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Dynamic Visualization and Analysis of Government Responses-A Support System to Control Pandemic Situations

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Abstract: Covid 19 has focused the world's attention on health care facilities across the globe. Data modeling is a latent contributor for dynamic assessment and reporting/analyzing in distributed research networks. During our research, it was found that without demonstrative data, data sharing among subgroups focusing on various policy-making classifications, discoveries, and predictions become problematic and inefficient. The dearth of illustrative pandemic data (COVID-19) is a holdup for showcase and deliberate potential solutions. The realization of data for pioneering new technology in clinical healthcare systems and designing government decision support systems to help fight novel coronavirus is crucial. Dynamic graphs are a potential tool that aids in the dynamic assessment of country-wise policy data at a given point of time and is extremely significant for estimating public health measures and stringent policies. In the present research, the openly accessible Oxford's COVID-19 Government Response Tracker (OxCGRT) dataset is used. The OxCGRT is counting statistics from more than 180 countries, it enables the investigators and officials to explore the pragmatic outcomes of policy responses on the accelerating spread of COVID-19, in addition to financial and communal welfare. The stringent policy index and Containment and health policy index is observed for the 11 Countries across the world with the highest occurrence of cases. This assortment of the sub-group countries reduces the complexity and upsurges the representativeness of data with respect to the model policy indicators.

Keywords: Dynamic Graph, Covid-19, Government Responses, Policy Indicator, Social Network.

1. INTRODUCTION

A dynamic graph is a method of representing time series network which represents vertex as entity and an edge between two vertex represents relation between them. The weight of edges represents strength of connection. The entities and their connections are dynamic i.e., varies with time. Using the dynamic network approach, the study explores the characteristics of the network structure for the countries round the globe and their relative policy responses in retort to the COVID 19[1,2]. The dataset demonstrated in the present research is extracted from the Oxford's COVID-19 Government Response Tracker (OxCGRT). OxCGRT collects the statistics through a sequence of four policy indices, namely-Overall government response index • Stringency index • Containment and health index • Economic support. These indices allow the competent and unpretentious across realm assessment of administration involvement in handling the pandemic situation. The current research explicitly emphasis on two extents of OxCGRT dataset – one is stringency index, and another is Containment and health index. Oxford University establishes, the "Stringency Index" that computes the actions instigated by the authorities and administrations across the globe to tackle the current challenging condition. Whereas, the "Containment and Health index" computes the lockdown restrictions and specific health trials in the process of testing policy, investment in vaccine etc. treaded up by the authorities.

The knowledge behind the assortment of these two indices – as the world is facing an economy downtown, Covid 19 has focused everyone's attention on healthcare and investors' attention on companies in the health sector. Different sub-sectors are experiencing different impacts-for example, there is a major increase in drug call as patients are more concerned about the health as well as the demand is anticipated to increase in future also [3,4]. How

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authorities will adapt these healthcare challenges and forthcoming difficulties will determine how rapidly countries economy will get recovered.

This graphical design is intended to persuade added exhaustive study [5] and to reveal the potential for legislators, scholars, inventors and investors to address significant public policies and epidemiological queries using OxCGRT data. The study epitomizes a government response network that assists in understanding the discrepancy consequences of policy indices on government response index specifically on - health sector parameters. The designed network comprises of nodes (countries and policies) and edges (indices value of each policy), the premediated network is further visualized and analyzed through the support of standard Gephi software. The contribution of the present research work can be summarized as: -

The research is among the first to present a visual dynamic approach to assess the two major dimensions-stringency factors and health and containment factors across the globe for COVID-19 pandemic. However, paper further presents a comparative analysis of customized government policies towards the specific nations like-China, Indonesia, Malaysia etc. The prime focus of the research is to evaluate the common factors that are shared by majority of nations and need to be addressed in the pandemic situation. The usage of dynamic graphs provides a visual dynamic approach that further helps to develop more precautionary measures, cures and solution strategies.

Primarily, it starts with the Visualization of disparity in government response network in accordance to the time variances. Further the research moves towards the comprehensive Analysis of the shaped network grounded on the policies indices and government indexes. The subsequent vital step is to identify the patterns that helps the effect of vaccination policy in refining the government response index. The paper is organized as follows: Section 2 consists of literature survey that covers the background and related work of the considered domain. It also covers the comparative analysis of relevant work to present research. Based on which, the main objectives behind this work are also specified in this section, that are well formulated in form of questions. Section 3 describes the workflow of this study which addresses the data elicitation part, covers pre-processing and conversion of data to be observed that forms the prerequisite for the process, enlightens the network formation and generation of time series network respectively. This section also covers visualization and analysis of dynamic network for conceptualizing the dynamic data and scrutinizing of the network in response to the addressed questions. In section 4, the attained results are presented and discussed established on the objectives of the study. Finally, section 5 covers the conclusion that summarize the discussion.

2. LITERATURE SURVEY

World is fighting with two battles simultaneously; one is against pandemic or health sector deficiencies and other is against the slowdown of world's economy. Innovative reforms need to be ensured in healthcare sector like consulting doctors across the country. History shows, innovation thrives during time of crises - take the financial crises of 2008 which led to the wide spread option of cloud computing. The cloud happens around early 2000 but it gained a new footing as the economic slowdown took place. As well as accelerating the adoption of technologies, crises can also foster the development of new ideas like at the time of second world war, digital computers, jet engines etc. are invented nuclear technology for nuclear weapons.

The pandemic is accelerating, as of mid-May 2021, the novel coronavirus disease (COVID-19) has triggered the contamination of about 160,813,869 people and accounts for more than 3,339,002 deaths (WHO, 2021).

A stringent lockdown is consigned by many countries. In the primary stage of covid-19 outbreak, countries like India, China, France, Italy etc. had imposed the strictest lockdown that is further relaxed outside the red zones. As per the data, Spain imposed strictest measures much later in its case and death count than all others. Sweden maintained the most liberal measures in this set, and Iran the second most liberal [6].

Although lockdown is an immediate solution, but the livelihood of the family's needs to be safeguard, there must be a return to normality. Due to the financial crises, few states and authorities abandon policies like ban on transportation, closing business and mass confinement [7,8].

In 1980s when neoliberalism, spread across the world private enterprises and open market became economic buzzwords while government reduced their roles as regulators this implies the major countries across the world in health care sector plays as per the free market rules, relying highly on Intellectual Property Rights (IPR) to guard their products. Lifesaving drugs are expensive and because of IPRs their formulations could never be shared. This becomes a bottle neck for multilateral organizations like WHO to operate and formulate a global plan to handle the current pandemic situation.

In 2020, when pandemic hits the world WHO created a COVID-19 technology access pool (C-TAP) to share knowledge with manufacturers of developing countries, but no companies signed for it they simply don't want to violate IPR.Exactly how many years it needs to nullify or handle the current pandemic situation entirely, depends upon the behaviour of the people and on the policies formulated by the countries across the world. During the research, it was discovered that there is a scarcity of global proposals for handling the pandemic situation. Many nations specific proposals were found stating their explicit

complications along with the measures that their government took to handle the situation. Table 1 presents the comparative analysis of some relevant to the present research.

TABLE I. COMPARATIVE ANALYSIS WITH RELEVANT RESEARCH

Countries	Purpose	Methodology	Findings	Research limitations
China [9,10]	To state the association amongst trust and preventive measures taken by government during the pandemic.	Data from 3000 Chinese adults conducted using quota-sampling method.	The constructive association between Government trust and excessive precautionary behaviour was found to be statistically substantial.	Trust is the only emotion analysed among the people with less knowledge and people with less negative emotion for evaluating the preventive behaviour during COVID 19.
Indonesia [11]	Etymological behaviour of the government is analysed to improve the confidence and self-esteem of the citizens	Positive Discourse Analysis (PDA) is reformed for communal variations through resistance discourse	Authorities made use of submission, predication, argumentation and mitigation policies to improve community 's optimism	Not talks about the government strategies at root level.
Malaysia [12]	To induce the familiarity levels, attitudes and practices toward pandemic midst the Malaysian public.	a quantifiable, cross-sectional survey was estimated for the Malaysian background. Online data gathering using the Inspection Monkey platform.	Efficacious control of COVID-19 is found (83.1%), the way the Malaysian government was handling the crisis (89.9%).	The cross-sectional online survey was conducted for 27th March and 3rd April 2020 only
Ethiopia [13,14]	Evince data on the - Public knowledge, Attitude, and Practice (KAP) is gathered to testify the response of the service providers in Addis Ababa, Ethiopia	self-govern opinion poll and observational taxation using a specification. For statistical analysis SPSS version Evocative information, association quantity and chi-square tests were performed.	More than 60.7% of the contributors had a positive attitude towards preventive measures by authorities. An optimistic correlation between knowledge and attitude is found.	Severity policies are explored. However, inhibition and healthiness index are yet to be revealed
Yogyakarta [15]	To reconnoiter the grounding of government policies towards the revitalization of economy in the form of Micro, Small and Medium Enterprises (SMEs) after Corona Virus Disease	A expressive investigation method of principal and subordinate data attained from field survey and publication sources	Business Model Canvas (BMC) becomes an applied and apposite substitute for economic reform.	This study is focused on stringency factors like - social distancing and physical distancing
Macao [16]	How government or policymakers might lessen the harmful impressions of pandemic and to classify operative policies for crisis management.	Both qualitative exploration and archival research method is used for eliciting primary data from the stakeholders and secondary data on the pandemic facts	crisis administration approaches to lessen devastation were organized based on - suitable procedures, opportune choices and the role of the government.	Sample size is mainly focussed on the people associated with gaming and financial institutions only

Therefore, to get an insight on how the policy indicators varied with respect to time and how these variation affects the government responses, we analyze the dynamic network based on questions as follows:

- RQ-1-What will be the effect of disparity in policy indices on the country wise stringency index?
- RQ-2-What will be the effect on country wise containment health with respect to these policy Indices?
- RQ-3-Significance of each policy and what will be their effect on the prevention of complete lockdown?
- RQ-4-Effect of vaccination policy in improving government responses to Covid-19?

A. Why dynamic graphs are used??

From decades, modelling is extensively used in defining the finest approaches or policies for the moderation of the influence of infectious viruses. Presently, the demonstrating of a composite structure for instance the outburst of COVID-19 contagion is amid the contemporary issues. The upsurge of the infectious diseases is at the prime attention of the world municipal and plays a critical role in decision making [17,18]in almost every sector i.e. public health sector, innovation sectors, industrial sectors or educational sectors etc. Apart from all disaster created by Covid -19, There is a less familiar story that the crises are boosting innovation with the emergence of brand-new ideas like mRNA vaccine, drone deliveries a new technology and with application of old ones with surprising new ways. The crises have turn out to be an acceleration of adopting technologies and new lessons to be learn for post pandemic era.

By representing the static tabular data sets in the form of dynamic graphs [19,20,21,22], more precautionary measures, cures and solution strategies may be discovered. Research around the world may get pioneered to advance new procedures or practices for the development of vaccines, drugs and medical equipment's etc. in months rather than in years. The aim of this artefact is to organize and formally represent the dynamic knowledge base [21] of novel corona virus in the form of dynamic graphs [22,23] based on the government policies towards the COVID-19 infection spread. This implies, at the first stage, understanding of the – government policies, their social and financial aftermaths, implementation issues and apprehensions that persons partake and the possible set of dynamic solution strategies [24]. Since most data is recorded in the form of text data or tabular data measuring the impact of policies is the vital chunk of information influencing the of the situation of people during pandemic. This is where dynamic graph modelling can play a crucial role.

3. WORKFLOW

The present research is inspired by the recent attempts to apply network analysis to researchers' community. The work consists of visualizing the co-policy network of observed OxCGRT dataset on response indexes. "Fig 1" depicts the workflow diagram of the process initiating from data collection to processing of data, further moves towards the generation of time series network and finally at end visualization and analysis of the designed network corresponding to the considered dataset is shown. The importance of analyzing the co-policy network for finding the results or answers lies in the ease to visualize as compared to the textual representation. Network analysis is used to understand aggregate patterns of connections and interactions of inter government policies and intra government policies towards the novel corona virus. The inter- actions among policies and countries helps to visualize effect on government responses i.e. stringency and containment health with respect to time. In the current research, the dynamic network visualization and analysis tool namely Gephi is used. The Gephi network visualization tool helps in analyzing the complex dynamic network [25,26,27] and is also empowered to demonstrate statistical analysis like degree distribution, modularity and cluster efficient.

A. Data Collection

For the analyses purpose, Oxford COVID-19 Government Response Tracker (OxCGRT) is customized, that reports the prerequisite for uninterruptedly updating, readily functioning and comparable statistics on policy measure. OxCGRT intelligences information on 20 indicators of government response of 186 nations across the globe. The indicators are of three types namely-*ordinal, numeric and text*. Ordinal pointers are used to quantify policies on a modest gage of sternness or intensity. Although, daily testification of data by the indicators is available, but to preserve the simplicity and clarity of process in our research we concentrate on fortnight data. The aggregated information of four policy indices as: Overall government response index, Stringency index, Containment and health index and Economic support index

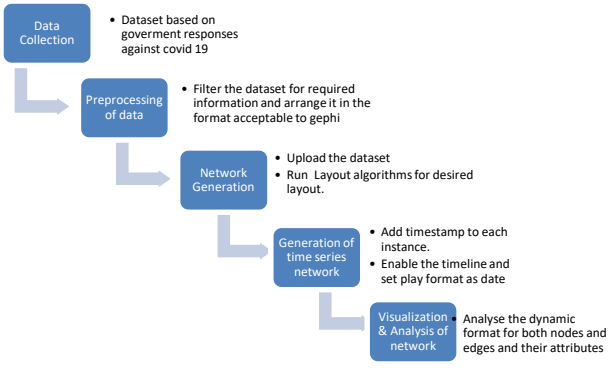

Figure 1. Workflow diagram of the designed Time Series Network

is accessible in the dataset for readily use. As mentioned above, the present research concentrates on two dimensions - stringency indices and containment and health indices and shows variation in these Reponses as value of policy indicator changes over time. Each index is composed of a series of individual policy response indicators. For each indicator, a score is created by taking the ordinal value and subtracting an extra half- point if the policy is general rather than targeted [20]. These are further escalated by their maximum value to create a score between 0 and 100, with a missing value contributing 0. The found scores are additionally averaged to get the composite indices. Table IV shows the relation between policy indicators and response indexes. Both indexes are simple averages of the individual component indicators. This is described in equation 1 below where *n* is the number of component indicators in an index and *Ij* is the sub-index score for an individual indicator.

B. Preprocessing of data

For simplification purpose, 11 countries are selected (that may have maximum impact of Covid-19 virus) and the five most influential ordinal policy indicators - Restriction on gatherings, international travel ban, testing policy, contact tracing and Vaccination policy to be observed. However, the model can be extended for numerous other countries and their corresponding policy indicators. Table II. illustrates the policy factor/indicators affecting the calculation of respective Index and their significance.

TABLE II. THE POLICY INDICATORS

Policy	Significance
Restriction Gathering	It accounts the size of - constraint on gatherings. Its value is measured in ordinal scale and binary for geographic scope.
Contact Tracing	It postulates the government effort in contact tracing and if yes then up to which level. Its value is also measured in ordinal scale.
International Travel Ban	It records the limitations on Worldwide travel and is measured in ordinal scale.
Testing Policy	It specifies the measures any government employs to select person/s that can be tested. Its value is also measured in ordinal scale.
Vaccination Policy	It records the principles government trails to select clusters for vaccination and its distribution. It is also measured in ordinal scale.

Table III. exemplifies the comprehensive set of value description corresponding to all the observed policy indices described in Table II. Policies having indices values in ordinal scale and as the scale increases the intensity of policy implementation also increased. Policy indices of policies like restriction on gathering, international travel ban and testing are measured up to scale 4, while contact tracing is measured up to scale 3 and vaccination policy is measured up to scale 5. No data is mentioned in columns where no information is available

The calculated index value is a linear function dependent on the policy indicators or policy factors of concern [28]. Table IV. shows the relationship between the observed Government response Indices and policy indicators. The index value and sub index value of the policy indicators will be calculated from equation (1) and (2) respectively [28]. These equations represent how index and sub-indexes values are calculated and are used for precision purpose. The precise values from dataset are selected and calculated on all policy indicators. The results demonstrate that these values vary in linear manner – that explains the statistic that limited policy indicators show the same variation in index values.

TABLE III. COMPREHENSIVE SET OF VALUE DESCRIPTION OF EACH POLICY INDICATOR VALUE.

Policy Indices	0	1	2	3	4	5
Restriction on Gatherings	None	Restriction on large gathering.	Restriction on 100+ people	Restrictions on 11-100 people	Restrictions on <=10 people	NA
Contact Tracing	No data	No contact tracing	Limited	Comprehensive	NA	NA
International Travel ban	None	Screening	Quarantine after arrival from high-risk regions	Ban on arrivals from some regions	Total border closure	NA
Testing	No data	No testing policy	Those having symptoms/ contact with infected/emigrates/key worker	Anyone showing symptoms	Open public testing	NA
Vaccination	No data	No availability	Any one of key workers/ clinically vulnerable groups / elderly groups	Any two	For all three	Partial addition of groups/ages

For Calculating Index Value

$$Index = \frac{1}{n}\sum_{j=1}^{n} I_j \quad (1)$$

Where: n- is the number of policy indicators. I-Index value calculated for each indicator.

For Calculating Sub-Index Value

$$I_{j,t} = 100\ (P_{j,t} - 0.5(F_j - f_{j,t}))/M_j \quad (2)$$

M_j is the maximum value of the indicator.

Flag (F_j =1 if the indicator has a flag variable, or 0 if the indicator does not have a flag variable.

$P_{j,t}$ is the recorded policy value on the ordinal scale

flag ($f_{j,t}$) =1 if the recorded binary flag for that indicator is true.

TABLE IV. RELATIONSHIP BETWEEN GOVERNMENT RESPONSE INDEX AND POLICY INDICATORS.

Response Indexes ⟶ Policies ⬇	Stringency index	Containment and health index
Restriction on gatherings	√	√
International Travel Ban	√	√
Testing Policy	-	√
Contact Tracing	√	√
Vaccination Policy	No data	No data

C. Network generation for visualization and analysis

Using Gephi, the visualization and analyzing tool of all types a network, the time series data is converted in form of nodes and edges. This process requires a thorough knowledge of the tool internal algorithms since the prerequisites required for the process needs to be arranged in a proper format supported by the visualization and analysis implementation. To maintain the consistency of the process separate sheets for nodes and edges must be created. A major part is to stipulate the timestamp or quantum (for dynamic graphs) for a node or edge to be present in the graph and decision support system to envisage its attribute value at that timestamp.

D. Generation of time series network

The government response network for the visualization and analysis purpose have separate nodes for distinct countries and policy indicators. Table V demonstrates the statistics about the network shaped in Gephi tool. The edges show the indices value of each policy employ by individual countries at any point of period. The government response index value has been taken as attribute of each country and the effect of variation in value of policy indicators over response index is illustrated. By converting a textual data in the form of graph it becomes much easier to visualize and analyses the variation of government responses over a period.

The network formed has sixteen nodes – Eleven for the identified countries across the world and five significant policy indicators (Testing policy, Contact Tracing, Restrictions on gathering, International Travel and Vaccination policy). All the acknowledged countries have attributes values that represents the value of stringency index and containment health in the time series way.

Network has maximum of 55 edges that connects all the countries with policy indicators respectively and edge weight represents the value of policy indices employed by its connected country.

TABLE V. GOVERNMENT RESPONSE NETWORK

Category	Co authorship Network
Dataset	https://covidtracker.bsg.ox.ac.uk/
Nodes	Countries, Policies
Edge type	Undirected, Weighted
Network Format	Undirected
Edge weights	Policy Indices value
Number of nodes	11(countries),5(policies)
Number of edges	55 edges
Average degree	6.6221 edges / vertex
Nodes Attribute	Stringency Index, Containment and health Index

1) Layout selection for the time series graph

To select a proper layout for graph is a significant part as it embodies the graph in most presentable and logical format that further effects the investigation of outcomes. Using the Gephi toolkit [25,29], the network is created and is analysed using an inbuild Force Atlas2 algorithm [30]. Force Atlas2 is a force directed approach that follows the principles of repulsion, attraction, and gravity to deliver a high gradation of accuracy for small to large datasets. It is an advanced version of Force Atlas which is very slow in comparison. Force Atlas2 works on the principle of attraction and repulsion where higher level of attraction will compose the nodes and lower attracting nodes are placed at a distance. This force-based approach, has multiple features like gravity, scaling and overlap prevention apart from these, it gives a layout that is more clustered and visually more vibrant. It's advanced value of gravity assistances in towing the nodes towards the centre of the graph and subordinate value supports in dispersion of the nodes. The *scaling feature* sets a revulsion level for the diffusion of graph to make it better decipherable. The *prevent overlap feature* is used avoid overlying among the nodes. This algorithm is finest suitable to deliver a improved outline of graph for visualization and analysis. "Fig. 2" represents the parameters settings used for Force Atlas2 algorithm. "Fig. 3" represents the parameters settings used for another inbuilt layout algorithms, Frutchterman-Reingold algorithm [31] used to provide better visualization to network.

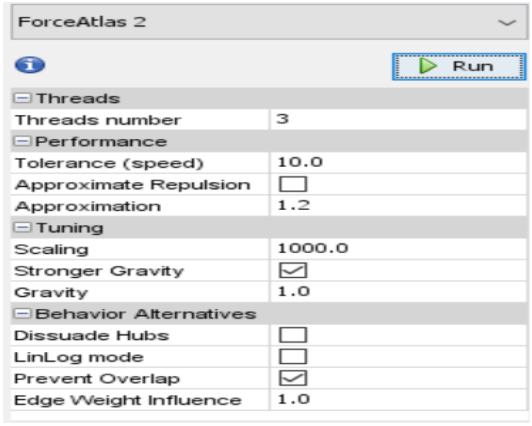

Figure 2. Parameter Settings for Force Atlas2 Algorithm

This algorithm provides a stationary assessment of the graph and operates on the similar principal as Force Atlas 2, the significant functional difference lies underneath, the altering of graph area rather than changing attraction and repulsion parameters. The combination of these two algorithms stretches an improved outline to the graph that can be easily understandable.

"Fig. 4" represents the resulting outline of graph, different colours are given to nodes to discriminate among policy indicators and corresponding nations. (For example, light yellow represents for policy indicators and brown embodies for corresponding nations). Values on edges represents the indices value of each policy implied by its connected nation.

E. Visualization and Analysis of Dynamic Government response network:

1) Visualization of dynamic network: The dynamic network created can be visualized to show the effect of variation in policies indices value on government response index values. These deviations can be easily viewed by applying the subsequent features like variation in size and colour of the nodes and edges based on their attribute values.

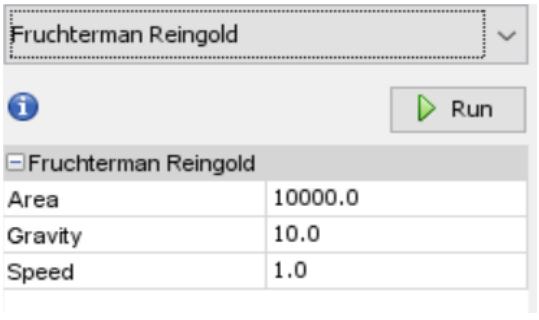

Figure 3. Parameter Settings for Furtcherman-Reingold Algorithm

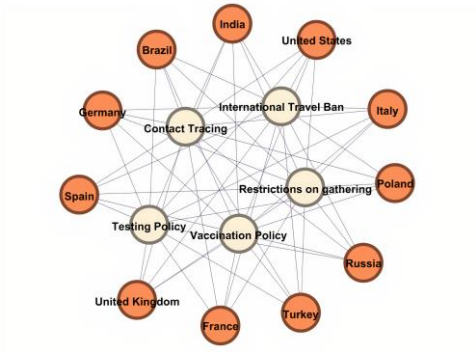

Figure 4. Overview of generated Graph with all nodes and edges.

a) Change of node size/color based on attribute value: The size and colour of a node determines the attribute (response index) [2,32] values in time variant fashion. Through the assistance of dynamic graph, it becomes best possible to analyse the size and colour intensity variations dynamically with respect to the variation in the pragmatic attribute value.For example "Fig. 5" illustrates these variations in nodes with respect to the stringency government policy index. The feature helps to discover the evolution of stringency and containment health index value change over time.

b) Change of edge color and width bottomed on attribute value: The edge colour and width can similarly be altered grounded on its attribute value. As the value of the edges are - indices value of each policy, this feature helps to novel the variation of indices value over time. "Fig. 6" shows how edge colour and width changes with variation in the policy indices.

c) Identification of connected nodes: The visualization and analysis tool offer a feature that shows the node sensible features specifically, its attribute value, count of connected nodes and the edge attribute value [25,33]. This feature further supports in the country wise analysis or policy wise analysis at any point of time.

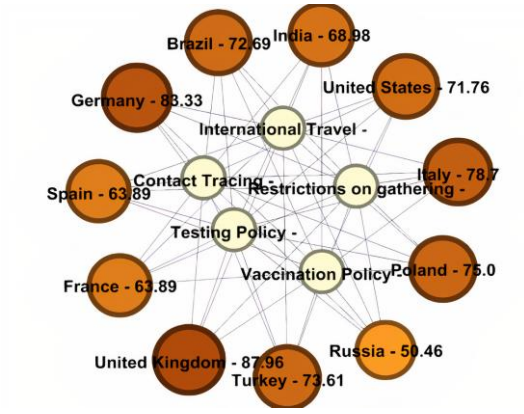

Figure 5. Variation in node size and colour grounded on attribute - stringency government policy index.

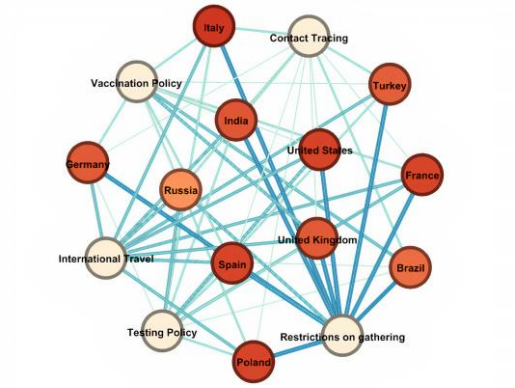

Figure 6. Variation in edge colour width based on weight (policy indices)

*"*Fig. 7*"* shows the country wise visualization respectively It demonstartes the policies implemented in The United States in Dec 2020,in response to Covid-19 and the values on edges specify the level of implementation like level of restriction on gathering was 4 whereas testing policy was implemented on level 3,contact tracing was on level 1,international travel ban was on level 3 and vaccination policy was in its initial phase of level1.Similarly graph can be viewed on the policy basis where all countries implementing that policy can be viewed with the level of implementation intensity.

*2) Analysis of Dynamic Government response network:*To analysis the dynamic graphs various methods and metrics are essential to address the temporal feature of these networks. The most common technique to cater with the temporal aspect is to simply divide the entire network over time into a series of static subgraphs by discretization of dynamic graph [26]. For example for a given graph G in a time period from t(1) to t(m-1), m different subgraphs such as G1,G2.---Gm represents the state of graph at timestamp t1,t2,…..up to tm-1.G1 represents the state of the graph in time interval t1 to t2.Similarly,G2 represents the state of network in time interval t2 to t3 and so on. The term time-stamp is used to refer to individual state of graph(subgraph) according to time periods sampled from G. Such discretization of the dynamic graph into a series of static subgraphs can enable the implementation of many statistical analysis metrics to be applicable on dynamic networks [35,36]. In the present research, statistical analysis is performed to analyse nodes and edges based on their attributes and weights respectively and th find the modularity and weighted degree of the network and explains the importance of this analysis for the better understanding of the process and retrieval of innovative information from the network.

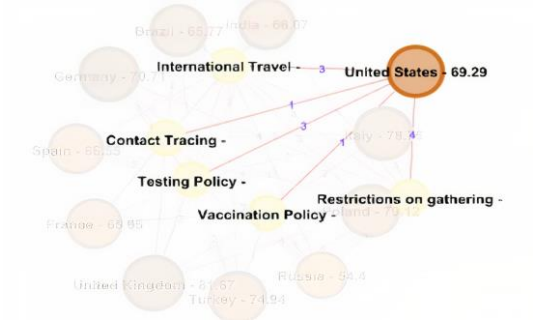

Figure 7. United State with containment and health index value(attribute) and indices value(weight) for observed policies.

a) Node based Analysis: A graph(G) is a pair of (V, E) where V is the set of vertices and E is the set of edges that connects the two distinct nodes(u,v).A dynamic graph can be node dynamic graph or a edge dynamic graph or in special cases, can be customized to perform both functions. A Node dynamic graph is a graph where the set of vertices V varies with the time and if these vertices(nodes) have some attribute value then it will dynamically be varied over time. The analysis of this dynamics can provide a useful information from a complex network. As in visualization section it can be seen that how nodes colour and size vary with respect to the attribute value over time. In the present research, the nodes specify the countries and government policy indicators. The attribute values of country nodes represent the administration response index i.e. stringency and containment and health towards the pandemic spread across the world.The index value at any point of time depends on the value of policy indices, denoted by edges between countries and policy indicators respectively.Now, the stimulating part here is to analyse the variation in government response index based on the policy indices. This variation can be productively analysed using the dynamic graphs.

The variation is an outcome of varying attribute values (stringency or health index) on the observed nodes. Substantial size and intense colour depict that the attribute value on the detected node is larger as compared to other nodes in the network.Relationship can now be established as - Higher the attribute value enormous is the size and more intense is the colour of the node.Since attributes are representing government response index, it directs to clearly identify the country that has higher response index at a given time and the countries that has the least response indexes. "Fig. 8" illustrates the scenario of May 2020 for the government stringency index across the world. India, an Asian country had the highest stringency index of 96.3, preceding the Italy with second highest stringency index index value of 93.5 and United States with the least stringency index of 72.69.Similar analysis can also be

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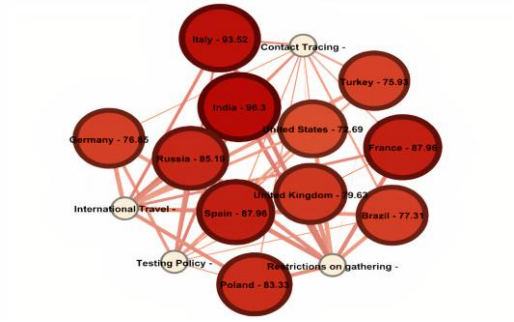

Figure 8. Stringency index in May 2020

done on another attribute i.e health index of countries. "Fig. 9" shows the situation in NOV 2020 for the health and containment index. It can be clearly identified that France had the highest containment and health index of approximately 76 as compared to other countries. Italy had second highest index of 69.94 and Russia had the least index of about 53. This analysis helps to find answers for the identified objectives RQ1 and RQ2 where the variation in node(country) size and colour resembles the effect of policies on government response index. The result obtained from the extensive analysis are discussed in Section 4 for the future reference. The deduced information after the analysis is decisive and significant for the forthcoming planning to face the similar type of situations and dynamic graph makes it more vibrant.

b) Edge based Analysis: As discussed in previous section, an 'edge' is a connection between the two distinct nodes (u, v). Edge can be *weighted* or *unweighted*. A Weighted edge has an additional value (weight) associated with it that specifies the strength or significance of connection between the nodes. Dynamic graph can be *edge dynamic* where set of edges and their associated weight varies with respect to time. In this study, edge represents the connection between countries to be observed and the government policies formed during the pandemic across the globe.

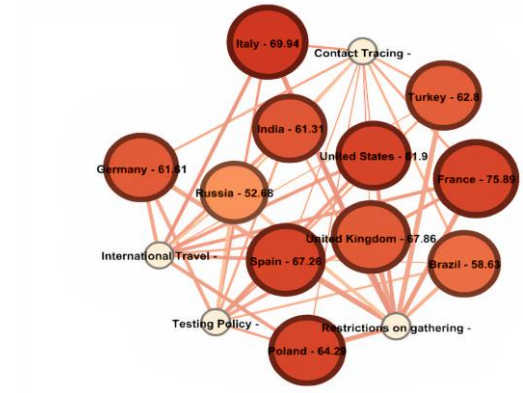

Figure 9. Health Index in Nov 2020

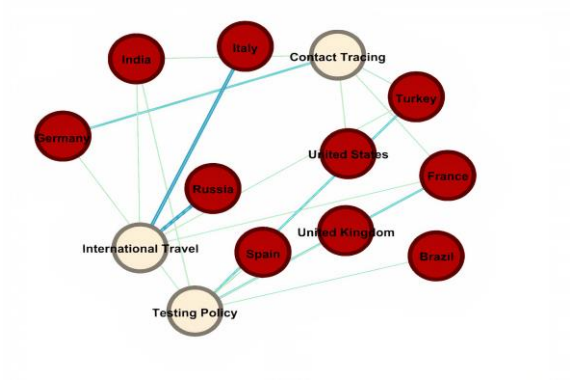

Figure 10. Policies implementation in Feb 2020

The weight of the edges represents the indices value of the policies, in other terms the intensity or severity to which these policies are followed. Higher the value of indices, more sternly policies are being followed. As conversed previously, the edge colour and width may be changed depending on the weight with reference to the varying time. The feature plays a significant role in analysing the policies and their implementation in the republics across the globe. For better visualization, the ranking process is restricted to execute on the set of edges only and nodes are exclusive.

"Fig. 10" shows the scenario in February 2020, where all the policies were in preliminary phase and policies that starts in early phases of pandemic like restriction ongathering and vaccination was not even started at that time. International travel ban was strictly implemented in Italy and Russia, the testing on the other hand was well instigated in United states, Spain, UK, Turkey and France. At that time, countries like India, Germany and Italy were in initial phase of these policies. In contrast, "Fig. 11" shows the situation of February 2021 where the government policies like restriction on gathering is well implemented in all countries.

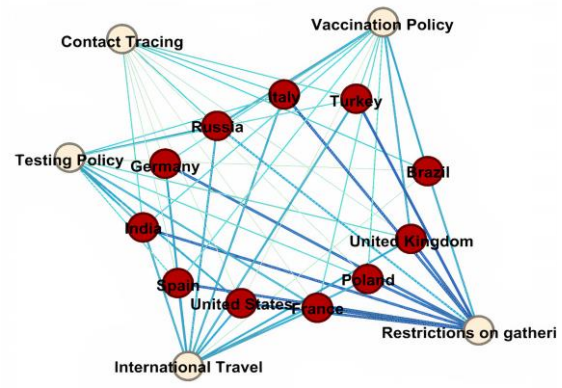

Figure 11. Policies implementation in Fen 2021

The vaccination policy got started and international travel ban becomes less intense. This analysis of transition in one-year aids to establish the replies for objectives RQ1 and RQ2 and also helps in getting more insight for RQ3 where wider and intense edges lead to higher government response index and RQ4 to find significance of each policy especially vaccination.

c) Modularity Class: Dynamic graph supports cluster representation to find the modularity of the graph [35]. Modularity assistances in spotting the existing groups in the graph. A group is a set of nodes that are coupled with ample strength as equated to the further nodes of the graph. Since, the graphs under research are time series graphs, it turns out to be interesting that how number of clusters behave with respect to time. The Blondel's modularity algorithm [37] is simulated to discover modularity classes with a randomise approach and with a resolution of 1.0(a feature to avoid weak groups, higher the value of resolution lesser is the number of groups). Different communities are detected dynamically in the graph based on the edge weight [27] that illustrates significant policies for some nations as likened to others. "Fig. 12" shows the node count distribution and detected two communities of size 7 and 8 nodes respectively. Identified two communities are sensed in December 2020 and specifies that policies like Imparting vaccination, restricting international travel ban and testing for the virus are more significant in nations like-United states, France, Russia, Spain and Poland while, contact tracing and restraint on assemblies are more momentous in other countries. Modularity score is 0.06 that implies that connection outside communities are not sparse. Modularity analysis helps to meet objective RQ4 by helps us in finding significance of vaccination policy. In result section it can be seen that vaccination policy is significant for most of the countries and its implementation leads to improved government response index.

d) Weighted degree: The weighted degree of a node considers the sum of weights of all the connected edges to a node- directed or undirected [32,35,38]. In our research weights on edges represents the policy indices value, that interestingly leads to find weighted degree of each policy and to analyse the severity in the implementation of observed policy at any point of time. "Fig. 13" shows the average weighted degree node distribution of weighted degree and the variation in size of policy nodes based on their weighted degree value in March 2021. This variation clearly indicates that testing policy is least implemented in all policies and international travel ban is the policy that is best implemented. (Average Weighted Degree: 11.875). This analysis of weighted degree helps to meet the objective RQ3 to find the significance of each policy, how well the policy is implemented? and where the improvement is

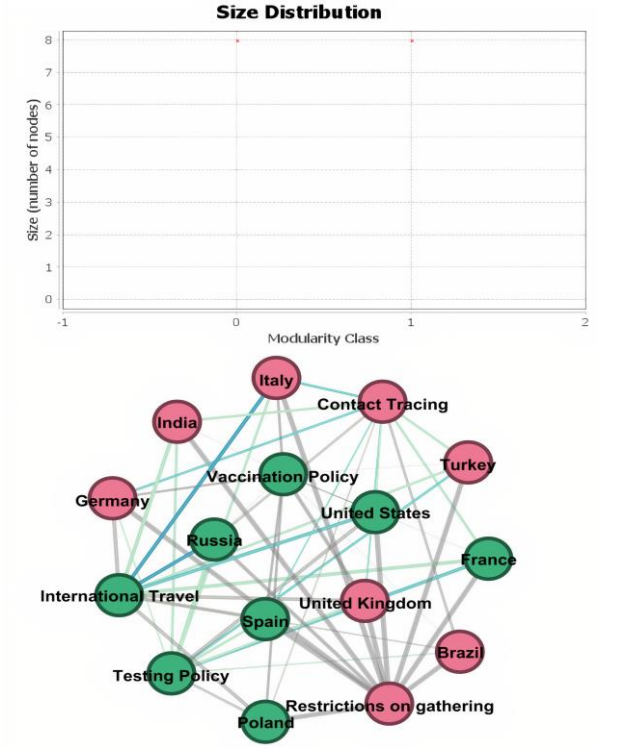

Figure 12. Node count sensible chart for Modularity class and detected communities in Dec 2020.

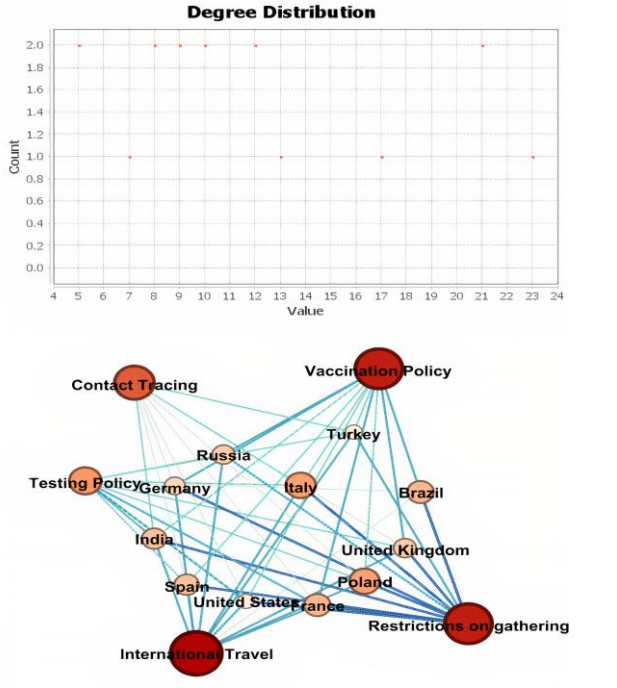

Figure 13. Weighted degree distribution and variation in policy nodes based on weighted degree in March 2021.

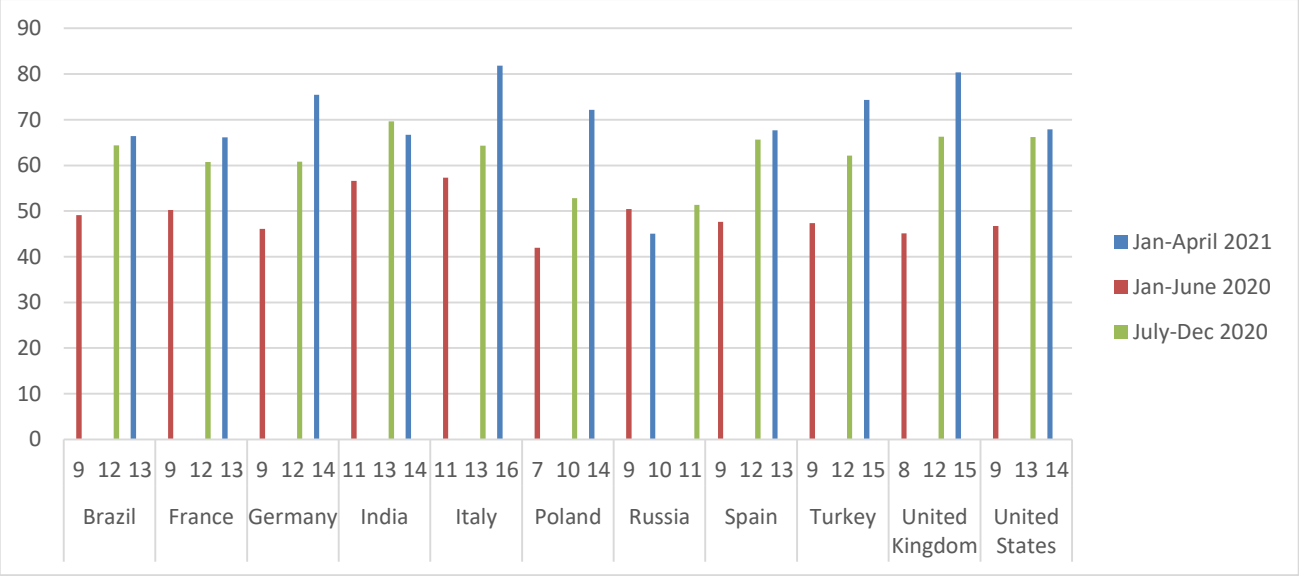

Figure 14. Average of government responses based on average of policy indicators.

required? Improved implementation of these policies can lead to the prevention of complete lock down in similar situations of pandemic. Similar Analysis can be done for any point of time to get better insight of the implementation depth of each policy and its effect on the government response indexes of each country

Based on the above analysis, we tried to show the variation in government responses based on policies. Figure 14 shows the average of both government responses: Stringency and Containment health concerning the par of all considered policies: Restriction, Contact tracing, Testing, International travel ban, and Vaccination. It can see that the higher the value of policy indicator better is the government response toward pandemic.

4. RESULTS AND DISCUSSIONS

Since the color and size of nodes varies conferring to two dimensions of pragmatic response index values namely, stringency index and another is health and containment health. By analysing the designed dynamic graphs in section 3, following results can easily be interpreted.

A Variation in Stringency Index with respect to policies implementation: As per the Oxford University definition *"The stringency index records the strictness of government policies. It does not measure or imply the appropriateness or effectiveness of a country's response*" [20]. However, studies through various paradigms demonstrates that nations with severer administration retorts have experienced gentler epidemic progress tolls in comparison with the countries which are less stringent "Fig. 15" and "Fig. 16" illustrates how the government stringency index varies in accordance to the policy index values with respect to the variation in time domain.

B. Variation in Containment health Index with respect to policies implementation: Containment is commenced in the initial phases of the outburst of novel corona virus and purposes to touch and separate all infested persons as a measure to break the virus from spreading. However, after a short period of time it becomes impossible to comprehend the virus, then exertions passage towards the mitigation stage. At thisstage, actions are engaged to slow down the blowout of virus and mitigate its aftermaths on the healthcare structure and humanity. An integration of both containment and mitigation measures may be commenced at the same time across the globe to improve the situation towards the pandemic.

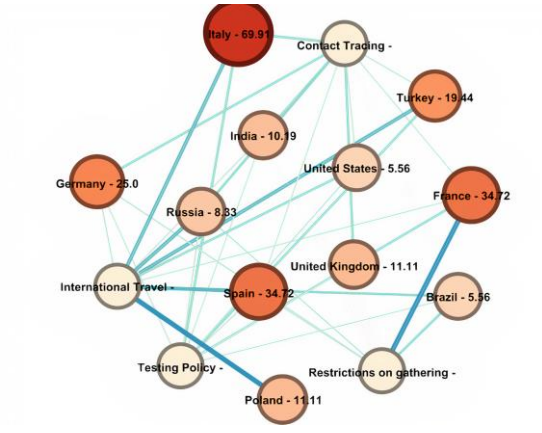

Figure 15. Strnngency Index in March 2020 based on policy indices.

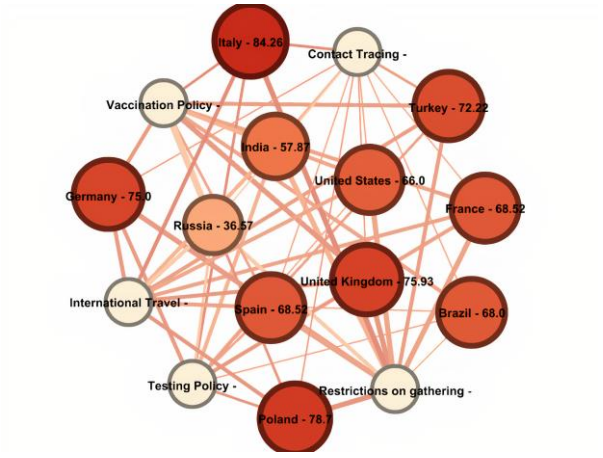

Figure 16. Stringency Index in March 2021 based on policy indices.

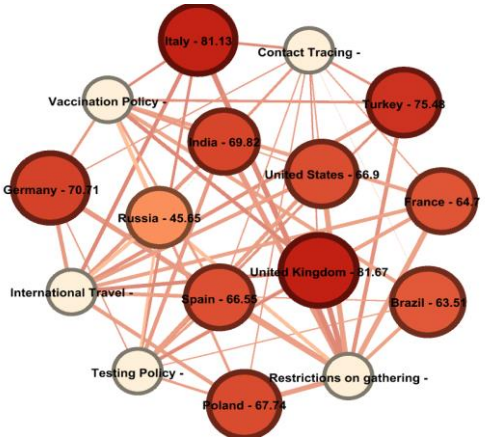

Figure 18. Affluence of Containment health in March 2021

"Fig. 17" and "Fig. 18" shows the variation in containment and health index at different timestamps.As the policy indices varies with time it leads to the variation in helath indexes which clearly visualize as variation in size and colour of country nodes.

C. Implication of each policy and outcome of their enactment on the anticipation of complete lockdown: The indices values considered as policy indicators in the current research are very crucial and are directly impacting the prevention of complete lockdown in a nation that will further influence the economic welfare of any country.Also, an indicator viz. vaccination policy of the nation is examined to demonstrate the outcome of realizing vaccination drives in each country that added primes to plentiful sooner results in improving index values.As previously discussed the impact of significant policies and their implementation depth on indexes as in "Fig. 19" which shows that how both stringency index and containment health index increase in most of the countries as the implementation of all the policies improves.

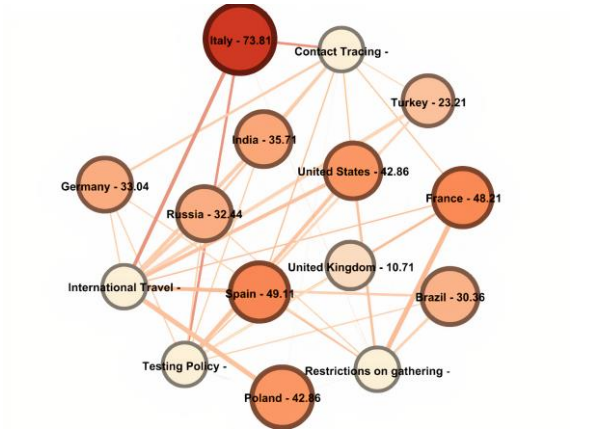

Figure 17. Affluence of Containment health in March 2020

Based on these results it can be stated that if these policies will be implemented by the authorities with more severity then the situation/requirement of complete lockdown can be prevented that also results in much less economic loss to any country.

D. Effect of vaccination policy in improving government responses to Covid-19: It's a well-known fact that there is a vaccine shortage across the world specially in poorer countries. The developed and middle-income countries are doing much better in the inoculation campaigns against the novel corona virus. Till April 2021, 0.93 billion doses have been administrated against Covid, only 2.79% people around the globe are fully vaccinated. Although more than a dozen of vaccines has been created to fight against this pandemic, distributing them equally and to everyone on the planet seems to have become the biggest challenge. Now WHO has developed a framework for production and distribution of vaccines, but the developed countries and major vaccine manufacturers are against joining this initiative.If the current pandemic situation is analysed closely, it is found that many vaccines are developed by public funding agencies. For example, the most popular vaccine AZD_{1222} was developed at oxford university and was intended to use freely by all but later university gives the vaccine marketing rights to British company Astrazeneca. Astrazeneca further signed a contract with Serum institute of India Private Limited to manufacture and market vaccine as Covishield. Wealthy countries that can afford the vaccine have booked more than $2/3^{rd}$ of vaccine doses that will be produced globally by the end of 2021. Remaining $1/3^{rd}$ of the vaccine must be share among 92 impoverished nations across the world.Presently, China, USA, India, EU and UK are major manufacturers. The US and UK are preserving medicines for domestic use only while EU only shares vaccines among its member states. India and China are two major countries that are

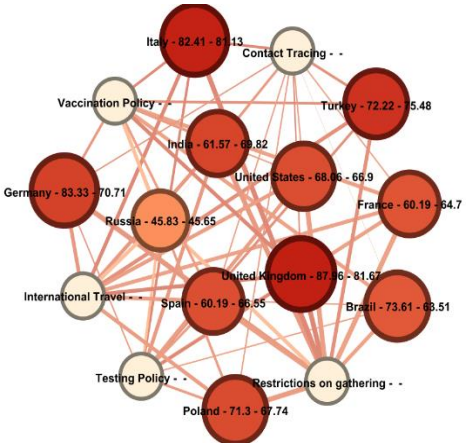

Figure 19. Improvement in both stringency and health indexes in Feb 2021

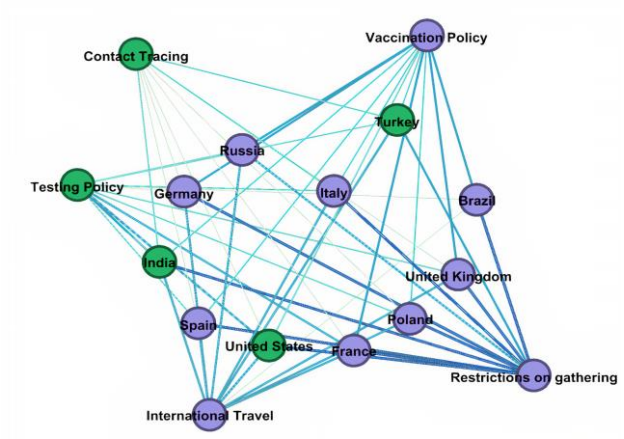

Figure 21. Modularity class distribution of communities in Feb 2021

exporting vaccines to developing world. India is providing the vaccine on the roadmap of "Vaccine diplomacy" to 70 countries across the globe. This helps the country to strengthen domestic ties with many nations, still it is facing huge domestic shortage of vaccines.Since it is implied that there is a major role of vaccination policy in improving the response indexes of any country. It is necessary that governments across the globe should necessary nourish the manufacturing institutes to ease the requirement.

"Fig. 20" shows that after the implementation of vaccination policy in Jan 2021 the index value of both stringency and containment and health increases after the introduction of vaccination policy in Dec 2020 in many countries.Although this indicator is not used in calculating the response index but by analysing its effect in graph it can be concluded that this policy will play a major role in near future for the improvement of the government response indexes in the similar pandemic situation. Similar results can be deduced based on modularity class distribution of communities where nodes of same community are representing in same colour.

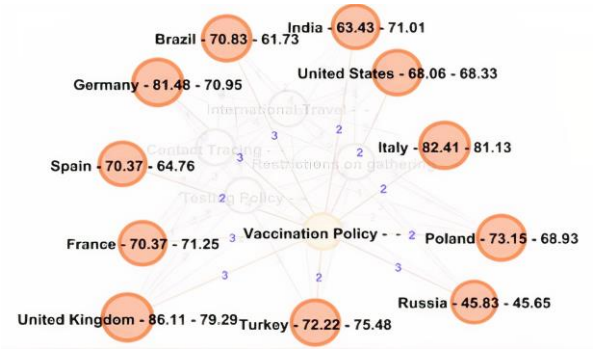

Figure 20. Vaccination policy and its indices value for each country

"Fig. 21" shows the result of modularity analysis in Feb 2021 and demonstrates how significant was vaccination policy for most of the nations it can be proved the most significant weapon in future to won the battle against current pandemic.

5. CONCLUSION AND FUTURE SCOPE

The illustrative application is designed to inspire exhaustive exploration and to ease the decision support system for policymakers and researchers that further helps them to answer significant communal policies and epidemiological queries on current pandemic situation.OxCGRT dataset is used for logical analysis of the outcomes of administrations' retorts to COVID-19 across diverse populaces and contexts, in conjunction with the description of major factors that influence the governments to adopt different policies.The research further argues that any analysis of an explicit nation should be done on the foundation of the fundamental policies, not on the indices alone. The paper concludes that governments across the world with more stringent policies to respond to Covid-19 pandemic may perhaps give rise to the improved performance that further contributes to curve the death tolls.Similar study can be implemented on states or district level to get better insight of effect of novel corona virus or any pandemic fighting policies in interior portions of the country that are otherwise unreachable for analysis.

COVID-19 is still at the gauge of pandemic, implies that authorities and government sectors altogether are experiencing the same 'exigency' stage. In the future, we intend to focus on the behavioural aspect of government policies to handle the pandemic situation. For example, the use of appropriate language used in communication by the government personals, to enhance the citizens' morale and help them recover from psychological distress from the Covid-19 pandemic. The government policies should be

designed that try to upsurge the self-esteem, essence to contest, and harmony among the people by bringing encouraging expressions, conveying optimistic posts and alluring the citizens to support each other. We intend to analyse the patterns among the speeches of various diplomats across the world and will try to establish the relationship between the citizens positive morale in accordance with the linguistic behaviour of the authorities.

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