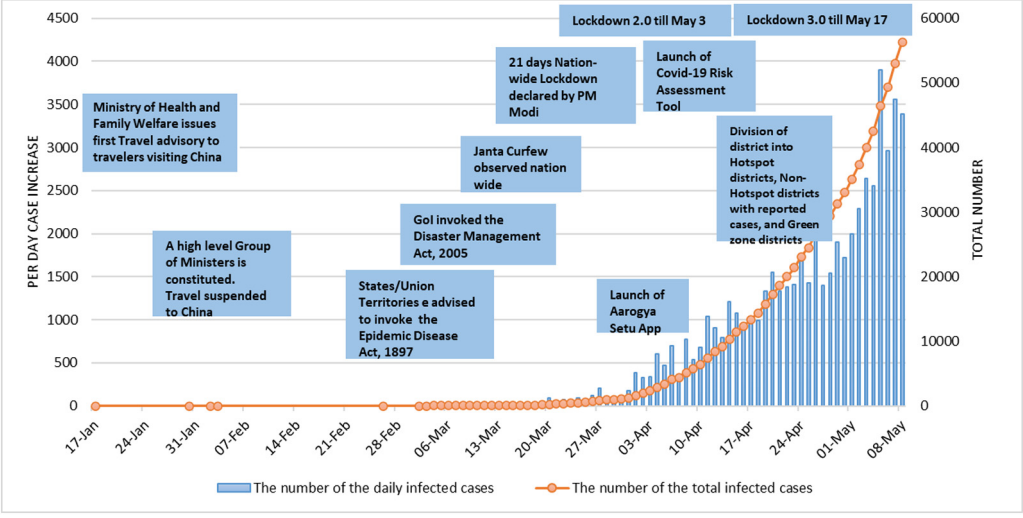

Fig. 2. Timeline Series Analysis of measures taken in India and an increase in affected cases [21].

Table 4
Descriptive statistics of respondents.

Total number of respondent data considered	
Total number of respondent data	2216
Number of duplicate and test entries	923
Total number of data considered for analysis	1293
Gender disaggregated data	
Number of males	1012
Number of females	272
Others	9
Age-group categorisation	
0–9	5
10–39	853
40–49	202
50–59	126
60–69	62
70–79	38
80 & above	7
Smoking habit	
Number of smokers	205
Co-morbidities	
Cardio-vascular diseases (heart problem)	64
Renal diseases (issues with kidney)	34
Diabetes	125
Respiratory disease chronic obstructive pulmonary disease (emphysema, bronchitis)/asthma, lung cancer	73
Tuberculosis	34
Cancer (in last 5 years) (except lung cancer)	24
Hypertension	164
Risk categorisation	
High risk	12
Moderate risk	585
Low risk	696

Spatially, maximum data entries have been received from the states of Uttar Pradesh, followed by Maharashtra, West Bengal and Gujarat (Fig. 3). While writing this paper, the state of Maharashtra has the highest number of COVID-19 affected cases with its capital Mumbai being the worst hit. Spatial analysis allows to identify areas which have maximum cases of the Covid-19 diseases and also allow the maps which are generated from crowd-sourced data to be more representative in nature.

The findings on the individual behaviour suggest that 89% people use mask and 87% people use sanitiser every time after coming home (Fig. 4a and b). However, when it comes to sanitizing hands before touching eyes, nose and mouth, 63% people are practicing it (Fig. 4c). It is often seen that we inadvertently tend to touch our face while being engaged in other tasks. As per the data reports, social distancing at individual level is being well-followed with 88% complying to it (Fig. 4d). Considering that there is no confirmed cure for the COVID-19 diseases, risk preventive behaviour is the key to mitigate and contain the spread of the disease.

Regarding the question on response to the COVID-19 outbreak, 51% people responded with the need to have new measures to bring it under control (Fig. 5) and 32% people believed that current measures are sufficient to bring it under control. This leaves scope for citizens to provide feedback with suggestions to improve the current measures of response.

With respect to anxiety, as depicted in Fig. 6, within the high risk category, there are 66.66% people who have reported being anxious due to presence of positive cases in their locality (i.e. scoring for Be5 in level 1), within the medium risk category, 36.92% people have reported similar levels of anxiety and within the low risk category, 25.67% have reported to be anxious. This states that there is more anxiety within high risk category people followed by medium and low risk categories.

In terms of effectiveness of lockdown, 75% of people have reported it to be followed with maximum compliance (Fig. 7a). In terms of mask wearing and maintenance of social distancing, 47% reported more than 80% people are following it while % people responded that some people (50–80%) are following it (Fig. 7b). Hence, while effectiveness of lockdown is being ensured, the community level compliance of wearing mask and maintenance of social distance needs to be improved.

With respect to respondent data regarding the type of residence, 40% reported it from detached houses, 30% from high rise complexes, 21% from Mohalla/chawl/shared accommodations and 8% from informal settlements (Fig. 8). As suggested in [28] building types have direct impact on the risk of spread of pandemic. The informal settlements and shared accommodations are at most risk. The high-rise apartments also increase the aggregation of people in less space.

The Exposure component is also measured in terms of occupation type (Fig. 9a). It is observed that maximum respondents (48%) did not fall in high risk occupation types (Medical and emergency professionals). Closely followed are the essential service providers (41%) who are at risk of exposure. Another important variable of exposure is the travel history including use of public transport or chauffeur driven cab and attendance of public meeting, mass congregation or wedding/conference. The 90% of the respondents have not been involved in any of these activities in the last 14 days (Fig. 9b).

Table 5 below depicts the important correlation aspects as observed from the Pearson's Correlation Analysis (Annex-2). The factors of age and co-morbidities has shown a positive and moderate correlation with coefficient of 0.434. As per Divo et al. [29] ageing population tends to be more affected by multiple morbidities. The same result is depicted by a negative

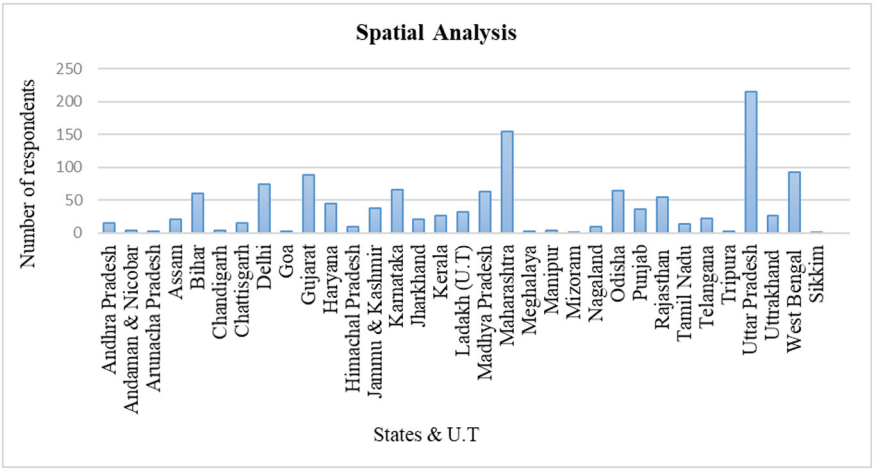

Fig. 3. State wise spatial distribution of respondents (` = 1293).

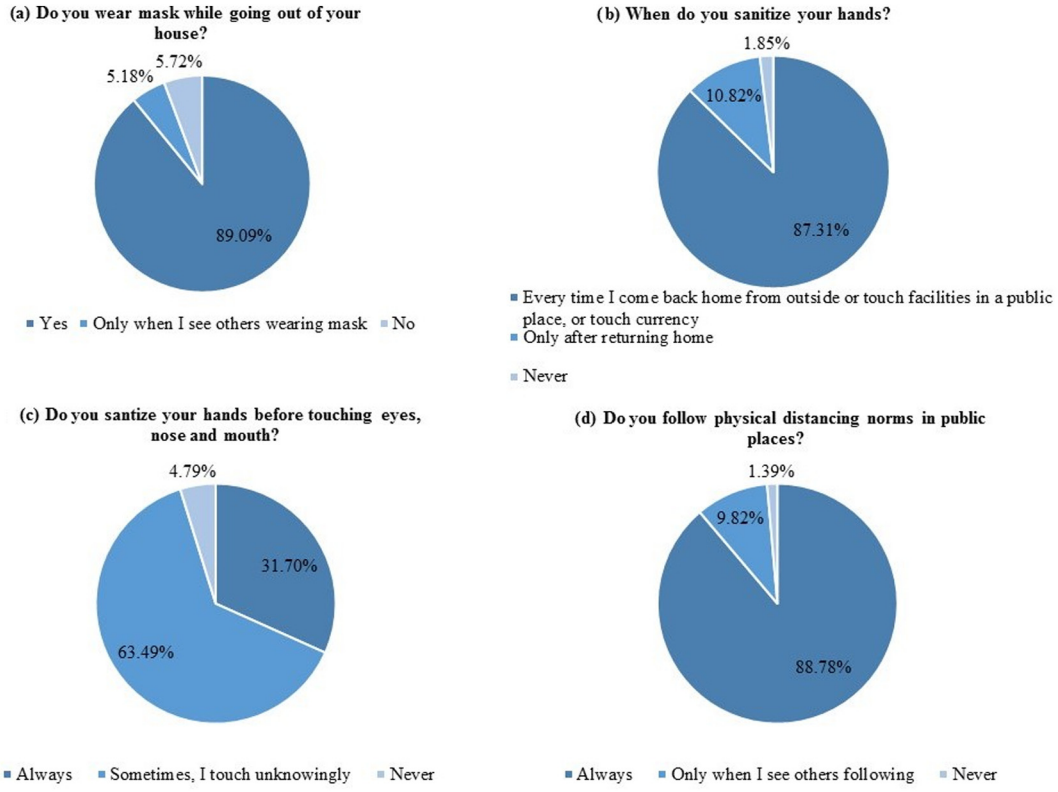

Fig. 4. (a): Use of mask; (b): use of hand-sanitiser; (c): sanitizing before touching face; (d): Social distancing (n = 1293).

correlation coefficient of −0.420 age-group with no disease factor. This relationship between age-group and co-morbidities is an important risk factor for Covid-19 disease too as it places the elderly population with existing disease at a higher risk of mortality. As observed, the age-group and total risk depict a strong positive correlation with coefficient of 0.835. Similarly, co-morbidities and total risk also have strong correlation with a coefficient of 0.678. Within the co-morbidities, hypertension stands-out most with a moderate positive correlation of coefficient 0.418. Diabetes also has a moderate positive correlation with a coefficient of 0.400. This means hypertension and diabetes are two important factors which increase the overall health risk. The tool gives maximum weightage to health factor in assessing the risk and this is also shown with a strong positive correlation coefficient of 0.98 between health and total risk.

With respect to individual behaviour, wearing of mask and following of social distancing norm has a weak correlation with a coefficient of 0.298. This depicts that while one may practice social distancing but might not comply with mask wearing or vice versa. However, washing hands and compliance of social-distancing has a slightly higher correlation coefficient of 0.364. The gender and behaviour show negligible correlation with a coefficient of 0.017 which means behaviour factors are not dependent on gender. Similarly, age-group and behaviour have negligible correlation with a coefficient of 0.048.

The study [27] states the need to reduce smoking as a possible preventable determinant of the Covid-19. Hence, the tool places smoking habit at a higher risk and as observed from correlation coefficient of 0.302, there is a moderate positive correlation between smoking and total risk.

There are two components considered in social policy factor: effective lockdown and community compliance of wearing of mask and practicing social distancing. Ideally, the two factors should have a strong positive correlation. However, as observed, there is a positive moderate correlation with a coefficient of 0.363 between the two factors. Further, the social

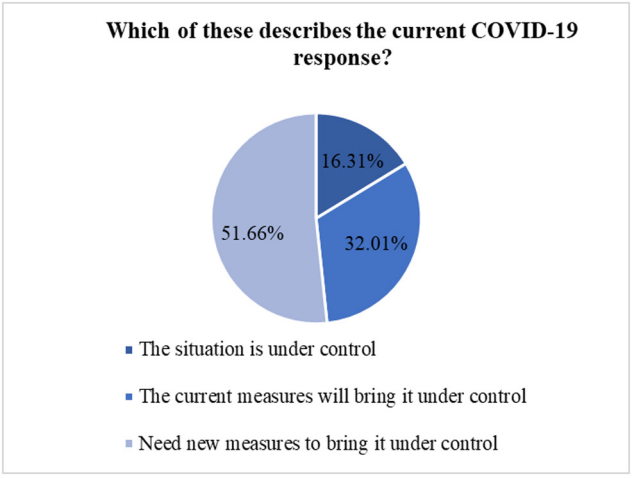

Fig. 5. Description of current measures (n = 1293).

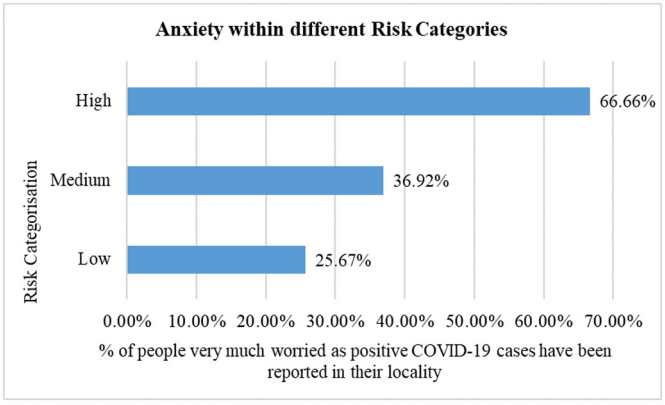

Fig. 6. Anxiety within different Risk Categories (n = 1293).

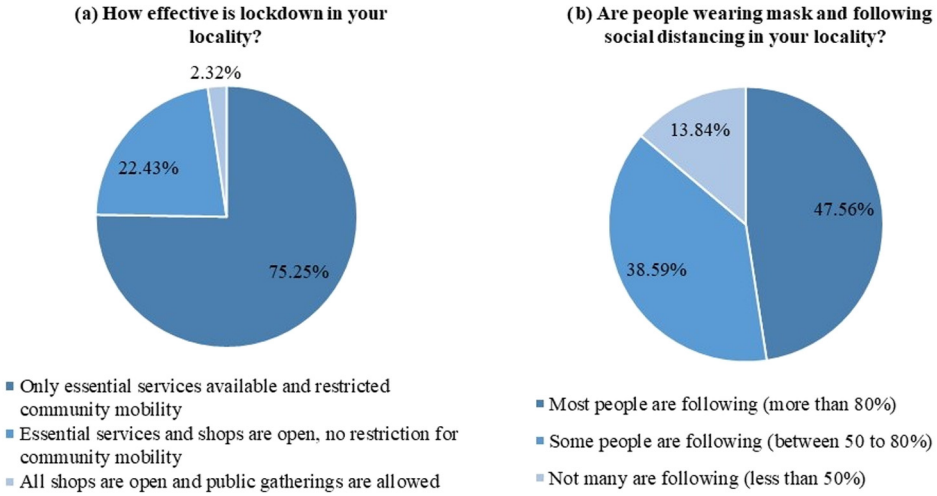

Fig. 7. Social policy compliance: (a) effectiveness of lockdown, 7(b) wearing mask and social distancing in locality (n = 1293).

policy and individual behaviour also depict a positive and moderate correlation with a coefficient of 0.266.

5. Discussion

Effective risk communication measures can result in increasing the awareness and creating social trust in the authorities [30]. Providing the right information can result in risk preventive behaviour and enhance risk governance mechanisms [ibid]. The COVID-19 Risk Assessment tool is aimed at awareness generation, risk communication and aiding in decision-making. As per Lin et al. [23], increase in information gathering with respect to google searches on hand-washing and wearing masks correlated with lowering the speed of COVID-19. The role of technology has emerged as of great importance in emergency management specially for risk communication. The important issue is how the technology can be used with proper governance mechanisms so as to enhance the capacity of the decision-makers in government set-up. The study has shown that the risk assessment tool is majorly being used via mobile devices and can thus be possibly enhanced as a mobile based app. Further, as per Silver et al. [31] the younger population are more likely to own a phone than the adults. This also features in the higher number of entries received from the age-group pf 10–39 than the other age-groups.

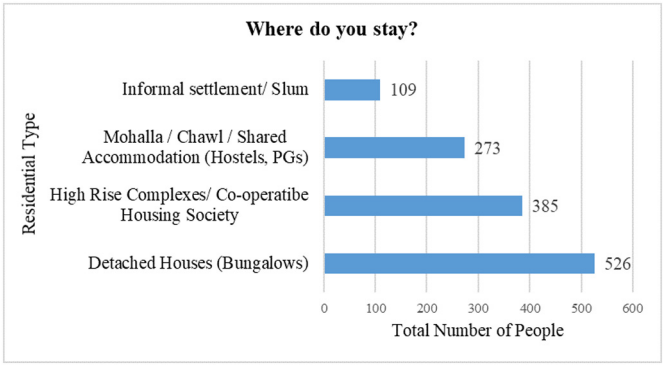

Fig. 8. Exposure based on residential type (n = 1293).

The study has re-iterated the characteristics of the COVID-19 pandemic as mentioned in [1] by showing strong correlation of total risk with age and co-morbidities. In terms of co-morbidities, hypertension followed by diabetes has appeared to be major factor in adding to the total risk. As per Sivasubramanian et al. [32], there is a high prevalence of hypertension, with almost one in every three Indian adults affected. In addition to it, smokers are found to be more at risk with a moderate correlation between smoking and total risk. This finding corroborates with the study in [27] which portrays smoking as a risk factor contributing to the COVID-19 fatalities. In terms of gender, males remain more susceptible than female in high risk category. Anxiety in general has appeared as a major cause of concern

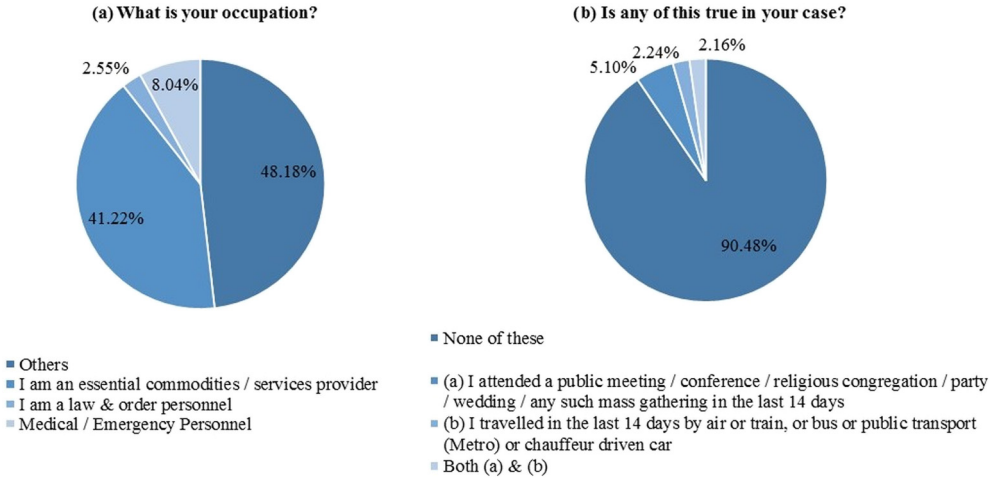

Fig. 9. (a): occupation type, (b): travel and public event attendance history (n = 1293).

Table 5
Pearson correlation analysis ($n = 1293$).

Variables	Strength of correlation	Pearson correlation coefficient
Age-group and Co-morbidities	Positive and moderate correlation	0.434
Age-Group and No disease	Negative relation with a moderate strength	−0.420
Age-Group and Total Risk	Positive and strong correlation	0.835
Wearing of mask and following of Social Distancing norm (Individual behaviour variables be1 and be4)	Positive and weak correlation	0.298
Washing hands and compliance of social distancing norms (Individual behaviour variables be2 and be4)	Positive and moderate correlation	0.364
Co-morbidities and Total Risk	Positive and strong correlation	0.678
Co-morbidities and hypertension	Positive and moderate correlation	0.418
Co-morbidities and diabetes	Positive and moderate correlation	0.400
Gender and Behaviour (be score - all four individual behaviour variables)	Negligible correlation	0.017
Age-Group and Behaviour	Negligible correlation	0.048
Gender and Health (health score accounting all variables of health factor)	Positive and moderate correlation	0.346
Total Risk and Health Score	Positive and moderate correlation	0.983
Smoking and Total Risk	Positive and moderate correlation	0.302
Social Policy Variables- Sp1 Effective Lockdown and Sp2 Community compliance of wearing mask and social distancing	Positive and moderate correlation	0.363
Social Policy Score and Behaviour Score	Positive and moderate correlation	0.266

and adequate mental health counselling measures are needed to be in place especially in areas where cases have been detected.

As the paper states, the COVID-19 Risk assessment tool goes beyond the medical symptoms and considers factors of individual behaviour and social policy. In this regard, it is observed that there is a weak correlation between individual behaviour and social policy. Also, there is weak correlation between individual behaviour of wearing mask and practicing social distancing. Cheng and Kwang [6] states the importance of social behaviour in contribution to the risk of contracting the disease as observed in the case of SARS. Thereby, a weak correlation between individual behaviour and social policy compliance depicts a gap in the governance and implementation mechanism. This implies that there is a need for more awareness generation among community. Since a major part of response of pandemic depends on culture and citizen behaviour [19], the decision-makers need to design targeted intervention policies for creating the risk preventive behaviour and increasing the community compliance of the social policy measures. The finding regarding the lower age group (0–9 years) being in moderate risk category depict that there is a need to educate children about touching the face without sanitizing their hands as they might do it more frequently than adults. Further, children specific risk communication means can be developed so as to ingrain the preventive behaviour. As noted in [33] people's behaviour is influenced by social norms: what they perceive that others are doing or what they think that others approve or disapprove of. Risk perception can be changed by promoting public messages reinforcing positive health-promoting norms[ibid]. Public knowledge of risk allows for change in perspective and more social compliance in terms of adoption of risk preventive behaviour. The interventions can focus on targeting well-connected individuals and making their behaviour change visible and salient for others to copy.

As only 8% people have responded from informal settlements, this depicts a wide gap in digital divide in the country. Many of the respondents living in informal settlements reflect the bottom most layer of the social and income structure. Inequalities in access to resources affect not only who is at greatest risk of infection, developing symptoms or succumbing to the disease, but also who is able to adopt recommendations to slow the spread of the disease. Such communities may be more likely to be wary about the public health information they receive, less willing to adopt recommended safety measures and potentially more susceptible to ‘fake news’[ibid]. In this regard, community-oriented tools of risk awareness need to be more popularized so that risk communication reaches the last mile. Tashiro and Shaw [19] mentions a human-centric society where technology connects people and tries to reduce the barrier of digital divide. The COVID-19 Risk Assessment Tool is multi-lingual tool which helps the communities to access the advisory and understand the individual risk in a simplified way. This is particularly helpful for migrants who need to understand the risk in their own language. Citizens might also be wary of using the government supported tools and apps for the concerns of privacy. Lack of national data privacy laws and non-transparency in governance of such data collected are some of the issues flagged by people as part of resistance to use the Arogya Setu app of Government of India [34]. RIKA's COVID-19 Risk Assessment Tool addresses the concern by not collecting any personal data like mobile number or accessing the location history of the user.

Artificial intelligence has been used for emergency data management, especially for managing social networks and big data. The people are using digital technologies to support disaster management. Crowdsourcing is helping to add vital details to maps of disaster areas. Citizen science is becoming more popular and effective before, during, and after disasters. Grassroots or demand-driven innovation has been practiced in many countries in recent years. In this aspect, the COVID-19 Risk Assessment Tool presents itself as an innovative approach of using science and technology for enhancing community preparedness. The crowd-sourced data and maps generated allow the stakeholders like Government agencies and NGOs to plan the response and interventions. The Risk Assessment tool is flexible and it has a simple user-interface. This allows it to be contextualised to cater to any target community with specific need. This adaptability of the tool places it as a unique innovation coming from the citizen science approach. The two-way data interface in the form of feedback mechanism provides platform for participation of citizens in decision-making for the response strategies. As observed from findings, 51% people have marked for the need of new measures to control the pandemic. This paves way for a more participatory approach for the decision-makers in planning an intervention at the local level. To re-iterate Shaw et al. [1] the pandemic is global but the response is local, this tool allows for a more contextualised and community specific response.

6. Conclusion

While writing this paper, the number of affected cases in India is still on a rise while countries like Singapore, South Korea, China and a few other are expecting a second wave of pandemic. In this backdrop, the preventive measures need to be strengthened at all costs and citizen's behaviour as has been seen in South Korea and Japan is an important factors to break the chain. For a populous country like India, where it is difficult for the current health infrastructure to accommodate and treat an exponential increase number of the patients as had been seen also in Italy, China and United States of America for treatment, it is best to follow the preventive strategies. RIKA's COVID-19 Risk Assessment Tool can be used to reach the last mile community, ascertain the individual behaviour, social compliance and exposure factors in order to find out relevant areas of intervention and at the same time increase awareness generation among the community. As rightly pointed out by [4], the management of COVID-19 pandemic is interwoven within the global governance, technology and risk communication. This pandemic is witnessing a change in the social norm and a new normal

is being established. This is also an opportunity for new innovative technologies to break the digital divide and increase the resilience of the most vulnerable communities through democratic information access and participatory decision-making to develop a local level response strategy.

CRediT authorship contribution statement

Ranit Chatterjee: Conceptualization, Methodology, Writing - original draft, Writing - review & editing. **Sukhreet Bajwa:** Formal analysis, Writing - original draft, Writing - review & editing. **Disha Dwivedi:** Formal analysis, Writing - original draft, Writing - review & editing. **Repaul Kanji:** Methodology. **Moniruddin Ahammed:** Investigation. **Rajib Shaw:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pdisas.2020.100109.

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