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# Identifying the Spreaders of Covid-19 Using the Approach of Multiplex Network

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**ABSTRACT:** In this paper, we present a methodology to identify spreaders of COVID-19, the use of relations, the analysis of the socio-cultural and economic functions, and the numbers of infections and causes the death of the COVID-19 virus, and in different countries. In order to do this, we analyzed the data from a country with an extensive network of the strategy, in particular, to analyze the distributor of the countries, and then, based on the separator to be installed in a 5-layer multiplex network. The results show that we get a classification of the countries according to their numerical value, in the socio-economic, population, gross domestic product (GDP) per capita, human health, and air-reports that I diffusers, it is of high, medium and low values of the different properties; however, the one aspect of all the countries which belong to the separator, which has a high level of air-to-value words.

**KEYWORDS:** Complex networks, complex systems, COVID-19, multiplex networks, optimization, social networks.

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## I. INTRODUCTION

This year (2020), the world is faced with an illness that is caused by the SARS-CoV-2), known as COVID-19. The virus began to spread in Wuhan, China, on 31 December 2019, [1] and, as the virus is spreading rapidly across the globe, the World Health Organization (WHO) identified it as a pandemic in January 2020. [2]

COVID-19 is classified as a virus consists of a single-stranded RNA as well as the symptoms of the disease caused by COVID-19, headache, dry cough, unfortunately, a fire, and respiratory failure [3]. But in the case of asymptomatic struggle of people with the virus have been identified, which is a very real problem for healthcare organizations.

On March 31, 2020, the united states became the epicenter of the pandemic, followed by Italy, Spain, China, and Germany 186 265, 105 792, 95 923, 82 278 and 71,690 a confirmed case, according to [4]. These five countries accounted for 63.4% of the total number of successful cases all over the world. The recovery of this new pandemic is leading the way in China, Germany, Spain, Italy, and Iran, 42.8, 10.8, 9.1, 8.8 and 8.2% of the cases. It is important to note that in Europe and the united states, the spread of COVID-19 around the world can be explained by the differences in infrastructure, health care, aviation, human development, and the socio-cultural and economic factors [5] - [7].

Therefore, in this paper, we analyze the impact of socio-cultural and economic factors, weather, the people, the development and proliferation, but also to the growth of COVID-19 in each of the countries of the Vertex separator problem (VSP) [8]. in large-scale complex networks. It is important to note here that the data of each subject, which was adopted by the websites on the European Union (EU), and [9]. the World Health Organization (WHO) [4] and the world bank (WB) [10], and the International monetary fund (IMF), [11] and, according to Transparency International's (TI) [12] on May 15, 2020.

On the other hand, a complex network is a network with non-trivial topology of the features that are not found in simple networks such as degree distribution, hierarchical structures, structures, communities, and the high level of a "public" address (as measured by the clustering coefficient) [13].

The identification and quantification of the authority of the nodes in the complex networks is an important activity in many applied areas, such as the transmission and control of disease [14], the personality; it is the most important and influential members of a criminal group, [15], and, of course, how many of the effectiveness of the scientific literature [16], the future of the relations of the prediction [17] - [19], among others [20], [21].

## II. LITERATURE SURVEY

### 1. C. Sohrabi et al., "World health organization declares global emergency: A review of the 2019 novel coronavirus (covid-19)," *International Journal of Surgery*, 2020

An unprecedented outbreak of pneumonia of unknown aetiology in Wuhan City, Hubei province in China emerged in December 2019. A novel coronavirus was identified as the causative agent and was subsequently termed COVID-19 by the World Health Organization (WHO). Considered a relative of severe acute respiratory syndrome (SARS) and Middle East respiratory syndrome (MERS), COVID-19 is caused by a betacoronavirus named SARS-CoV-2 that affects the lower respiratory tract and manifests as pneumonia in humans. Despite rigorous global containment and quarantine efforts, the incidence of COVID-19 continues to rise, with 90,870 laboratory-confirmed cases and over 3,000 deaths worldwide. In response to this global outbreak, we summarise the current state of knowledge surrounding COVID-19.

The onset of the novel Coronavirus Disease 2019 (COVID-19) outbreak in Wuhan, China, suggests animal-to-person spread and later person-to-person spread. The complete clinical picture following COVID-19 infection is not yet fully understood. A recent report on over 72,000 COVID-19 cases by the Chinese Center for Disease Control and Prevention showed the case fatality rate was overall 2.3%. The mortality rises to 8% in patients between 70 and 79-years-old, and spikes to 14.8% in those aged 80 and above [1]. Sohrabi et al. give an informative and comprehensive account of the timeline, etiology, symptoms, supportive treatment, and transmission prevention of COVID-19 [2].

The WHO's declaration of COVID-19 to be a Public Health Emergency of International Concern is attributable to the high case fatality rates in China and the global economic effect of COVID-19, which may compound the current ongoing influenza epidemic [3]. Furthermore, there is the potential for higher death rates in countries with vulnerable health systems in resource-limited regions. The ability to control local transmission depends on the application of the principles of rapid identification, prevention, and control, followed by patient isolation, rapid diagnosis, and contact tracing. Some countries remain ill-equipped with limited diagnostic capacity, resulting in delays from suspected case identification to vector confirmation and patient isolation, which increases the risk of disease transmission [4]. Though, 74% of countries in Africa have an influenza pandemic preparedness plan; however, most are outdated and inadequate to deal with a global pandemic such as COVID-19 [5].

Recent epidemics and pandemics (e.g., severe acute respiratory syndrome (SARS), H1N1 pandemic, Middle East respiratory syndrome (MERS), and Ebola) have highlighted the need to reinforce national public health capabilities, including disease-surveillance systems and health care workforce. Pandemic preparedness requires specific training in surveillance, epidemic response, and diagnostic testing. Strengthening health care systems worldwide, particularly in resource-poor settings, is imperative. Recurrent novel pandemics is our new global reality.

## III. MATERIALS AND METHODS

In this section, we present the way of model the multiplex networks, and the methodology to analyze and identify the most spreader countries of COVID-19. This study is divided into four phases, which are:

- 1) Data collection: In this phase, we build the data set through a statistical analysis applied to the Information obtained from the IMF, WB, WHO and IT.
- 2) Construction of networks: In this phase, based on the similarity of the characteristics for each country, we model the monoplex and multiplex networks.
- 3) Analysis of spreader nodes: For the modeled networks, we use an adaptation of the VSP to identify spreaders countries in multiplex networks.
- 4) Analysis of results: In this phase, we show the study of the countries that are classified as spreaders, which cause the rupture of the multiplex networks.

### A. MATERIALS

As mentioned above, to model the networks used in this work, we use the information about COVID-19 available on the websites of the European Union (EU) and World Health Organization (WHO); while for the socio-cultural and economic data we use the information available on the websites of the World Bank (WB), the International Monetary Foundation (IMF) and Transparency International (TI).

The information of COVID-19 (infections and deaths), includes the period from 12/31/19 to 05/15/20 and the indicators used to define the socio-cultural-economic characteristics, are: projected real Gross Domestic Product (GDP)

(2020), projected consumer prices (2020), special drawing rights (millions), quota (millions), human development index (HDI) (2009-2018), corruption perception index (2018), Gross national income (GNI) per capita, GNI per capita rank minus HDI rank, country population (population/km<sup>2</sup>), real population density (hectares by person), Gini Coefficient, current health expenditure (% of GDP 2000-2016) and air travels (2019-2020).

Specifically, in this work, we modeled two 5-layer multi-plex networks; where each layer represents the relationship between each pair of countries  $v$  as follows:

- Layer 1 (L1), for Human Development Index and its components.
- Layer 2 (L2), for Human Development Index Trends, 1990-2018.
- Layer 3 (L3), for the Inequality-adjusted Human Development Index.
- Layer 4 (L4), for the air travels (inbound and outbound) between each country.
- Layer 5 (L5), L5.1 for the number of infections and deaths network, and L5.2 for the GDP and health network.

These relationships are given by the number of characteristics in which the countries are similar, and their quantification is obtained as follows:

- The Mahalanobis distance between each pair of countries is calculated.
- The median of the Mahalanobis distances is calculated.
- For each pair of countries with a distance less than the median, a link is added.

Here, it is essential to emphasize that, although GDP is frequently used to compare international economies or the air travels are used to analyze the population movement; the idea of modeling five different types of layers is to be able to carry out a classification based on a multi-criteria analysis that allows a stable assessment of the different elements included, thus streamlining the decision-making process.

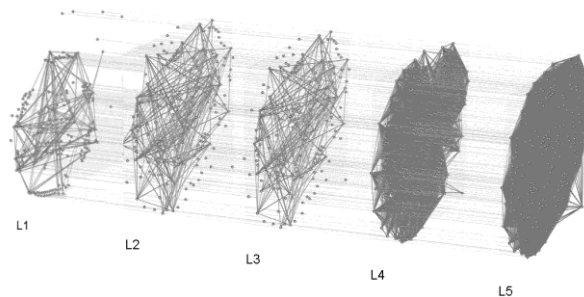


FIGURE 1. Graph of the infection multiplex network.

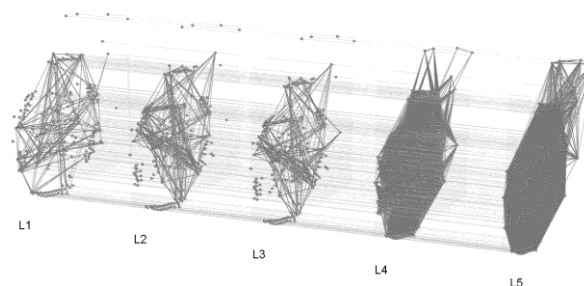


FIGURE 2. Graph of the GDP multiplex network.

## B. METHODS

In this work, the VSP is used to identify the spreaders countries. The approach of VSP is based on the robustness in networks finding the nodes that cause the rupture of the GC. In the case of multiplex networks, the GC is denoted as the Mutually Connected Giant Component (MCGC) defined in [62]:

Each node  $i$  is in the MCGC if it has at least one neighbor  $j$  that belongs to the MCGC and if all its replica nodes in each interdependent network are also in the MCGC.

From this definition, Bianconi et al. [62] deduce that if a node  $i$  in a particular layer of a multiplex network is in an MCGC, then all its replica nodes in all layers are in the MCGC.



On the other hand, the VSP [53] consists of finding a minimum set of C nodes that, when their links are removed from the network, produce a disconnection from the multiplex network into at least two connected components (A, B), such that A and B are maximized. Then, the adaptation of VSP can be summarized as:

- Instance: A MCGC of a multiplex network  $GP = (G\alpha, C)$ .
- Problem: Find a partition of nodes belonging to the MCGC of GP that results into three disjoint sets A, B and C, A and B nonempty, such that:  
There are no interlayer or intralayer links between the elements belonging to each set A, B or C.  
 $|A|$  and  $|B|$  are maximized.  
 $|C|$  is minimized.

It is essential to mention that we can quantify the robustness and the number of spreaders in the networks by analyzing the percentage of nodes that belong to the separator set C (set of spreaders). For example, a high percentage (more than 70%) of nodes in C indicates that the network is robust (there are a high number of spreader countries). In contrast, a low percentage (less than 30%) indicates that the network is not very robust (there are a low number of spreader countries).

#### IV. RESULTS

In this section, we present the results and discuss the key structural statistics of the simulated network, as well as those that caused the spread of COVID-19.

##### A STRUCTURALMETRICS

In order to facilitate the understanding of the results of the networks structural metrics, we briefly introduce some fundamental concepts:

Clustering coefficient [69]. It quantifies how much a node is interconnected with its neighbors; where, two nodes are neighbors if exist a link that join them, and for non-directed graphs, it is calculated in the following way:

$$C_i = \frac{2|E_{ab}|}{k_i(k_i - 1)} : v_a, v_b \in N_i, e_{ab} \in E$$

where,  $k_i$  is the degree of the node  $v_i$ ;  $v_a$  and  $v_b$  belong to the neighborhood for the node  $v_i$  ( $N_i$   $k_i$ ) and;  $e_{ab}$  is a subset of the total number of links (E) that connect any pair of nodes  $v_a, v_b$ .

ID	Degree	Clust. C.	Triangles	Closeness C.	Betweenness C.	Diam.	Path L.
Av.	35.630	0.933	822.361	0.812	0.832	.	.
Var.	421.636	0.012	335328.341	0.042	0.047	.	.
Low L.	34.178	0.921	741.032	0.742	0.818	.	.
High L.	40.083	0.948	921.225	0.842	0.848	.	.
Av.	38.761	0.215	823.263	0.815	0.842	.	.
Var.	422.462	0.092	383342.402	0.0624	0.049	.	.
Low L.	33.712	0.189	729.631	0.763	0.832	.	.
High L.	43.826	0.271	916.831	0.831	0.853	.	.
Av.	37.405	0.946	837.774	0.824	0.856	.	.
Var.	423.726	0.015	395388.351	0.064	0.051	.	.
Low L.	34.515	0.929	749.520	0.789	0.824	.	.
High L.	40.294	0.954	926.028	0.860	0.888	.	.
Av.	190.342	0.992	20129.969	0.971	0.985	2	1.056
Var.	4.841	0.001	4842.545	0.001	0.002	.	.
Low L.	186.893	0.989	20120.201	0.970	0.984	.	.
High L.	193.257	0.994	20139.736	0.973	0.986	.	.
Av.	3.437	0.191	5.064	0.203	0.203	.	.
Var.	10.066	0.145	217.914	0.029	0.029	1	1
Low L.	2.991	0.138	3.892	0.146	0.146	.	.
High L.	3.882	0.245	8.036	0.260	0.260	.	.
Av.	54.869	0.654	1239.767	0.549	0.534	.	.
Var.	883.359	0.032	883668.239	0.020	0.028	.	.
Low L.	50.697	0.633	1107.825	0.529	0.610	.	.
High L.	59.040	0.675	1371.709	0.569	0.657	3	1.86

TABLE 1. Structural metrics of layers.

Based on the information presented in Table 1, we can see that L1 to L4 and L5.2, have characteristics of the small-world model [73], while the layer 5.1 has characteristics of the scale-free model[74].

For example, L3 has a clustering coefficient of 0.952 and an average path length of 1.32, while L5.1 has 0.191 and 1, respectively. On the other hand, for closeness and between centralities, L1 to L4 and L5.2 have high values, while L5.1 has low values.

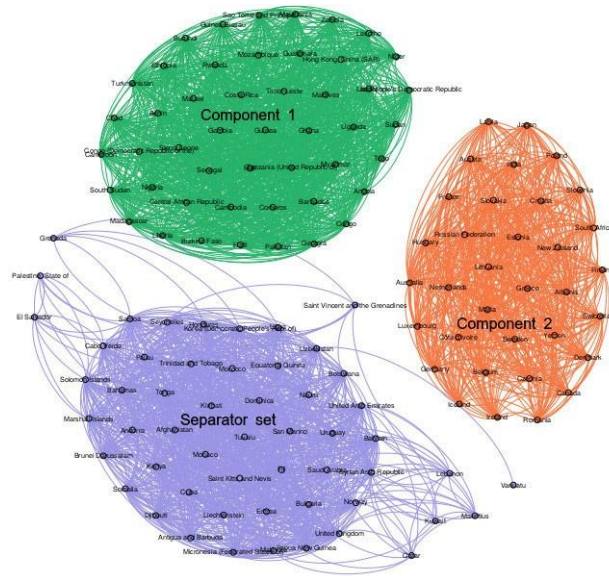


FIGURE3. Graph of the set of countries after the rupture of the MCGC (infection network).

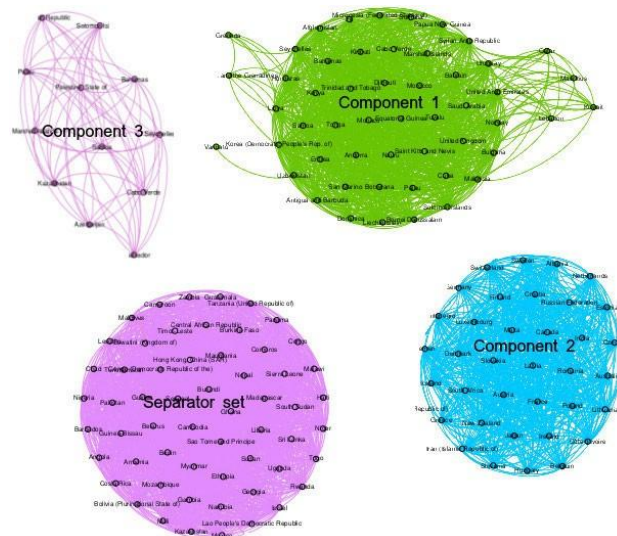


FIGURE4. Graph of the set of countries after the rupture of the MCGC (GDP network).

It should also be noted that in the figure. 4 shows the connection of nodes included in each set of 5 levels. As in the previous case, based on the information shown in the figure.4 and in Table. 4 you can see that in each set there is a separator, component 1, component 2), and those are all attribute values.

For example, in sections 2 and 3, some countries, such as Ghana, Nepal, Uganda, and Egypt (among others), have a low human development index and a high rate of infections and deaths.

For the socioeconomics, GDP and health characteristics, in the separator set (spreaders), are countries as Norway, Switzerland, Germany (among others) that have high values in Human development index (HDI), life expectancy at birth, expected years of schooling, percentage of infected and deaths by day; countries as Costa Rica, Mexico, Colombia, Armenia (among others) that have average values and countries like Nauru, San Marino, Somalia, Tuvalu (among others) have low values.

Infection network	
Separator set	Norway, Ireland, Hong Kong, Australia, Sweden, Singapore, Netherlands, Denmark, United Kingdom, Liechestein, Austria, Luxembourg, India, Israel, France, Lithuania, Andorra, Qatar, Chile, Croatia, Argentina, Kazahstan, Romania, Kuwait, Bahamas, Malaysia, Serbia, Trinidad and Tobago, Iran, Mauritius, Panama, Georgia, Sri Lanka, Cuba, Saint Kitts and Nevis, Antigua y Barbuda, Mexico, Armenia, Algeria, Nicaragua, North Macedonia, Peru, Tunisia, Mongolia, Lebanon, Jamaica, Venezuela, Suriname, Belize, Maldives, Tonga, Turkmenistan, Uzbekistan, Libya, Samoa, South Africa, Gabon, Egypt, Marshall Islands, Viet Nam, Iraq, Morocco, Kyrgyzstan, Mozambique, Tjikistan, Cabo Verde.
Component 1	Brazil, Bangladesh, Colombia, Thailand, Philippines, Guyana, Indonesia, Uruguay, Dominica, Palau, Brunei Darussalam, Kribati, Botswana, Bahrain, Fiji, Central Africa Republic, United Arab Emirates, Honduras, Azerbaijan, Dominican Republic, Palestine, Moldova, Saint Vincent and the Grenadines, Grenada, Saint Lucia, Paraguay, Ecuador, Ukraine, El Salvador, United States, Cyprus, Bosnia and Herzegovina, Spain, Oman, Italy, Korea, China.
Component 2	Congo, Ghana, Belarus, Rwanda, Niger, Togo, Barbados, Senegal, Sudan, Mali, Nepal, Ethiopia, Costa Rica, Belgium, Germany, Hungary, New Zealand, Russian Federation, Estonia, Switzerland, Montenegro, Slovakia, Finland, Slovenia, Malta, Latvia, Yemen, North Macedonia, Algeria, Sweden, Albani, Czechia, Canada.

TABLE 3. Sets of countries after the rupture of the MCGC (infection network).

**B IDENTIFICATION OF SPREADERS OF COVID-19**

In the table. 3 shows the numerical values that can be obtained by modifying the GSP for the MCG Infection, as well as for the GDP in the network. The first column is the identification number for each network; in the second column we give the values of C, and in the third column we give the values of A and B.

Based on the results shown in Table 2, it can be seen that the use of GSP regulation allows you to install many nodes that can cause the failure of the MCGK for 5-layer multiplex networks , as the sum of A , B and C, as well as the isolation of elements (nodes that do not have connections with other nodes, it is equal to the total number of nodes belonging to the MCGK.

In addition, we can guarantee that the networks are not reliable, and that there are many spreader nodes; in this regard, we can conclude that the removal of the left side of the countries where the separator is installed, for the global pandemic caused by COVID-19, can be controlled, since both networks are in C, which is 54% and 56% of the total number of nodes owned by MCGC, respectively.

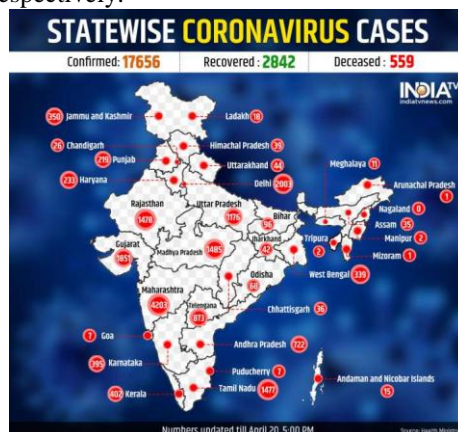


FIGURE 5. State wise CORONAVIRUS cases

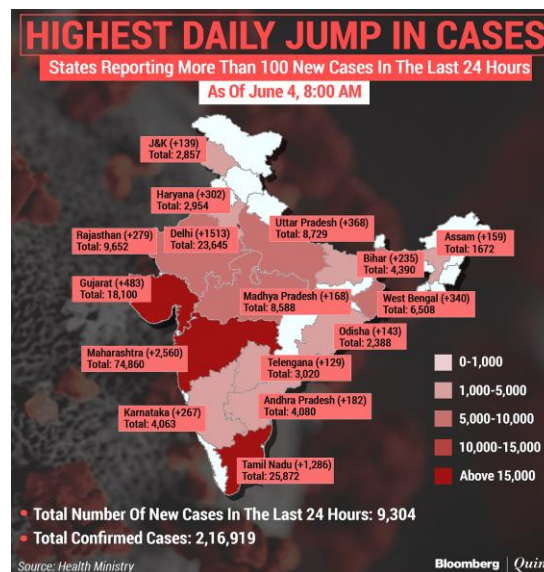


FIGURE 6. Highest daily jump in cases

## V. LIMITATION AND DISCUSSION

The analysis presented in this paper is based on the model of two multiplex networks consisting of 5 layers, each of which shows the similarity of countries and different features.

The concept of the model has five different layers to access only for identifying nodes based on multi-criteria analysis, which reduces the disadvantages of using only one set of nodes; thus, the method is able to identify those countries in which, based on several features, the majority of COVID-19 spreaders.

Do we use a multiplex network approach based on convergence ?????????? A separator whose task is to identify these countries that have as their connections that are in solution at all levels of the network, and are the cause of the collapse of the system, and, as a result, the distributor of COVID-19 countries.

The main advantage of this approach is the ability to obtain information from various related fields, such as economics, health, and transportation. So with this approach, we can quantify the relationships between different countries, as well as the network (s) model to help in understanding the dynamics of the system that needs to be analyzed (in this case, the spread of COVID-19).

It is also important to note that in this work, we can quantify the dynamics of COVID-19 behavior from the information that is available until May 15, 2020.

Therefore, a limitation of the study is that a sudden change in one or more variables causes a change in the dynamics of the system. And then, since most of the information about COVID-19 is updated every day and the choice of distribution countries in which we should find it needs to be maintained, and if the behavior of variables persists, otherwise we will be forced to re-model the networks with a new analysis.

Although we are schematizing the dynamics of the spread of COVID-19 behavior, the analysis is very sensitive to those elements that have changed in one or more layers of the entire multiplex network. However, as long as the code of conduct stores (values are in the range of 95% confidence level of the readings indicated in the table.1, and the parameters of the supplier countries, as it turned out, will not change.

## VI. CONCLUSION

In this paper, we present an analysis of countries that have been suppliers of COVID-19, and are based on the most important social, cultural, economic, political features and relationships, such as GDP, life expectancy and number of flights, as well as the health budget, among other things.

The results show that the methodology can break the 5-layer multiplex network, and help in identifying supplier countries, and view the ranking of countries by their characteristics, which, when combined by distributors, in countries are high, medium or low, in different sociocultural and economic factors; this is, however, a feature that we all share, the importance of airports.





## VII.FUTURE WORK

In the future, this function can be extended to predict the pandemic level diseases such as COVID-19, EBOLA, LASSA FEVER etc. Additional testing on more data sets is essential, and if more data could be accessed such as the current availability of vaccines, the predicted results will be more accurate.

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