



# Evaluation of Factors to Respond to the COVID-19 Pandemic Using DEMATEL and Fuzzy Rule-Based Techniques

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**Abstract** Since social and environmental conditions have changed dramatically in recent years, the spectrum of diseases caused by infections is also evolving rapidly. The outbreak of COVID-19 has resulted in an emergency situation across the globe with significant effects on the population's lives, families, and societies, leading to concerns the World Health Organization. Accordingly, the virus has substantially threatened the Malaysians' public health and contributed considerably to increased healthcare expenses. Since the novel coronavirus was found in China,

Malaysia's government has started its actions according to the World Health Organization procedures and concentrated on addressing and preventing the spread of the infection. The present paper aims to find and evaluate the factors to respond to the COVID-19 outbreak in Malaysia, limiting the outbreak of the disease in this country. This study used the Decision-Making Trial and Evaluation Laboratory (DEMATEL) and Fuzzy Rule-Based techniques to evaluate the factors through a set of questionnaires completed by the health care professionals. According to the data analysis results, movement control order, international travel restrictions, and the mass gathering cancellations were of most importance in the prevention of COVID-19 infections transmission.

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## 1 Introduction

The outbreak of the COVID-19 virus, which caused respiratory problems, was initially emerged on the 31st of December, 2019 in Wuhan, Hubei province of China [1–3]. The virus spread across this country and then worldwide quickly. Several transmission cases by tourists were reported in different countries such as Taiwan, Singapore, Vietnam, Korea, Malaysia, Thailand, Japan, Germany, France, United States, and Australia, leading to serious health emergencies across the world [4]. All the activities were postponed globally due to the virus's outbreak, it is supposed that the public health burden of COVID-19 would be increased, and therefore immediate decisions have to be made [5, 6].

In Malaysia, the first case of COVID-19 was detected on 25 January 2020 and traced back to three Chinese citizens who previously had close contact with an infected person in Singapore [7, 8]. The number of infected persons remained less than 25 till the 1st of March [9]. After that, total COVID-19 cases enlarged gradually, leading to a sharp growth beginning on 14 March. The initial two mortality cases caused by COVID-19 were recorded on 17 March [10]. Following that, the number of death cases increased dramatically, however, the number remained less than 100 till 29 April. Since 30 April, the death rate because of COVID-19 was 1.70%, below the worldwide average of 7.1% [9]. The government forced a two-week Movement Control Order (MCO) beginning from the 18<sup>th</sup> of March to 31 March to decrease community spread and overburdening of the health system [11]. Based on MCO, the number of active cases of COVID-19 reduced gradually and was consistent as infected persons healed from COVID-19. Following the accelerated growth in the third wave's active cases, the Malaysian government organized a Conditional Movement Control Order (CMCO) beginning from 14 October 2020, at which 5768 active cases were recorded [12]. Until 8 November, the total number of cases was 40,209, and the daily number of infected individuals had increased surprisingly [12]. After recognizing the COVID-19 cases, the Prime Minister declared the implementation of the CMCO for Selangor's state based on preventive and proactive efforts.

Several studies have been conducted in terms of COVID-19 disease in the Malaysian context. Mat et al. [7] conducted a study focusing on the massive transmission of COVID-19 infections in Malaysia. They suggested that mass gatherings for religious or other determinations should be canceled and prevented during the COVID-19 pandemic. Another study by Nadzir et al. [13] showed how the estimated pollutants' level decreased to 60% by implementing MCO during the COVID-19 outbreak. Azlan et al. [11] examined the knowledge levels, attitudes, and practices of COVID-19 among Malaysian people. The results of their research showed that the most outstanding respondents (83.1%) had positive attitudes to the effective control of COVID-19, the capability of Malaysia to overcome the disease was 95.9%, and the way the Malaysian government controlling the crisis was 89.9%. Sundarasan et al. [14] investigated COVID-19 and quarantine's psychological influence among university students in Malaysia. They found that from the 983 participants, 20.4%, 6.6%, and 2.8% encountered the smallest to medium, marked to critical, and most severe anxiety levels, respectively. Chung et al. [15], investigated university students' readiness for online learning during the COVID-19 pandemic. They observed that, in general, the participants are slight to moderately willing to practice online

learning. Many of them were not keen on online learning practice due to the absence of student control, self-directed education, and online communication productiveness.

Previous studies have neglected the importance of factors that influence COVID-19 prevention.

Kou et al. [16] highlighted that employing combined Multi-Criteria Decision Making (MCDM) methods to examine the decision problems is significant as the outcomes determined by the several MCDM methods are more reliable than solely relying on one MCDM technique. The Decision-Making Trial and Evaluation Laboratory (DEMATEL) approach has been effectively implemented in multiple disciplines by inspecting complicated political, economic, and scientific issues [17–20]. DEMATEL is particularly useful and beneficial for examining the complex causal relationships using particular measures. The measures depict a contextual relationship among the system's components, in which a number reflects the strength of the effect. Thus, the DEMATEL approach can transform the relationship among the cause and effect of measure into a comprehensible structural framework. MCDM concentrates on effectively ranking choices and reaching the best among various alternatives depending on several measures, which can help decision-makers make decisions accurately [21].

The present study investigates how Malaysia's government deals with the virus and its contribution to the mitigation of the risks associated with the virus. We rely on DEMATEL and Fuzzy Rule-Based techniques to evaluate the factors impacting the prevention of the rapid outspread of the COVID-19 virus. Firstly, the DEMATEL technique was employed to investigate the crucial factors for preventing COVID-19. After that, Fuzzy Rule-Based techniques were used to expose the significance level of determining factors based on the model inputs. This paper is organized as follows. In Sect. 2, the factors impacting the prevention of the rapid outspread of the COVID-19 virus are discussed. In Sect. 3, the methodology is presented. Data analysis results for the DEMATEL and Fuzzy Rule-Based approaches are provided in Sect. 4. In Sect. 5, the discussions on the results are provided. In Sect. 6, the conclusion and recommendations for future studies are presented.

## 2 Factors to Respond to the COVID-19 Pandemic

This study selected the frequently used factors in the previous research to respond to the COVID-19 pandemic in the Malaysian context. This is the first attempt by researchers to examine the factors that prevent the rapid outspread of the COVID-19 virus. As shown in Table 1, these factors comprise social media sharing, governmental

**Table 1** Identified factors in terms of COVID-19 from prior research

Factors	References
Cancellation of Mass Gathering	Karami [22], Tee [23], Crawford et al. [24], Montanez [25], Ahmad et al. [26], Idris [27], Ahmed et al. [28], Escher Jr [29], Alshammari et al. [30]
Movement Control Order	PMO [31], Aitsi-Selmi et al. [32], Sarif, Yahya [33], Yusof [34], Heikal Ismail et al. [35], Abdullah et al. [36], Karim et al. [37], Khor et al. [38], Tang [39], Nadzir et al. [13], Ash'aari et al. [40]
Social Media Sharing	Cinelli et al. [41], Ahani, Nilashi [42], Chinazzi et al. [43], Cuello-Garcia et al. [44], Apuke et al. [45]
International Travel Restrictions	Adekunle et al. [46], Anzai et al. [47], Tognotti [48], Wells et al. [49]
Distance Learning	Rabi et al. [50], Stein [51], Ting et al. [52], Philips [53]
Economic Stimulus Package	Ahmad et al. [54], Dorn et al. [55], Briefings [56]

contributions consisting of mass gathering cancellations, movements control order, limitation of international traveling, and distance learning seem essential. In the following sub-sections, these factors are discussed.

### 2.1 Cancellation of Mass Gathering

Public health authorities have different concerns about mass gatherings, such as the risk of the spread of infections by attendees across the world [22]. Prime Minister Muhyiddin restricted all collective unnecessary social functions such as religious ceremonies, sports, social and cultural activities during 18–31 March to deal with the outspread of COVID-19 [23, 24]. Moreover, to fight against the novel virus outspread, Latin American governments used usual prevention actions such as canceling mass events, classes of schools and universities, closing the borders, and limiting foreign travelers' entrance [25]. Furthermore, according to Aitsi-Selmi et al. [32], the population's mass gatherings as religious pilgrims and sports events can lead to considerable risks such as infection transmission, physical problems, and effects on the local as well as international health systems and services.

### 2.2 Movement Control Order

According to the Ministry of Health's recommendation, Malaysia's government concentrated on the execution of the MCO, aimed at addressing the outspread of the COVID-19 virus. Accordingly, the state authorities could track the cases in all units over the determined period [31]. The order is primarily focusing on the isolation of the virus pandemic source. Prohibiting mass movements and gatherings across the country, such as sporting occasions, social and cultural functions, suspending all religious events in mosques such as the Friday prayers, prohibiting going out of the country along with restricting the entrance of non-Malaysian travelers into the country, closing all

organizations and institutions except for the fundamental services as well as supermarkets, wet market, grocery stores and, those who sell daily necessary items, closing the nurseries, public and private schools consisting of boarding and international schools, secondary and pre-university educational institutes, together with the public and private universities and employment education, were all among the strategies to prevent or isolate the sources of virus spread [33]. Moreover, the general population has been asked to remain at homes and not to break regulations over the determined period toward preventing the virus from spread across Malaysia [34]. There has been a notable decline in traffic and industrial discharge because various industrial and commercial actions were rigorously not permitted during the first MCO phase [35]. During MCO, numerous activities, including operating business, is not permitted, except for necessary services [36].

### 2.3 Social Media Sharing

The modern media context is significantly dependent on social media as an important communication channel for news and information. One out of three individuals worldwide is involved in it, and two-thirds of internet users are utilizing it, along with its application as a critical instrument for public health [57]. In the current digital context worldwide, online platforms have been probably the most readily available sources of information associated with public health issues. These platforms, including Youtube, Instagram, and Twitter, can provide immediate access to vast amounts of content while contributing significantly as the sources of healthcare-associated information [58]. Mainstream platforms, including YouTube and Twitter, have documented the highest volume of interactions regarding the users' posts and comments associated with COVID-19 [41].

Social media is expected to contribute even more considerable in the distribution of information about COVID-

19. As an instance, 255 million active users have been reported to be on Twitter in February 2014 when Ebola was prevalent [59], while the number came to 330 million in 2019 [60]. Social media provide forums for the collection of significant amounts of data that can be beneficial in making users and businesses aware of the current conditions so that they can make correct decisions at the proper time [42]. Moreover, social media can be considered an efficient marketing channel through which the integration of communications and marketing of travel services would be possible [61].

Tourists are growingly dependent on online comments instead of advertisements or guides to select experiences that are more compatible with their interests and expectations from the selected destinations [62]. The increase in social media application in tourism industries can be related to the users' direct recommendations provided by these media in relation to travel and the effective performance of mouth to mouth communications [63]. Thus, the tourists' destination priorities may change considerably through their awareness of the possible risks [64] over the outspread of the COVID-19 virus. As Chinazzi et al. [43] have stated, travel limitations because of COVID-19 outspread will impose moderate impacts, and the interventions aimed at reducing the virus transmission will have the highest advantages for the mitigation of the epidemics.

Based on the Malaysian Prime Minister's Office PMO [65], the government of Malaysia has taken the procedures determined by WHO since the start of the COVID-19 outspread, while the experts have also been advised to address the problem and assist in the prevention of the virus wide outbreak. Prime Minister Muhyiddin restricted all unnecessary social functions such as religious ceremonies, sports, social and cultural activities during 14–18 April to deal with the outspread of COVID-19 and react against the increasing trend of infection spread in Malaysia subject to the Movement Control Order across the country [24]. In addition to enforcing the Movement Control Order along with governmental financial assistance through specific economic packages, Senator Datuk Seri Dr. Zulkifli Mohamad Al-Bakri, Minister in Prime Minister's Department of Religious Affairs, asked Muslim communities to pray across the country. In addition to praying, charities seem necessary at the time of crisis, particularly given the public population's serious requirements to essential items for their survival. All charities and worshipping places have been invited to engage in charitable affairs [66], which seems necessary for the provision of physical as well as spiritual support. This has been predominantly observed in Waqf institutes, which have taken actions in advance in this regard [33].

### 3 International Travel Restrictions

Following the primary period of inactivity, different countries are recently imposing limitations on international travel aimed at the prevention of more importation of the COVID-19 virus into their borders. Nevertheless, considering that COVID-19 has become a worldwide pandemic at present, reaching almost all nations, investigating the effects of persistent travel limitations would seem reasonable [46]. Following restrictions in Wuhan, limitations on travel and control of the borders were carried out by different countries in the form of comprehensive travel bans, travel limitations and quarantines, allowing for restrictions of healthy people, entrance screening for every individual who enters the country, or some combinations of these strategies. Some governments have applied entrance limitations due to the emergence of the novel virus, while visa suspensions and quarantine measures have been considered for travelers [47]. The impacts of the travel ban, which were taken in Wuhan, and the global travel limitations which were imposed by different countries such as Malaysia were aimed at mitigating the outbreak in early February 2020. Travel limitations for disease control can be traced back to a long time ago and have always attracted policymakers as an instrument to calm the public concerns regarding foreign transmission [48]. The majority of modeling studies agreed that serious travel limitations could theoretically delay the outspread of the virus. Even though, according to estimations of one analysis, China's interior travel limitations decreased the speed of exporting SARS-CoV-2 infectious diseases and postponed the outbreak to unaffected cities. Simultaneously, according to another study, restrictions in Wuhan could delay the internal epidemic in China by 3–5 days [49].

#### 3.1 Distance Learning

Cancellation of the public school programs has been started in different countries to control the COVID-19 virus outspread and reduce the public health burden while releasing suggestions on school closure criteria [50]. The closure of educational institutes worldwide is supposed to result in fundamental (and probably unequal) interruptions in students' learning and problems in internal assessment procedures and cancellation of public evaluations for qualification or replacing them with lower-quality alternatives. The enrollments to distance learning programs through online instructional schedules and course accessibility are increasing [51]. According to Ting et al. [52], the ever-growing exploration of virtual online learning platforms aims at eliminating physical contacts. Nevertheless, since the MCO is extended another two weeks, teachers,

parents, and students in Malaysia will adapt to distance learning with schools turning to online classes [53]. Several campuses are employing full-time “instructional designers” at present to facilitate faculty map out courses together with degree programs. Moreover, learning modules, online exercises, virtual laboratories, and measurements are also provided [67].

### 3.2 Economic Stimulus Package

The Malaysian government on 27 March 2020 publicized a stimulus package of 25 billion ringgit (US\$2.3 billion), it is the third since the beginning of the COVID-19 pandemic to delay the economic impacts of its month-long partial nationwide lockdown [68]. This package contains a 25 billion ringgit straight monetary injection by the government which, is intended to support families and business vendors impacted by the economic downturn caused by the coronavirus outbreak. The package could be vital for Small and Medium-Sized Enterprises (SMEs), making up 98 percent of Malaysia’s economy. Support packages for businesses are designed to provide governments with the ability to keep community distance and stay home without worrying about the economic consequences and help keep the economy flooded by supporting the demand side of the economy.

## 4 Methodology

In this research, we used DEMATEL to find the causal relationships among factors impacting the prevention of the spread of the COVID-19 infection in Malaysia. Accordingly, Fuzzy Rule-Based techniques were applied to explore the critical significant influencing factors and expose the importance of determining factors based on the model inputs. The factors which this study aims to investigate on the prevention of infection are Social Media Sharing (SMS), Cancellation of Mass Gathering (CMG), Movement Control Order (MCO), International Travel Restrictions (ITR), Distance Learning (DL), Economic Stimulate Package (ESP). The data collection was performed by a questionnaire, as attached in Appendix A. For data analysis, we applied the DEMATEL technique to find the importance level of factors for preventing disease in Malaysia. The DEMATEL technique and data collection procedure will be described in the following sections.

## 5 DEMATEL

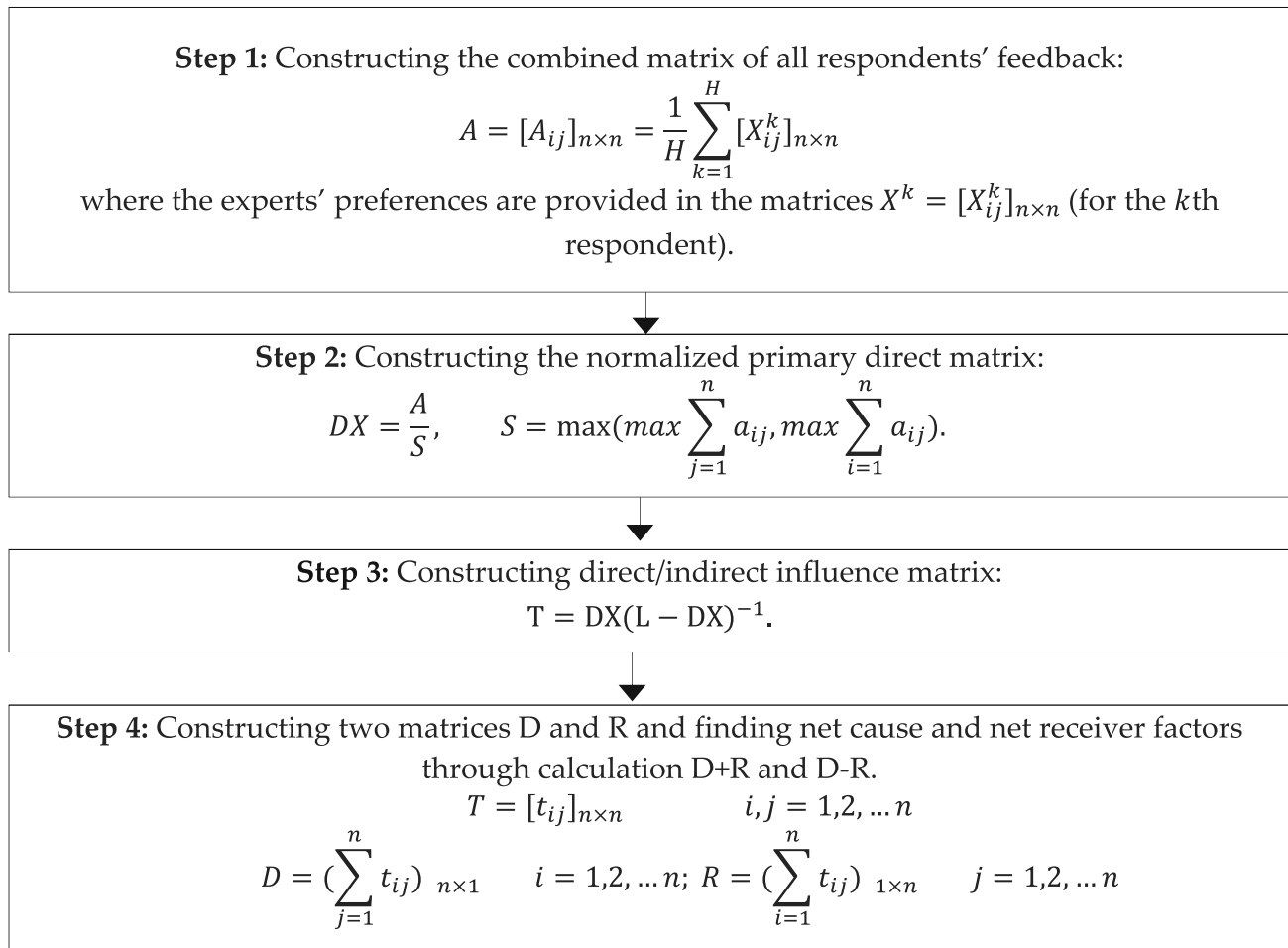
DEMATEL is widely used as a MCDM approach for many real-world decision analyses in recent years [17, 69, 70]. Compared to the other methods, the advantage of this technique is its ability to find the interdependencies among the factors in their impact from the decision-makers’ perspectives. This MCDM approach can also find the relative importance of each factor in the net cause and net receiver groups and plot the network relationship map in the causal relationships, which can be better understood. The digraphs provided by DEMATEL show the direct relationships of sub-systems, representing a communication network. The steps of DEMATEL are shown in Fig. 1.

### 5.1 Mamdani Fuzzy Rule-Based Systems

Fuzzy logic is identified as a useful approach for handling the nature of uncertainty in human mistakes [71–73]. The fuzzy logic applications have been successfully investigated in several areas for handling complex problems directed to uncertainty [74–76]. The fuzzy system classifies complex decision-making difficulties into an easy hierarchical structure and then conducts evaluations by pair-wise comparisons. Fuzzy logic enables researchers to examine the input data imprecision and vague it comprehensively, and generate a more consistent model for calculating input–output relations [77].

Mamdani Fuzzy Rule-Based Systems (MFRBS) is the fuzzy model and a well-known soft computing approach proposed by Mamdani [78]. In a widespread sense, fuzzy rule-based methods are rule-based methods, where fuzzy sets and fuzzy logic are utilized as mechanisms for expressing various kinds of knowledge regarding the problem at hand and modeling the communications and existing relations among its variables [79, 80]. Each rule’s output is a fuzzy set in this type of Fuzzy Inference System (FIS) (see Fig. 2). As Mamdani Fuzzy Inference System (FIS) has more intuitive and easier to understand rule bases, it is well-suited to expert system applications. For the inference process of the Mamdani fuzzy inference system [81, 82], two fuzzy rules (Rules 1 and 2) are presented, where  $x_i$  and  $y_i$  are input values for the fuzzy input set  $A_i$  and  $B_i$ ,  $C_i$  is the fuzzy output set, and  $\mu_{C_j}(z_j)$  is the membership degree of the output value  $z_j$  (see Fig. 3). The defuzzied output  $z_c$  is obtained using the centroid method as presented in Eq. (1).

$$z_c = \frac{\sum_{j=1}^k \mu_{C_j}(z_j) \cdot z_j}{\sum_{j=1}^k \mu_{C_j}(z_j)} \quad (1)$$



**Fig. 1** Overview of DEMATEL procedure

## 5.2 Data Collection and Analysis

The quantitative method was used in this study, along with questionnaires, to gather the required data. Data were gained by using the DEMATEL questionnaire survey (see Appendix A) of 22 experts applying purposeful sampling. Data collection was performed referring to the key knowledgeable people in health sciences and health care management, including public and private healthcare administrators at Malaysian universities. As for the educational level, 46.1% of the respondents have graduate degrees, followed by 31.2% of respondents as college graduates, and 22.7% of respondents as high-school graduates. More than three-quarters (77.6%) of the respondents had more than eight years of healthcare experience. Furthermore, most of the respondents were female (65%), and the rest were male (35%). Despite the classical Structural Equation Modeling (SEM) method that needs an extensive research sample size to derive causal associations of factors, the DEMATEL, and fuzzy logic techniques can give acceptable research results from an almost small sample

size through experts' perspectives [83]. Additionally, studying the literature about the defined sample sizes for DEMATEL determines that the maximum number of the studies employed a sample size between 10 and 30 [84–86]. Thus, a sample of 22 experts was enough to collect data in the present study for analyzing DEMATEL and fuzzy logic techniques.

## 6 Data Analysis

In this research, DEMATEL and Mamdani FIS are employed for data analysis. The results for these techniques are presented in this section.

The average matrix was identified in the first step of the DEMATEL technique. A pairwise comparison between factors established the measurement scale. Likert-scale at the range of 0 to 4, indicating “no influence”, “low influence”, “medium influence”, “strong influence”, and “very strong influence”, correspondingly was employed. In the next step, the overall average impact value was

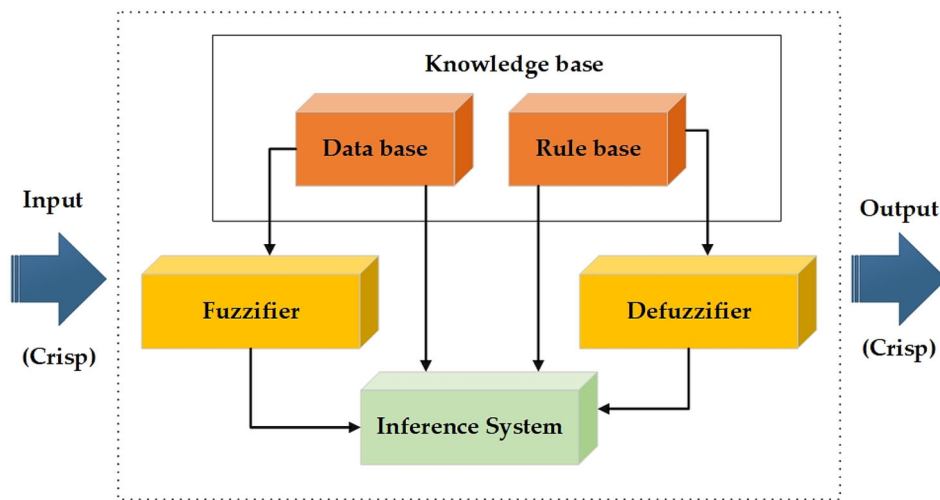


Fig. 2 Structure of fuzzy rule-based system

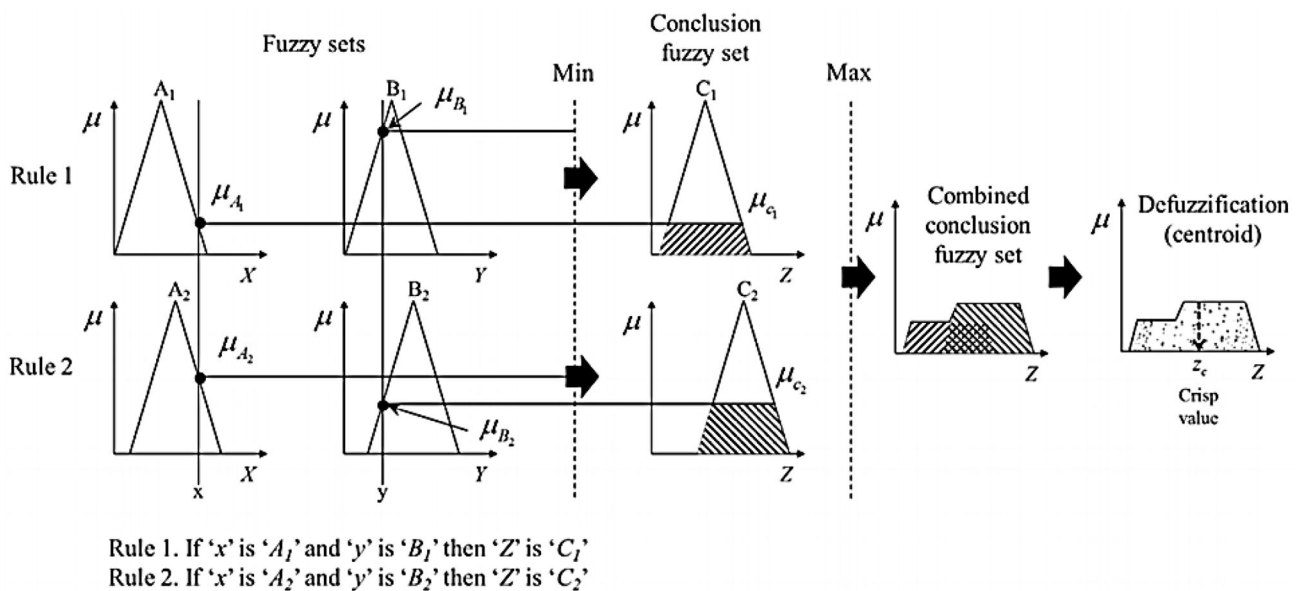


Fig. 3 Mamdani fuzzy inference system [81]

determined for all respondents, and then the normalized initial direct-relation matrix was calculated. The average of the twenty-two responses was employed to develop the average matrix (see Table 2). The normalized initial direct-relation matrix was calculated through the normalization of the average matrix (see Table 3). The computation of the total relation matrix is was performed (see Table 4). It was possible to obtain the total relation matrix by the use of simple numerical calculations as represented in Step 3 in Fig. 1.

The net cause and net receiver factors were obtained from the total relation matrix. The results are presented in Table 5. Calculation of the value of each column (D) and row (R) was eventually performed by the use of equations

in Step 4, as indicated in Fig. 1, so that the prominence (D + R) and relation (D–R) could be obtained. According to the results, the significance of factors based on their weights is social media sharing, cancellation of mass gathering, movement control order, international travel restrictions, distance learning, and economic stimulate package. Moreover, according to findings, social media sharing, distance learning, and economic stimulate packages were affected by other preventive factors of COVID-19. Finally, a threshold value was calculated, and the impact-relation map was obtained. It was necessary to eliminate some inappropriate impacts from the total relation matrix in order to illustrate the structural associations between the factors. The average value of the normalized

**Table 2** Average matrix

Factors	SMS	CMG	MCO	ITR	DL	ESP
Social Media Sharing (SMS)	0	2.45	2.95	2.6	2	2.2
Cancellation of Mass Gathering (CMG)	2.4	0	2.5	2.75	2.8	2.7
Movement Control Order (MCO)	2.45	3.05	0	2.95	3.25	3.15
International Travel Restrictions (ITR)	2.9	2.6	3.1	0	3.2	2.95
Distance Learning (DL)	2.45	1.9	2.25	2.45	0	2.8
Economic Stimulate Package (ESP)	2.65	2.35	1.65	1.7	1.85	0

**Table 3** Normalized initial direct-relation matrix

Factors	SMS	CMG	MCO	ITR	DL	ESP
Social Media Sharing (SMS)	0	0.16	0.2	0.18	0.13	0.15
Cancellation of Mass Gathering (CMG)	0.16	0	0.17	0.19	0.19	0.18
Movement Control Order (MCO)	0.16	0.21	0	0.2	0.22	0.21
International Travel Restrictions (ITR)	0.2	0.18	0.21	0	0.22	0.2
Distance Learning (DL)	0.16	0.13	0.15	0.16	0	0.19
Economic Stimulate Package (ESP)	0.18	0.16	0.11	0.11	0.12	0

**Table 4** Total relation matrix

Factors	SMS	CMG	MCO	ITR	DL	ESP
Social Media Sharing (SMS)	0.89	1	1.03	1.01	1.02	1.07
Cancellation of Mass Gathering (CMG)	1.08	0.9	1.05	1.06	1.11	1.15
Movement Control Order (MCO)	1.18	1.17	1	1.17	1.23	1.28
International Travel Restrictions (ITR)	1.2	1.14	1.17	1	1.22	1.26
Distance Learning (DL)	0.99	0.94	0.96	0.97	0.86	1.06
Economic Stimulate Package (ESP)	0.9	0.86	0.83	0.83	0.87	0.79

**Table 5** Prominence and relation results obtained by DEMATEL

Factors	D	R	D + R	D - R
Social Media Sharing (SMS)	6.02	6.23	12.25	- 0.21
Cancellation of Mass Gathering (CMG)	6.35	6.01	12.36	0.34
Movement Control Order (MCO)	7.03	6.04	13.07	0.99
International Travel Restrictions (ITR)	7.00	6.04	13.04	0.96
Distance Learning (DL)	5.78	6.3	12.08	- 0.52
Economic Stimulate Package (ESP)	5.07	6.61	11.68	- 1.55

direct-relation matrix obtained equal to 0.07. Thus, the importance of the factors are shown in Fig. 4. Visualization of the sophisticated causal associations was possible when the impact-relation map was drawn for the factors.

According to the impact-relation map matrix results (Table 6), movement control order affected all factors regarding preventing COVID-19 disease. Cancellation of the mass gathering was also affected by social media sharing, movement control order, international travel restrictions, distance learning and economic stimulate

packages. In contrast, distance learning affected the economic stimulate package. Moreover, international travel restrictions affected the cancellation of mass gatherings, social media sharing, movement control order, distance learning and economic stimulate package. The findings also indicated that the economic stimulate package was significantly affected by movement control order, cancellation of mass gathering, social media sharing, international travel restrictions, and distance learning.



The data analysis was further extended to the Mamdani fuzzy inference system. In a fuzzy rule-based system, we have applied different membership functions which are Gaussian and Triangular membership functions. Specifically, we considered Gaussian membership functions for the inputs and Triangular membership functions for the output (see Fig. 5). The linguistic variables for the inputs are: Low, Moderate, and High. We have considered five linguistic variables for the output: VLow, Low, Moderate, High, and VHigh. These linguistic variables are used to form the fuzzy rules in the FIS.

The data provided by the experts was collected and the fuzzy rules were extracted to be used in the inference process of the Mamdani fuzzy inference system. The extracted fuzzy rules are presented in Table 7. The fuzzy rules played an essential role in the prediction of Respond to the COVID-19 Outbreak through the input variables. It

is seen that a total of 27 fuzzy rules were discovered from the data. The fuzzy rules are in the form of IF-THEN. These fuzzy rules are used in FIS to assess the level of Respond to the COVID-19 Outbreak according to the levels of Movement Control Order, International Travel Restrictions, and the Cancellation of Mass Gathering.

From Table 7, the first fuzzy rule is: IF [Cancellation of Mass Gathering = High] AND [Movement Control Order = High] AND [International Travel Restrictions = High] THEN [Respond to the COVID-19 Outbreak = VHigh]. This indicates that for three input variables, “Cancellation of Mass Gathering”, “Movement Control” Order and “International Travel Restrictions“ if they are in the high level, the output (i.e., Respond to the COVID-19 Outbreak) is in very high level. In addition, from the third fuzzy rule, IF [Cancellation of Mass Gathering = Low] AND [Movement Control Order =

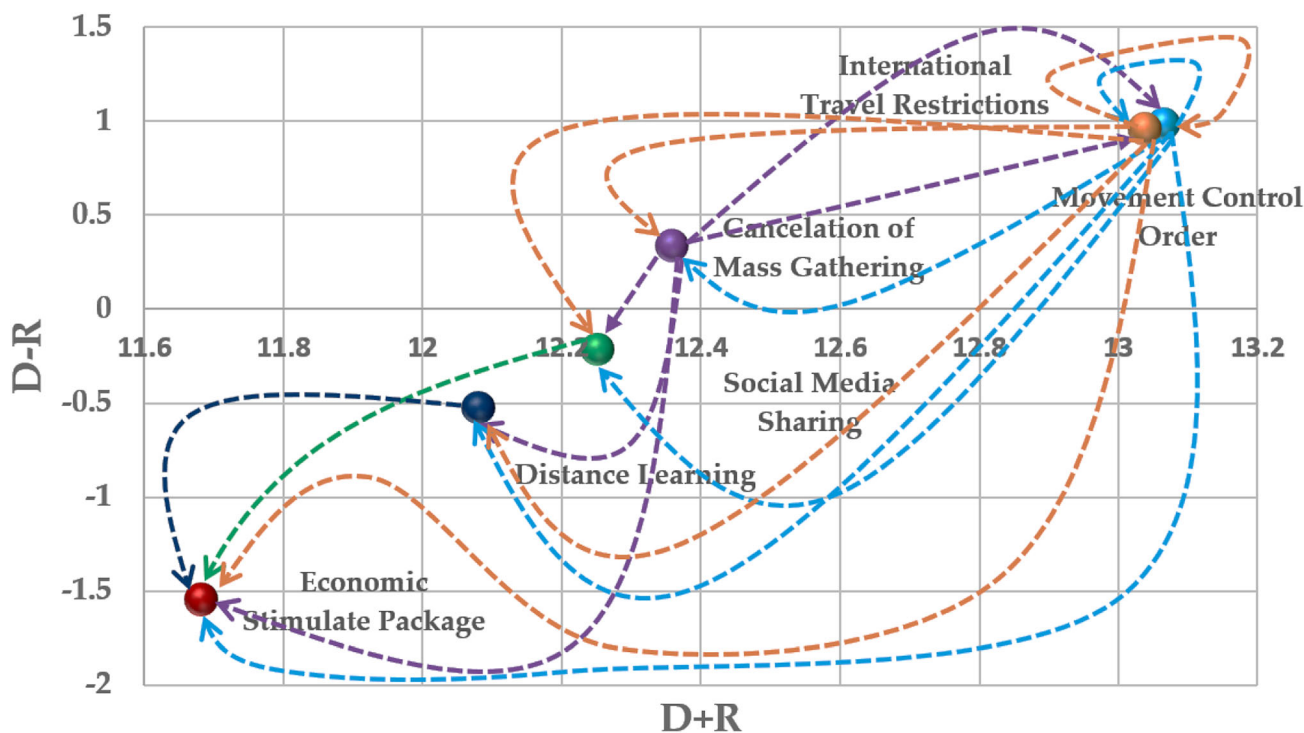


Fig. 4 Interactive influence between the six factors for responding COVID-19

Table 6 Impact-relation map matrix

Influence	SMS	CMG	MCO	ITR	DL	ESP
Social Media Sharing	-	-	-	-	-	→
Cancellation of Mass Gathering	→		→	→	→	→
Movement Control Order	→	→	-	→	→	→
International Travel Restrictions	→	→	→	-	→	→
Distance Learning	-	-	-	-	-	→
Economic Stimulate Package	-	-	-	-	-	-

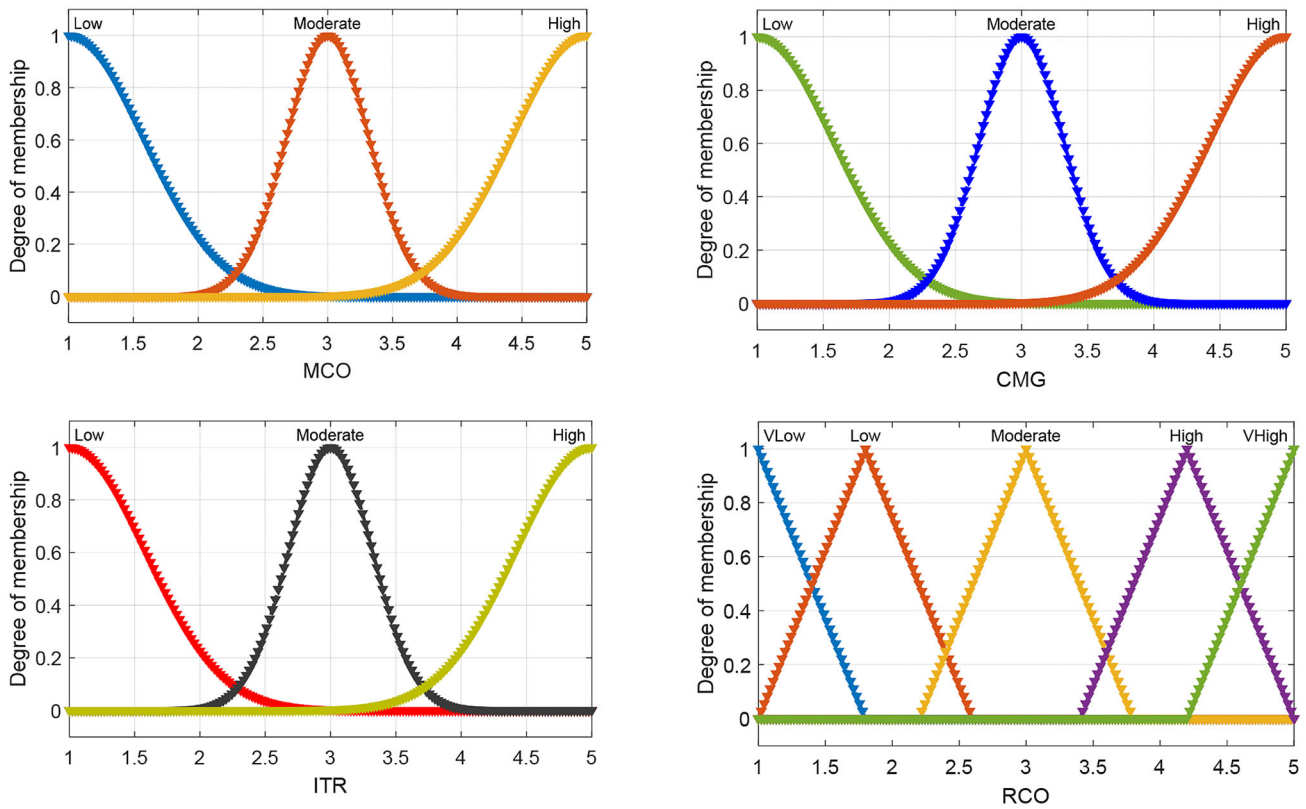


Fig. 5 Membership functions for system design

Table 7 Extracted fuzzy rules

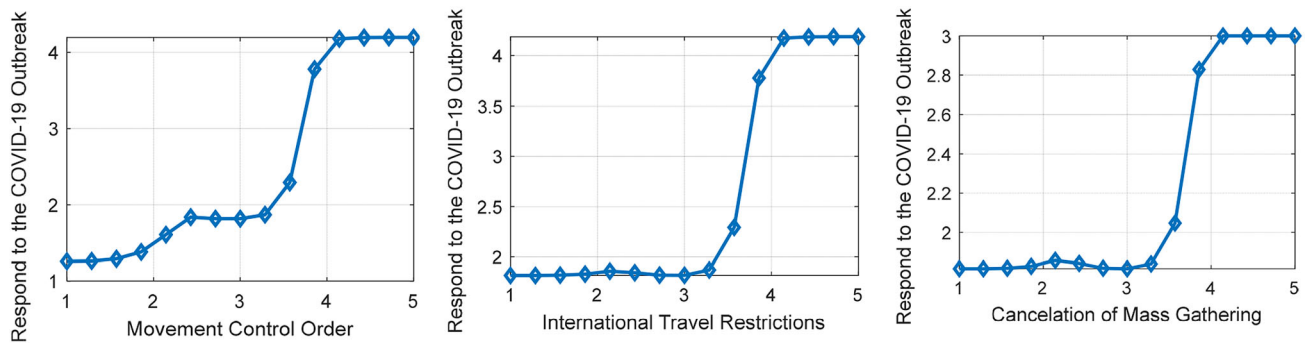
Rule #	Movement Control Order	International Travel Restrictions	Cancellation of Mass Gathering	Respond to the COVID-19 Outbreak
1	High	High	High	Very High
2	High	High	Moderate	Very High
3	High	High	Low	High
24	Moderate	Low	Low	Low
25	Moderate	Moderate	High	Moderate
26	Moderate	Moderate	Moderate	Low
27	Moderate	Moderate	Low	Low

High] AND [International Travel Restrictions = High] THEN [Respond to the COVID-19 Outbreak = High]. This indicates that for Cancellation of Mass Gathering in low level and two input variables Movement Control Order and International Travel Restrictions in the high level, the output (i.e., Respond to the COVID-19 Outbreak) can be obtained in a high level. These results can be better shown in Figs. 6 and 7. In Fig. 6, the outputs are shown in 2D plots. In Fig. 7, 3D-plots of the surface view of the FIS are shown. From the results, it is clear that there is a positive relationship between the levels of Movement Control

Order, International Travel Restrictions and Cancellation of Mass Gathering, and Respond to the COVID-19 Outbreak.

### 7 Discussion

This study suggested several strategies for the government to help reduce the spread of the COVID-19 virus in Malaysian. The government’s communication procedures toward enhancing the general population’s awareness about the best ways to avoid the disease spread and additional



**Fig. 6** The output for rule-based system

support for the management of economic challenges are of great importance. The proposed study applied the DEMATEL and fuzzy logic techniques to identify the most significant factors for the spread of COVID-19 prevention in the Malaysian context. As indicated, the preventive factors of spreading this virus in Malaysia can be considerably associated with social media sharing, cancellation of mass gathering, movement control order, international travel restrictions, distance learning, and economic stimulate package.

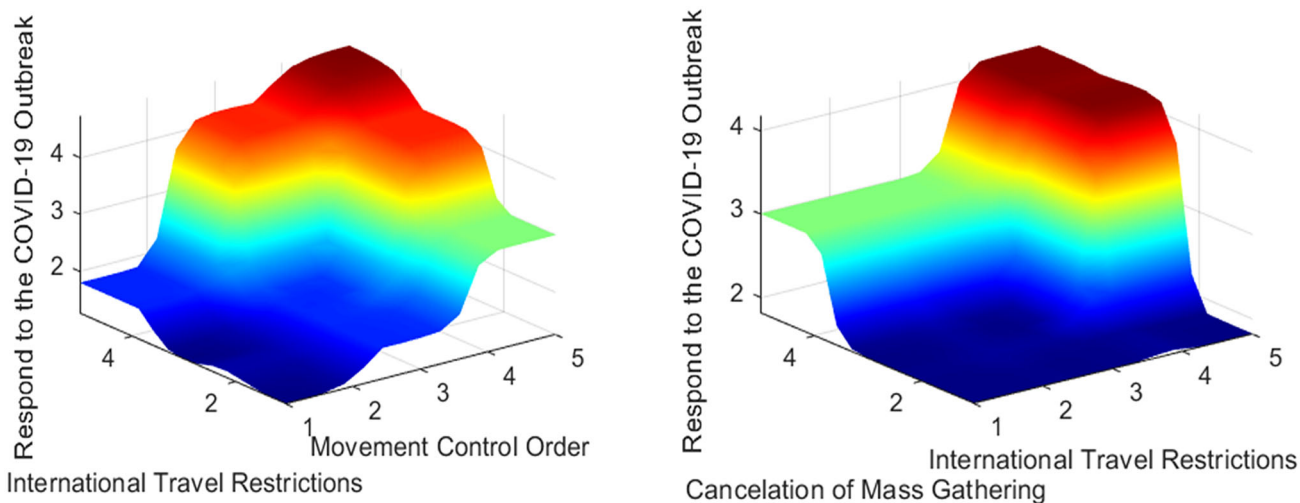
Based on the results of DEMATEL analysis, from the decision-makers' point of view, movement control order was regarded as the most influencing factor to decide regarding the prevention of COVID-19 spread in the Malaysian context. Regarding the most recent outspread of COVID-19, the Malaysian government's Movement Control Order was continued up to June 9, which was the fourth extension since March 18. Foreign and interstate travels were forbidden subject to the order, and citizens could leave their homes only for necessary shopping, leading to a nearly dead stop in the economy. No vaccines or efficient antiviral drugs are potentially accessible in the near future. Therefore, the only mitigating procedures at hand include voluntary as well as mandated quarantine, cancellation of mass gatherings, closing educational institutions or places of work that have been exposed by the infection, and isolating households, towns, or cities. According to Park et al. [87], although social distancing can ultimately prevent the outspread of the infection alone, its potential in flattening the epidemic curve would decrease the burden on the healthcare system. It can supply additional time to design and consider future plans.

As the DEMATEL method results indicated, international travel restriction was the second significant factor by the decision-makers to control and moderate the COVID-19 expansion. Therefore, it was found that limitations on international travel by Malaysia's government affect the prevention of COVID-19 rapid spread significantly. This finding is consistent with the results of Adekunle et al. [46],

who employed international flight data and disease transmission models for the prediction of national epidemic trajectories if the traveling restrictions were not imposed. According to the results of Costantino et al. [88], limitations of traveling affected the control of COVID-19 outspread in Australia considerably and prevented a broader and more extensive epidemic. Therefore, travel limitations are expected to have moderate impacts on the areas which have been already exposed by COVID-19. Simultaneously, interventions aimed at reducing transmission can result in the most significant benefits of epidemic mitigation.

Canceling or suspending the mass gatherings seems essential to mitigate the pandemic based on the results of DEMATEL and decision-makers' selection. While mass gatherings are regarded as the central determinants of the epidemiologic development of the disease outspread [11]. It was found in the present paper that canceling mass gatherings by the government of Malaysia has affected the prevention of COVID-19 rapid spread significantly. This finding agrees with the results of Anderson et al. [89], who indicated that the avoidance of people's large gatherings would decrease the number of super-spreading events. Nevertheless, if more extended contacts are needed for transmission, this action may reduce a small proportion of transmissions. Thus, broader-scale social distancing would probably be required, as was carried out by the Chinese government.

Social media sharing was found as a critical factor from the decision-makers' point of view toward COVID-19 prevention practices in Malaysia. Thus, in this paper, social media contribute significantly as an information source to enhance the awareness of population and travelers = and facilitate the prevention of COVID-19 rapid spread. Xiang, Gretzel [90] found that social media are actually a fundamental component of online tourism and can contribute considerably to travel planning through search engines. Social media platforms, including YouTube, and Twitter, make a tremendous volume of content available directly and reinforce rumors and doubtful information. Meantime,



**Fig. 7** The output for rule-based system 3D plots

Cinelli et al. [41] performed the analysis of mainstream platforms, including Twitter, Instagram, and YouTube, along with less regulated social media platforms consisting of Reddit and Gab. They indicated that topics were relatively the same, along with every social media platform. Comments ranged from comparing the current virus with other viruses, requesting God's blessing, to racist ideas, whereas the most incredible form of interactions was associated with the cancellation of flights. Furthermore, according to another finding in this paper, MCO by Malaysia's government affected the prevention of COVID-19 rapid spread significantly. The Malaysian government considered prevention measures via Movement Control Order on the 18th of March 2020 by preventing and controlling infectious diseases. According to Ahmad [91], the Malaysian government enforced the same law in 2010 to prevent malaria.

Eventually, other results by the DEMATEL approach and decision-makers' perspectives showed that distance learning could significantly impact the prevention of COVID-19 rapid spread. The outbreak of the virus profoundly affected the economic world, and the educational settings experience the effects. This finding is in line with the results of Abidah et al. [92], in which some regions closed their schools for the prevention of COVID-19 outbreak. The ministry of education and culture has provided different facilitating strategies to keep on their education. In this regard, distance learning applications have been developed according to electronic portals and applications' availability. Conventional and routine learning styles emphasizing the teachers' and learners' interactions have changed to distance learning.

The fuzzy rule-based also are used in the fuzzy inference system to assess the level of response to the COVID-19 outbreak. This method is utilized to reveal the hidden

relationships between significant factors. Therefore, fuzzy rule-based results showed a positive relationship between the levels of a movement control order, international travel restrictions, and the cancellation of mass gathering in response to the COVID-19 outbreak.

## 8 Conclusion and Recommendations

The government of Malaysia has taken the procedures determined by WHO to reduce the outbreak of the infection caused by COVID-19. At the same time, the experts in the country have also been requested to address the problem and assist in preventing the virus outbreak worldwide. According to the findings of the current study, factors including social media sharing, canceling mass gatherings, control of the movements, restrictions on international travels, and distance learning can significantly affect the prevention of COVID-19 increasingly rapid outbreak. The COVID-19 outbreak has had considerable impacts on people's lives worldwide. Considering that no particular medicine has been found for it yet, prevention approaches seem essential. Thus, over this increasingly rapid emergence of the infection, learners and educators should be more flexible, while there is an evident need to investigate learning strategies that have not been well-studied before. Limitation of physical contacts through engagement in social distancing can help in the reduction of the virus outbreak. People's mass gatherings at religious ceremonies and sports will be associated with different health risks such as infection transmission, physical injuries, and effects on the local and international health systems and services. Therefore, the fights against the outbreak of travel-associated infectious problems and other risks increased by globalization, arising from mass

gatherings, should be considered a common commitment among all countries, sectors, and different contexts to get beneficial outcomes in risk reduction. Moreover, at the society level, the public population is supposed to keep away from crowded places and put off their unnecessary travels to destinations that can increase the continuous transmission challenge. In addition, as the virus has spread globally, reaching many areas of the world, investigating the effects of persistent travel limitations will be reasonable. Nevertheless, the limitations are expected to result in more favorable outcomes.

Before generalizing the results of the study, some of its limitations need to be presented. First of all, the principle of mass gathering, control of movements, restrictions on international travels, and distance learning effects on the control of disease spread has been illustrated in the present study focusing on the Malaysian context. The results of this study can be generalized to other countries. It is recommended for future researchers to consider a large sample population to achieve high result validity. For instance, with a large sample size, the clustering method can be performed for extracting fuzzy rules. Nevertheless, more studies are required to investigate other significant factors in preventing the COVID-19 rapid outbreak. Furthermore, for improving the accuracy and reliability of the achieved outcomes, integrated methods can be applied, i.e., using different MCDM tools along with DEMATEL methodology. Moreover, our method can be optimized with the help of new fuzzy methodologies developed in the previous research [93–95]. As this study focused on Malaysia as a scope of the research, future comparative studies might be conducted to extend the generalizability to entail other regions and compare their outcomes. Although the DEMATEL approach can present good results from a small sample size, future research might focus on deploying different statistical techniques with larger sample sizes that could include other decision-makers among organizations’ staff and business sectors. The outcomes of their studies can then be compared with the results of this research.

### Appendix A: Study Questionnaire

The COVID-19 pandemic has caused an unprecedented global crisis and led to many deaths, economic hardship and the disruption of everyday life. Malaysia’s preparedness and planning began in December 2019, when they first heard from Chinese authorities that there were cases of acute respiratory illness. The present study investigates how Malaysia’s government is dealing with the virus and its contribution to the mitigation of the risks associated with the virus. Therefore, we want to evaluate the factors impacting the prevention of the rapid outspread of the

COVID-19 virus. First, understanding these factors can aid us in moving in that direction. Second, it can help health administrators respond more effectively to the pandemic and ensure necessary care access.

Please specify the effect of the factor in the row on the factor in each column using one of the values (“no influence = 0”, “low influence = 1”, “medium influence = 2”, “strong influence = 3”, and “very strong influence = 4”). Be assured that your responses to the questionnaire are for research purposes only and will not be used outside of this study. Finally, we appreciate your participation in this study. If you need the research results, we will be happy to provide professionals with the study outcome.

Thank you.

### Part I. Demographic Information

**Gender:**

Male  Female

**Age:**

18–25  26–35  36–45  46–65  66 and above

**Education level:**

High School  College  Graduate School

**Field of expertise:** .....

**Experience in your field:**

< 3 years  3–5 years  6–8 years  > 8 years

**Part II. Comparison of the impact of the 6 factors (Please fill out the compared level of 6 factors in the following table)**

Factor	SMS	CMG	MCO	ITR	DL	ESP
SMS						
CMG						
MCO						
ITR						
DL						
ESP						

Social Media Sharing (SMS); Cancellation of Mass Gathering (CMG); Movement Control Order (MCO); International Travel Restrictions (ITR); Distance Learning (DL); Economic Stimulate Package (ESP)

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