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Mathematical Description of Social Distancing to Prevent Transmission of COVID-19 between Human to Human

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ABSTRACT

Social distancing is one kind of preventative measure to reduce the spread of COVID-19. COVID-19 transmits mainly from one person to another during close contact for a prolonged period. Different types of preventive measures like thermal screening, social distancing, hand sanitization, office sanitization, building sanitization etc. are taken by an organization for smooth functioning of the organization. Implementation of social distancing in the organization is really a challenging task. Some work is done by the group of people and some work may be done by the individual. In some cases symptom of COVID-19 is shown but it in some cases its symptoms are not shown. Recent studies indicate that people who are infected but do not have symptoms likely also play a role in the spread of COVID-19. Social distancing helps the limit opportunities to come in contact with infected person and contaminated surface in an organization. The challenging task is taking decision in implementing social distance among employee in the organization. Organization may use different types of sampling methods to check the performance of employee or organization after introducing social distancing in its institution. In the present paper the authors will try to explain the importance of social distancing in mathematical way to combat COVID-19 transmission.

Keywords : COVID-19, Social distancing. Employee, Organization

I. INTRODUCTION

A Corona Virus is a kind of common virus that causes an infection in our nose, sinuses, or upper throat. Most corona viruses aren't dangerous. In early 2020, after a December 2019 outbreak in China, the World Health Organization (WHO) identified SARS-CoV-2 as a new type of Corona Virus . The outbreak quickly spread around the world.COVID-19 is a disease caused by SARS-CoV-2 that can trigger what doctors call a respiratory tract infection. It can affect our upper respiratory tract (sinuses, nose, and throat) or lower respiratory tract (windpipe and lungs). It spreads the same way other corona viruses do, mainly through person-to-person contact. The infection range from mild to deadly. SARS-CoV-2 is one of different types of corona virus, including the ones that cause severe diseases like Middle East respiratory syndrome (MERS) and sudden acute respiratory syndrome (SARS). The other corona viruses cause most of the colds that affect us during the year but aren't a serious threat for otherwise healthy people.

Corona virus disease (COVID-19) is an infectious disease caused by a newly discovered corona virus. The virus is primarily spread between people during close contact from infectious person to healthy person in different way. Small droplets produced by coughing, sneezing and talking are major recourses in spreading the virus. The droplets may fall to the ground or onto surfaces. There are different preventative measure are taken to reduce the transmission of infection. At this time, there are no

specific vaccines or treatments for COVID-19. However, there are many ongoing clinical trials evaluating potential treatments. People are taking different steps to minimize the transmission rates of covid-19. Hand sanitization, social distancing and wearing mask are precautionary measure taken to reduce the spreading of corona virus. Social distancing measures are taken to slow down the infection rates. Experts agree that the COVID-19 outbreak cannot be stopped, but that it can be slow down through the implementation of social distancing measures. The term social distancing have emerged as an important word to minimize the outbreak of Covid-19.Social Distancing means keeping some minimum required space between one people to other people. Social distancing is also called physical distancing in which two people will stay at least 6 feet(about 2 arms length).Any person of society should not gather in group and also it is require to stay out of crowded places and avoid mass gatherings. Social distancing, self-quarantine or isolation is used to prevent the spread of Pandemic COVID-19.Generally, self-quarantine or isolation is being utilized to minimize the corona virus spread. Major difference is related to some restriction. A quarantine or isolation restricts the movement of people within a certain area or zone to minimize the transferring and spreading of infection. But Social distancing places no such location constraints, rather it is a human behavioural practice to maintain some required minimum distance to lower the risk in most circumstances. Aim of social distancing is to prevent disease transmission from sick people to healthy people. Social distancing is applicable for individual person or large- scale people. Individual people can take decision to avoid crowds whereas large-scale people can cancels group events or close public spaces. But when an organization runs their company, the role of each employee plays an important role. In some cases employee can work by maintain social distance but some employee cannot do so. Based on the work culture of employee some case studies have made where it is discussed about different types of architecture of working methods during social distancing phase. Implementation of social Distancing in an organization can give better result to minimize the pandemic of COVID-19. But there exist some positive side and negative side with respect in working environment. The positive side is that employee of organization will prevent the spread of COVID-19, but the negative side is that not every type of work can be done remotely. However, it is not a clear that how an organization will implement the social distancing methods to get its profit. So an organization needs to study sampling and testing of hypothesis methods to study regarding its performance during social distancing.

CASE STUDY OF DIFFERENT TYPE OF ARCHITECTURE IN MAINTAINING SOCIAL DISTANCING

In public health, social distancing, also called physical distancing, is a set of non-pharmaceutical interventions or measures intended to prevent the spread of a contagious disease by maintaining a physical distance between people and reducing the number of times people come into close contact with each other. Minimum distance between two people should be maintained as specified by the competent authority. COVID-19 has succeeded to change of our daily routine or habit. The researcher have done the survey regarding social distance and its impact in reduction of Coronavirus disease (COVID-19) The results from this survey will be helpful to change the lifestyle of human being .The working atmosphere will also be changed in the coming days. COVID-19 cases are rising dramatically and one important factor creating problem as some cases is asymptomatic. So the role of social distancing is important. The importance of social distancing is shown in the following figure:

Figure1 : Social contact and its effect

The usual distance function on the real number line is a metric, as is the usual distance function in Euclidean n-dimensional space. Given a set X and a function d: $X \times X \rightarrow R$, we say that the pair M = (X, d) is a metric space if and only if d (·) satisfies the following properties:

(1) (Non-negativeness) For all x, y ∈ X, d (x, y) ≥ 0
(2) (Identification) For all x, y ∈ X we have that d (x, y) = 0 ⟺ x = y
(3) (Symmetry) For all x, y ∈ X, d (x, y) = d (y, x)
(4) (Triangular inequality) For all x, y, z ∈ X we have that

$$d(x, z) \leq d(x, y) + d(y, z)$$

Social distancing is based on distance concept in which some certain distance should be maintained among two people

Social distance can be defined as

S= infimum {d(x, y) : x,y∈ X}>6 feet or 2 meter or as guideline by Govt.

An organization may take different steps to maintain social distancing. Some case studies have study to implement social distancing in an organization.

A. Social Distancing Among Working Employee In Hierarchical Structure

In an organization social distancing will be different in comparison to normal free space. To maintain social distancing hierarchical organization structure can be created where employees are grouped with every employee having one clear supervisor.

The grouping is done based on a few factors like product, their geographical location and according to function they provide. Here employee is divided into their working category. Each employee will contact with their senior employee only. There is no need to contact with each employee. So here social distancing is maintained.

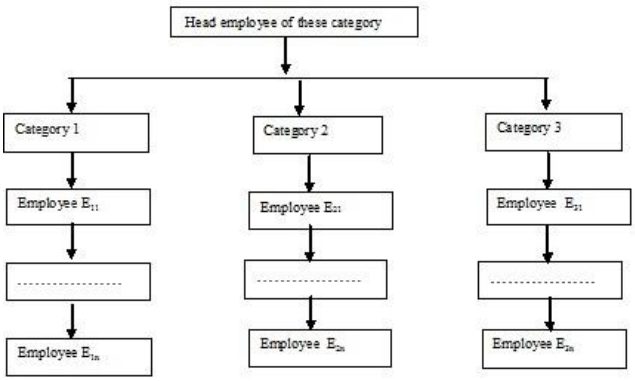

Figure2: Hierarchical structure of employee

B. Social Distancing Among Working Employee In Horizontal/Flat Structure

An organization may divide its works in different flat structure which will be helpful to

Maintain the social distancing among employee. Employee will work in different building or flat. This

concept may be applicable to the employee who is working remotely.

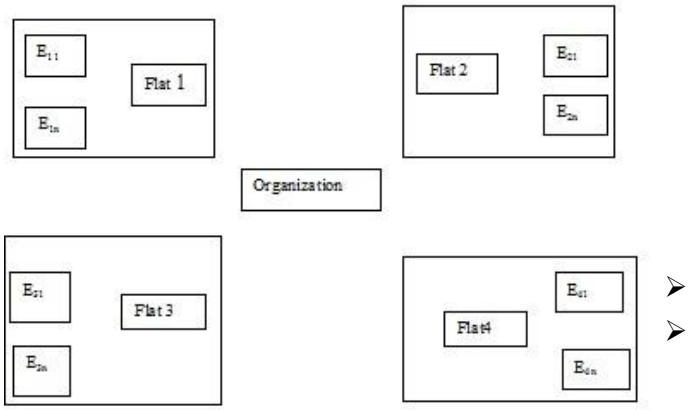

Figure 3: Flat structure of an organization

Example1. Let in an Organization there are finite number of employee represented by set X = {a, b, c, d, e} . Let A_1 = {a, b}, A_2 = {c} & A_3 = {d, e} represents the employee working in different flat structure. Then P = {A_1, A_2, A_3} is a partition of X. The topological structure of combination of employee maintaining social distance on X generated by P is = {Ø, {a, b} , {c} , {d, e} , {a, b, c} , {c, d, e} , {a, b, d, e} , X}.

When an organization divides its employee into flat structure, management may take decision to engage their employee in different flat as the need of organization. But it is really tough task to depute employee on the basis of rotation system for shifting Employee. Organization may take different methods to engage their employee. But here two important methods are given.

a. Combination of Odd-even number Assigned employee and no common employee in any flat

Suppose every employee is map with set of Natural number(N) and their identity are given as E_1, E_2, E_3 E_4,……..,E_n.

Then the employees are deputed in the partition (where each flat is taken as partition).

- When only two employee are deputed in each flat then it may be taken as
  $P_k = \{(E_{(2k-1)}, E_{(2k)}) : k \varepsilon N\}$
- When only three employee are deputed in each flat then it may be taken as
  $P_k = \{(E_{(2k-1)}, E_{(2k)}, E_{(2k+1)}) : k \varepsilon N\}$
- When only m (m<n) employee are deputed in each flat then it may be taken as
  $P_k = \{(E_{(2k-1)}, E_{(2k)}, E_{(2k+1)}, \ldots\ldots\ldots, E_{(2k+m-2)}) : k \varepsilon N\}$.

In this case no employee will contact with other member of partition .i.e. other member of flat.

b. Combination of Odd-even number and some common employee in next flat

Suppose every employee is map with set of Natural number(N) and their identity are given as E_1, E_2, E_3, E_4,……..,E_n.

Then the employees are deputed in the partition (where each flat is taken as partition).

- When only two employee are deputed in each flat then it may be taken as
  $P_k = \{(E_{(k-1)}, E_{(k)}) : k \varepsilon N\}$
- When only three employee are deputed in each flat then it may be taken as
  $P_k = \{(E_{(k-1)}, E_{(k)}, E_{(k+1)}) : k \varepsilon N\}$
- When only m (m<n) employee are deputed in each flat then it may be taken as
  $P_k = \{(E_{(k-1)}, E_{(k)}, E_{(k+1)}, \ldots\ldots\ldots, E_{(k+m-2)}) : k \varepsilon N\}$.

Note: Organization may take different types of combination of employee as per requirement to run the system with maintain social distance.

C. Social Distancing among working employee in matrix structure

In some organization it is possible that employee can work by maintaining social distance but in some organization it is required to work employee in together. Here a matrix form of the combination of employee is given. For maintain social distancing, organization may decide the combination of employee in the following matrix form where

E_{ij} =0 when employee are not working together E_{ij}=1 when employee will work together.

i =1,2,3,…..,m and

j=1,2,3,….,n.

	E_1	E_2	E_3	…..	E_n
E_1	E_{11}	E_{12}	E_{13}	…..	E_{1n}
E_2	E_{21}	E_{22}	E_{23}	…..	E_{2n}
….	….	…..	….	…..	….
E_m	E_{m1}	E_{m2}	E_{m3}	…..	E_{mn}

Fig 4 : matrix representation of employee

In some case organization can maintain social distancing by distributing time work of employee. Organization may decide the combination of employee with time in the following matrix form where

E_iT_j =0 when employee are not working at that time &

E_iT_j=1 when employee will work at that time.

i =1,2,3,…..,m and

j=1,2,3,….,n.

Time / Employee	T_1	T_2	T_3		T_n
E_1	E_1T_1	E_1T_2	E_1T_3	… …..	E_1T_n
E_2	E_2T_1	E_2T_2	E_2T_3	… … …	E_2T_n
…….	…… .	…… ..	……	… … ….	……
E_m	E_mT_1	E_mT_2	E_mT_3	… …..	E_mT_n

Figure5 : matrix representation of employee and time

D. Social Distancing among working employee in network structure

In mathematics and computer science, connectivity is one of the basic concepts of graph theory: it asks for the minimum number of elements (nodes or edges) that need to be removed to separate the remaining nodes into isolated sub graphs. It is closely related to the theory of network flow problems. The connectivity of a graph is an important measure of its resilience as a network.

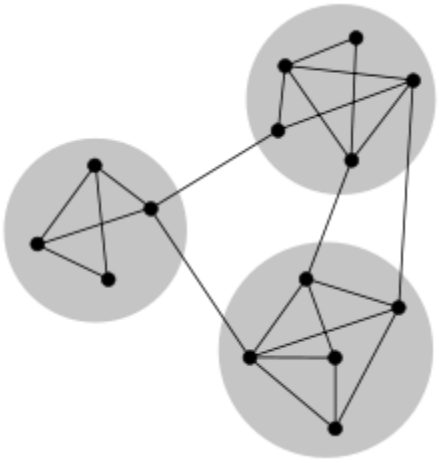

Fig 6 : graphical representation of combination of minimum employee

An organization may develop the combination of minimum number of connecting employee to

maintain social distancing as shown in the above figure.

E. Role of organization towards its employee during implementation of social distancing

1) Awareness program

Organization makes arrangement of awareness program in employee regarding Covid-19. It is responsibility of organization to provide Sanitizer and social distancing system in the premise.

2) Update the employee with latest technology

Organization should arrange some training program to show the importance of IoT based technology like connected thermometers, Smart Wearable, IoT Buttons.

3) Stay in regular touch with employee

Management should take medical information of every employee on each day. Feedback from employee will be helpful to choose the fit employee in work place.

II. PERFORMANCE STUDY OF ORGANIZATION AFTER SOCIAL DISTANCING WITH SOME EXAMPLE.

An organization has to take different types of decision in implementing social distancing among its employee. Going through some statistical analysis of the sample information the validity of the assumption is tested. For example, organization will decide on the basis of the sample data whether social distancing is really effective for the performance of the organization.

Mathematical Definition:

1) Statistical Hypothesis

Any assumption taken on a population, regarding its probability distribution or its parameters, is called a 'statistical Hypothesis'. Such a hypothesis may or may not be true. For Example, let we assume that the mean of a population is 60. Then " =60" is statistical Hypothesis. Drawing samples from this population we can test the validity of this hypothesis and this is test of hypothesis. There are two types of hypothesis:

(a)Simple Hypothesis:

A Statistical Hypothesis which specifies the probability distribution and all related parameters of a population is called simple hypothesis.

(b)Composite Hypothesis:

A statistical Hypothesis which does not specify the population completely is called composite hypothesis.

2) Null Hypothesis

Test of Hypothesis starts with a statistical Hypothesis. A statistical Hypothesis whose possible acceptance or rejection is tested on the basis of sample observation is called a Null Hypothesis. Usually it is denoted by H0

3) Alternative Hypothesis

A statistical hypothesis which is different from the Null Hypothesis is called Alternative Hypothesis. It is denoted by H1

.

4) Both sided Alternative Hypothesis:

Let H0 (0) be a null hypothesis where is parameter. Then the alternative hypothesis H1(0) is called both sided alternative hypothesis.

5) One sided Alternative Hypothesis:

Let H0(0) be a null hypothesis where is parameter. Then the alternative hypothesis H1 (0) is called one sided (right) alternative hypothesis. The alternative hypothesis H1 (0) is called one sided (left) alternative hypothesis.

6) Test Statistics

To test the possible acceptance or rejection of a null hypothesis we have to take the help of a statistics whose sampling distribution is known. By evaluating the value of the statistics whose sampling distribution is known. By evaluating the value of the statistics we decide whether the null hypothesis is to be rejected

or not. This statistics is called Test- Statistics. Parametric tests are used if the data is normally distributed .A parametric statistical test makes an assumption about the population parameters and the distributions that the data came from. These types of test includes t-tests, z-tests and (Analysis of variance (ANOVA)tests, which assume data is from normal distribution.

7) Critical Region

A critical region, also known as the rejection region, is a set of values for the test statistic for which the null hypothesis is rejected. I.e. if the observed test statistic is in the critical region then we reject the null hypothesis and accept the alternative hypothesis.

8) Confidence Interval

A confidence interval, also known as the acceptance region, is a set of values for the test statistic for which the null hypothesis is accepted. I.e. if the observed test statistic is in the confidence interval then we accept the null hypothesis and reject the alternative hypothesis.

9) Significance Levels

Confidence intervals can be calculated at different significance levels. We use α to denote the level of significance and perform a hypothesis test with a 100(1–α) % confidence interval.

Confidence intervals are usually calculated at 5% or 1% significance levels, for which α=0.05 and α=0.01 respectively. Note that a 95% confidence interval does not mean there is a 95% chance that the true value being estimated is in the calculated interval. Rather, given a population, there is a 95% chance that choosing a random sample from this population results in a confidence interval which contains the true value being estimated.

1) Critical Values

The critical value at a certain significance level can be thought of as a cut-off point. If a test statistic on one side of the critical value results in accepting the null hypothesis, a test statistic on the other side will result in rejecting the null hypothesis.

Example: Suppose a person claims that he will arrive to his office in 20 minutes by maintain social distancing in path. In 6 days time taken by the person by maintain social distance are 27, 18, 26,15,20,32 minutes. Can the person claim be accepted?

Solution: Here n=6, let X be the time taken to arrive in the office by maintain social distancing. From given data $\overline{X}$ =average time taken

$$\overline{X} = \frac{27+18+26+15+20+32}{6} = \frac{138}{6} = 23$$

Standard deviation: $s=\sqrt{\frac{\sum(Xi-\overline{X})^2}{n-1}}$

$S^2 = \{(27-23)^2 + (18-23)^2 + (26-23)^2 + (15-23)^2 + (20-23)^2 + (32-23)^2\}/ (6-1)$

$S^2 = 40.8$,

$S = 6.38748$

Step1.Null Hypothesis: X=20 minutes

Step 2.Alternative hypothesis: X>20

Step 3.Level of significance: α =0.10

Step 4.Critical region:

Reject null hypothesis, if $t > t\alpha = 1.476$ where t0.10 with $\vartheta = n-1 = 6-1 = 5$ degree of freedom.

Step 5. Calculation:

$$t = \frac{\overline{X}-\mu}{S/\sqrt{n}} = \frac{23-20}{6.39/\sqrt{6}} = 1.15$$

Step 6. Decision: Accept H0 since t=1.15< 1.476=t0.1 with 5 degree of freedom. i.e. accept the claim of the person.

Example : In a study usefulness of Social Distancing in a production company , a random sample of 16 person undergoing with social distancing were examined with their production before (without

using social distancing) and after (with maintain social distance) the following result

No of production before social distancing	209	178	169	212	180	192	158	180	170	153	183	165	201	179	243	144
No of production after social distancing	196	171	170	207	177	190	159	180	164	152	179	162	199	173	231	140

Test whether social distancing is useful in work performance at 0.01 level of significance.

Let μ be the mean of population differences

Step 1.Null Hypothesis: μ=0 i.e. not useful

Step 2.Alternative hypothesis : μ >0 i.e. social distancing is useful in work performance.

Step 3.Level of significance: α =0.01

Step 4.Critical region: right one tailed test

Reject null hypothesis, if t >$t_{0.01}$ with 16-1=15 degree of freedom. From table $t_{0.01}$=2.602

Step 5. Calculation: difference d_i's are

13, 7 , -1 , 5 , 3, 2 , -1 , 0 , 6 , 1 , 4 , 3 , 2 , 6 , 12 ,4

$\bar{X}$ = mean of differences of sampled data=66/16=4.125

$S^2 = \frac{247.73}{15}$ =16.516

S=4.064

$t = \frac{\bar{X}-\mu}{S/\sqrt{n}} = \frac{4.125-0}{4.064/\sqrt{16}}$ =4.06

Step 6. Decision: Reject null hypothesis since t=4.06>2.602=$t_{0.01}$ .i.e. social distancing is not useful in work performance.

Example: If 57 out of 150 workers working on machines of a company by maintain social distancing and 33 out of 100 workers are working on the same machine without maintain social distance, is there reason to believe that social distance is better than without social distance at 0.05 level of significance.

Solution: Let p_1 and p_2 be proportions of worker are working by maintaining social distance and not maintain social distancing respectively.

Step 1.Null Hypothesis H_0:$p_1=p_2$

Step 2.Alternative hypothesis H_1 : $p_1 > p_2$. i.e., social distancing is superior than not maintain social distancing.

Step 3.Level of significance: α =0.05

Step 4.Critical region:

Reject null hypothesis, if z>1.645 by right one tailed test.

Step 5. Calculation: n_1=150, x_1=57, n_2=100, x_2=33

$$z = \frac{\frac{x_1}{n_1}-\frac{x_2}{n_2}}{\sqrt{\{\hat{p}(1-\hat{p})(\frac{1}{n1}+\frac{1}{n2})\}}}$$

$$= \frac{\frac{57}{150}-\frac{33}{100}}{\sqrt{\{0.36(0.64)(\frac{1}{150}+\frac{1}{100})\}}} = 0.807$$

Step 6. Decision: Null hypothesis cannot be rejected or accept null hypothesis since

Z=0.81<1.645=z_α =$Z_{0.05}$

There do not appear any significant differences at 0.05 levels between the work on doing by maintain social distancing or not.

(1) Example: If 6 out of 20 workers are randomly chosen preferred 'social distancing' test the claim at 0.05 level of significance that 20% worker prefer 'social distancing'.

Solution:

Step 1: Null Hypothesis: H_0 : proportion of workers preferring social distancing= p=0.2

Step 2: Alternative Hypothesis: H_1 : p≠0.2 Step3: Level of significance α=0.05

Step 4: Test statistics: Let X is the random variable which is the number of social distancing user with p=0.2 and n=20.

Step 5: computation: X=6, np_0= (20) (0.2) =4

Since X=6> np_0=4

P=2[probability that X≥6 when p=0.2]

=2P(x≥ 6 with p=0.2)

$=2[1-\sum_{X=0}^{5} b(X; 20,0.2)]$

=2[1-0.8042]

=2(0.1958) =0.3916

Since P=0.3916 >0.05, accept H_0 i.e., p=0.2.

III. ADVANTAGE

The lifesaving benefits of strict social distancing rules during the corona virus pandemic will make significance changes in human life. Social distancing will be helpful to save lives and the working environment in family, society and in any institution or organization will change. The overall working structure of company will be changed. In some cases, methodology used by the company may be acceptable in the sense of profit and in some case it may be reject able. Sampling and testing of hypothesis will be helpful to take decision for the company. A rapid assessment, based on the best currently available information, with the help of testing of hypothesis will help the organization to prepare the better policy decision in implementing social distancing.

III. CONCLUSION AND FUTURE SCOPE

Social distancing measure will reduce the average contact rate among individual. It will be helpful o reduce the peak of the infection curve. It is required to study to the different types of methods to implement social distancing so that an organization may get maximum profit and will be able to tackle the impact of Covid-19 pandemic. In this paper some methods of implementing social distancing have discussed .Also some example is taken to show their performance in organization with the help of testing of Hypothesis. There exists scope to implement social distancing with different methods in future to get optimum profit.

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