30

A two-level deterministic reasoning pattern to curb the spread of COVID-19 in Africa

Olumide Mohammed Lawal, Olufunke Rebecca Vincent
DEPARTMENT OF COMPUTER SCIENCE, FEDERAL UNIVERSITY OF AGRICULTURE ABEOKUTA, ABEOKUTA, OGUN STATE, NIGERIA

1. Introduction

The pandemic virus outbreak of COVID-19, which erupted in China, has necessitated the urgent intervention of science in the public health sector to rescue the situation as fast as possible [1]. Although some related viral infections such as **Psittacosis** had been in existence and associated with birds takes its tolls on the respiratory system [2]. China responded more quickly against this outbreak of the virus [3]. Yet, its active measures to prevent the spread of disease across other countries were to no avail until the United Nations and other concerned countries took steps to help it [4]. Still, the process failed and was later elevated to the pandemic level [5].

Cases of COVID-19 in some highly populated countries in Africa, such as Nigeria, South Africa, Egypt, Kenya, Morocco, and Tanzania, suddenly rose within a few weeks. Research associated this rise with international interactions and business optimism [6,7]. Suspected cases of COVID-19 grew within these countries even though international airports shut down their operations. However, the spread of COVID-19 in each of these countries is still being monitored internally [2]. Though, COVID-19 was being recognized as an epidemic, and was decreasing in China, some countries outside of China, such as France, Iran, Japan, Germany, America, Italy, and South Korea, were recording more than a dozen cases [4]. Awareness of symptoms such as a high fever, constant cough, the inability to breathe comfortably, tiredness, and headaches, was echoed daily by authorities [8].

As a result of the inability to curb the spread of COVID-19 at an early stage, the pandemic spread to many countries through international associations. Thus, affected countries have to take to the advice of the United Nation's preventive strategy rules regarding social distancing, regular hand washing, the use of face masks, and other hygienic culture [9]. Some countries have gone so far as to close of their international

Data Science for COVID-19. https://doi.org/10.1016/B978-0-12-824536-1.00017-4

airport and other international and local businesses [10]. All of these measures were taken to mitigate the spread of the disease and monitor the rate at which people have contracted it while the hope was for a possible vaccine to prevent the spread.

Researchers studied and designed some statistical models and reasoning patterns for COVID-19 and how to mitigate its spread and the future occurrence of other pandemic diseases [8]. However, the data traits of this virus may have been characterized by risk minimization and optimization inaccuracy [2,11]. In Artificial Intelligence, modeling often deals with the production of knowledge over parameters, which is different from other new theories that are usually fed into the prior knowledge to extend [11]. Thus, the Petri net is consider in this study.

The Petri net is used to analyze and clarify areas such as medical-related problems and e-commerce. For instance, an outbreak of a vapor cloud was studied and the effect was modeled with a Petri net to mitigate the impact of the outbreak and combat its future occurrence. The cascading and domino effects of the vapor cloud explosion effect were analyzed by measuring the probabilistic analysis of the model of the domino and cascading effects of vapor cloud explosion [7]. The efficiency of the model was applied to a gasoline storage tank. The impact of one incidence was measured on other implications, which resulted in the conclusion that there was always a linking effect of one accident on others, with the use of the Petri net as a viable measure of the model [1,12]. The statistical analysis and proofs of this Petri net model on the vapor cloud explosion were also measured; the result proved worth using for other incidents.

The structure of security and the characteristics of a business process for e-commerce were also modeled and analyzed with Petri nets [13,14]. Random data were used to consider the security structure of the business; they exhibited some inadequacy in the security of the company when processed [15,16]. Moreover, other functions of e-commerce were analyzed to measure illegal behaviors of e-commerce. Both models were analyzed with a three-dimensional matrix. Random data associated with some illegalities for the e-commerce site compromised the business. In contrast, those of the structured data security were immune to security breach. Thus, the Petri net was not viable for it [10,16,17].

To develop a faster model for the Petri net, a statistical model, together with graphic processing, was used as a hybrid model. The study created a faster and low-cost Petri net in which the computational characteristics of this Petri net were worth acceptance in the implementation space [18,19]. The probabilistic behavior of the model was measured with a Monte-Carlo simulation. Ultimately, the computational implication of the model was based on parallelization to ensure high decision-making for managing infrastructure in industries. The model resulted in sophisticated PN modeling with rapid computation primarily when it was used for desktop computers. However, the final analysis of the model showed that the model is computationally high for implementation for commercial use [20].

Also, a bowtie model was used to modify the Petri net, which is often used as a tool to restructure assets, redirect operations, and make some policies to exhibit a level of adequate maintenance and inspection to create good conditions for any system within which it is implemented [21,22]. The Petri net was simulated with the Monte-Carlo simulation framework to ascertain its viability and performance over other time-based Petri net models. Moreover, the bowtie model was used to check the results of the proposed Petri net model by analyzing the risks involved. The model was then suggested to have made the initial condition of an asset for which it was used distinctive against a well-known approach of the bowtie model in assessing the operation of the asset [23,24].

An optimization algorithm was used to extract information and execute the cast and time for a business process. It achieved a highly rewarding result, and a genetic algorithm was merged with the colored Petri net to extract further information from the business process. The obtained data were laced with some resource schemes of the genetic algorithm [25–27]. The result of the simulated model was analyzed on the genetic algorithm population and was fit for ranking and calculation, selection, mutation, and crossover operators until the specific predefined difference was observed [28–31]. This enabled a business process with a high desire level, resulting in allocation of the scheme.

Another model was developed with a colored Petri net. The model was seen to be flexible with the modeled variable. The colors were used as a token to solve the complex system for service and supplies [32]. However, the graphic potential showed that it was suitable for supplier selection, despite the ease of implementing the algorithm. The response time of the algorithm was slow when it was used with more than 50 type of supplies. The model was also good for future research when artificial intelligence techniques were built with it. Also, fuzzy logic was used to boost the performance of the model and proved that quantitative analysis was optimized for logic and linguistic rules [33,34].

According to another perspective, functional programming of a high order with Petri net could provide an excellent semantic business process for business process modeling that is different from object-oriented semantics [35]. The behaviors prove useful primarily when related they are to Haskell language, which is beneficial because it helped develop a generator that translates business processes automatically into a functional programming model [36,37]. This model is more complicated but useful and efficient when it is used as a simulator on a graphical user Interface. Then, functional programming and object-oriented programming were compared for the benefit of the adjoining Haskell language.

Petri net modeling and optimization are aimed at creating a system that increases knowledge awareness, such as a case of pandemic disease. In addition, this Petri net model is built on devising ways of reasoning, which entails building a real-time process based on interactions between interdependence with prior knowledge in space [38,39]. Petri net deals with undecidable but desirable uncertainties with true or false in the embedded statistical distribution model [40,41]. Also, ideas that are outside the designer's knowledge background, together with organized knowledge to clarify new ideas, were designed to solidify the theory that is considered viable compared with the rest [42].

This study presents a modified Petri net model based on a two-level deterministic pattern to curb the spread of the pandemic, COVID-19. COVID-19 data were analyzed and modeled in the Petri net to detect the rate at which people contract the virus. The spread of COVID-19 is modeled with the Petri net and normal distribution as a two-level reasoning pattern to curb it. Six countries in Africa (Nigeria, South Africa, Egypt, Kenya, Morocco, and Tanzania) were considered to be case studies. The data include suspected cases, confirmed cases, deaths, and discharged cases and were modeled to forecast future pandemic diseases.

2. Proposed two-level deterministic reasoning pattern for COVID-19

The spread of COVID-19 is modeled with the Petri net and normal distribution as a two-level reasoning pattern to curb the spread of disease. Six countries in Africa (Nigeria, South Africa, Egypt, Kenya, Morocco, and Tanzania) were used as case studies, and the data of different cases of COVID-19, which had details about the confirmed cases, deaths, and discharged cases, were modeled to forecast possible future pandemic diseases. Data for suspected cases were used as universal data from which death and discharge data were sieved from the raw data collected [43,44].

This work first classified the raw category of data by checking for the rate at which the three incidences occurred with the Petri net. On this basis, the average rate of the three occurrences were known for normal flow or transition in the general incidence occurrences [45,46]. This flow produces the two main Petri net diagrams for statistical generalization of the occurrence of COVID-19 incidences. The result of the transition in the Petri net suggested the various types of behavior and spread of COVID-19 among people. Whereas the statistical normal distribution suggested various ways in terms of numbers, COVID-19 spreads among people. The patterns of the data for each country are represented as random variables after the data were classified to fit into function f_n, which results in a normal distribution of 1 and a normal distribution whose mean is 0, because normal distribution is useful in statistics and in many applications. Thus, function f_n is determined by analyzing the growth and changes in data from relevant institutions [47].

2.1 Rescue-to-discharge pattern for COVID-19

The rescue to discharge is a representation of the transition function of what happens between the time the disease is confirmed and the discharge or death of patients. The spread of recoveries is also relevant to curbing the pandemic. To ensure that the rescue and discharge of COVID-19 patients are met at the expected time and manner, Fig. 30.1 represents a running process for handling COVID-19 pandemic disease for any case. If we consider the COVID-19 suspected cases to be that of patients in any location, or in diagnostic center, which could be a quarantine center or a hospital and suppose a suspected patient initiates the rescue process by calling a medical rescue center, a response is expected from the clinical team. In this situation, two possible outcomes are ensured at an interval of time. The rescue process may end on a positive or negative note, tagged as through or decline in the rescue initiation process. If the rescue request is declined, which happens rarely, the situation may result in increase in death rate. If the

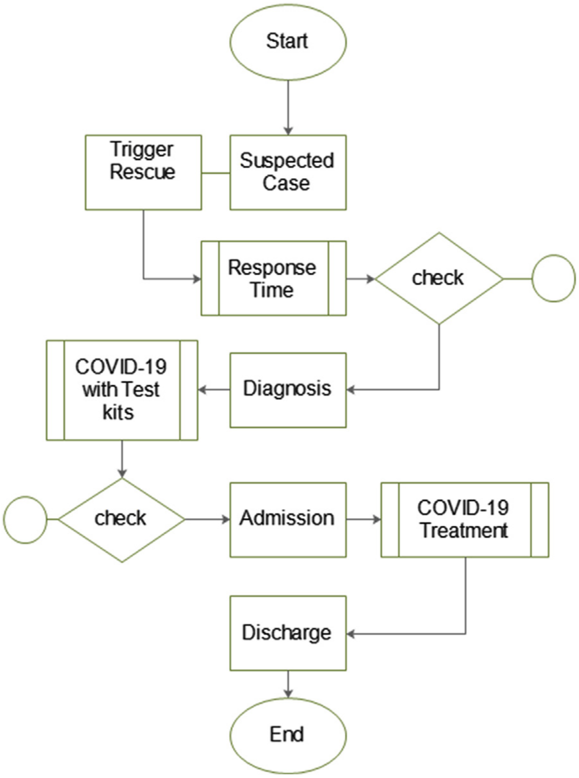

FIGURE 30.1 A framework of rescue-to-discharge pattern for COVID-19.

suspected patient eventually dies, the time of death and burial are recorded for evaluation as the process is terminated [48].

On the other hand, if the rescue process is positive, the suspected patient then waits for a response at a time interval. The time of request and response are noted in the process. The patient is taken to the quarantine center or hospital for diagnosis and treatment. If the suspected cases are diagnosed as negative, patients are treated for other diseases. The time of diagnosis and treatment for different situations are recorded, and the patient is discharged as the process is terminated. Suppose the suspected cases are diagnosed with COVID-19; the patient is admitted to the hospital for treatment until he or she is discharged with the time recorded, and the process is terminated. If during therapy the patient dies, the death is arranged for burial immediately, with the time recorded, and the process ends [49].

This process aims to predict the duration of time of the spread of COVID-19 and other related pandemic diseases, and the risk for breaching the deadline for handling the pandemic. The model has been evaluated against likely future occurrences and predicts the possible rescue process for future events using the elapsed time [45]. Fig. 30.1 represents this transition from admission to discharge.

2.2 Transition Chain Petri net

A Petri net is often used to model a transition system, in which the state of the system is represented by placing and corresponding tokens; hence, the execution of the transition of Petri net measures the change in state. In modeling the incidence of COVID-19, some terminologies are essential in terms of states and how they change. Tokens represent the situation of COVID-19 cases in any environment; a transition represents the impact of infection from one person to another. Individuals infected with COVID-19 may interact with each other in a crowded environment. A place could be a pointer to another place to show an individual's correspondence, because the state of this individual can occur at least once. Moreover, after an individual has been contacted and cured, he cannot contract it or spread the disease. The resultant effect of one individual case may be from the incidence of another under certain conditions of safety lapses [46].

Upon execution, the model is designed so that the token that serves as input in one place also serves as a pointer to another future event. As a result of these changes in Petri net behavior, the consequence of the transition of incidence is analyzed for future occurrences of any severe event of such a pandemic. Using two environments as an example, when an incidence of COVID-19 takes place in environment *A*, the transition has a ripple effect on another individual as a result of inadequate safety measures. Therefore, it may result in another incidence in environment *B*. Fig. 30.2 expresses the Petri net transition analysis of pandemic behavior, in which $p(i)$ indicates COVID-19 incidents in one situation, $p(i+1)$ is shown as resultant lapses of the previous environment, and $p(n)$ points to later COVID-19 cases. In Fig. 30.2, i is an index with the initial state for a token $p(i)$ that shows a COVID-19 incidence that took place in environment *A*. Transition $t(i)$ indicates the impact of COVID-19 incidents at environment *A* on environment *B*, and $t(i+1)$ represents the damage that environment *B* would cause the next environment $p(n)$, where $i \leq 1$ [50,51].

2.3 Petri net model to determine death rate in COVID-19 cases

Petri nets are mathematical modeling tools used to analyze and simulate COVID-19 cases by considering the cause and flow of transmission in terms of the increasing number of patients in different environments. This study modeled the circumstances of two linking nodes that serve as the place or situation in which the pandemic disease takes place within a particular country. This set of places and objects, and the set of

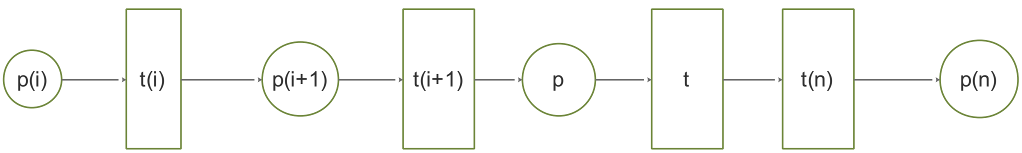

FIGURE 30.2 Reasoning transition pattern for resolving COVID-19 cases with Petri net.

events or transitions have behaviors interpreted for pandemic cases. The mathematical behavior is expressed as:

$$PN = \{P, T, I, M, O\}. \tag{30.1}$$

Eq. (30.1) represents a Petri net behavioral transition of the disease, patients, and environment, where $P = \{p_1, p_2, \ldots\ p_n\}$ is a set of cases associated with COVID-19 and $T = \{t_1, t_2, \ldots\ t_n\}$ is a set of transitions around the COVID-19 case. I is an input function such that $(P \times T) \rightarrow N$, where N is a positive set of integer numbers. The scaler, $I(p, t)$, is the interactive behavior that exists between place p and transition t, in a forward direction. At the same time, O is an input function such that $(T \times P) \rightarrow N$. Scaler $I(t, p)$, is the interactive behavior that exists between place p and transition t in a backward direction [52].

Now, $M \rightarrow N$ is the marking that exists in the proposed Petri net. The number of places, $n \times 1$, for the incidence of the COVID-19 represented by the vector in each environment is tokens represented in the form of a circle with dots place inside it. The first marking is represented as M_0, which is always at the initial state in the Petri net model, whereas M is used over place p_i. In the Petri net, a circle represents places whereas transitions are represented with a rectangle. The direct line represents the arcs whereas tokens take the form of dots. The number of directions shows the execution of the Petri net. Suppose $(*_t)*_p$ is the input places of transition t and $t^*(p^*)$ is the output places of transition t. Then, these two rules determine the execution of the Petri net that shows that t was enabled at marking M as it changes form to marking M'. Hence, $M'_{p_i} = M'_{p_i} + a$, for all $p_i \varepsilon t^*$ and $M'_{p_j} = M'_{p_j} - b$, for all $p_j \varepsilon t$, where a is the number of arcs from transition t to place p_i and b represents arcs from place p_j to transition t [53].

Input function $I : P \times T \rightarrow (0, 1)$ is the arc from place p to transition t, whereas output function $O : T \times P \rightarrow (0, 1)$ shows the arc from transition t to place p. Also, mapping $M : P \rightarrow (0, 1)$ is the marking of a Petri-net. Place p can have 1 token. Function f_n for t is used to show that an enabled transition can be executed and meets the conditions for tokens to take effect on its input places. The enabling rule for transition t of a Petri-net takes effect in marking M. If $M(p_i) > 0$, then $p_j \varepsilon t^*$ and $f_n(t) = true$ and $M(p_j) = 0$, for $p_j \varepsilon t^*$. Thus, when the execution or firing rule for transition t fires, marking M of the Petri-net changes to M', where M' is $M(p_i) = M(p_i)$ for $p_i \varepsilon\, *_t$ and $M(p_j) = 1$, for $p_j \varepsilon t^*$ [54].

To determine enabling function f_n for the transitions, the normal distribution is fed into the modeled Petri net, because a normal distribution is useful in statistics and is employed in many applications. The pattern of data for each country is represented as random variables after the data have been classified to fit into function f_n, which results in a normal distribution and normal distribution whose mean is 0.

Because the standard deviation is 1 for the statistics of the data, the density function becomes comparatively smaller. According to the standard, the data distribution was calculated to achieve a goal by classifying the data to represent the transition, and the mean and variance were determined by using parameters μ and λ, and variable Z with

0 and 1. Thus, function f_n is determined by collecting real and growing COVID-19 data from relevant institutions. The transition for a case is a pointer to the next case with the same distribution, so that enabling function f_n is given as:

$$f_n = \begin{cases} 1, true, if \;\; DISTR(0,1) \leq 20 \\ 0, false, otherwise \end{cases} \tag{30.2}$$

In Eq. (30.2), $DISTR(a,b)$ is a function to generate 20 cases across six selected countries, in which the average total death rate in a week satisfies the normal distribution with values for a and b fed into the Petri net [55,56].

3. Determining distribution function for Petri net with COVID-19 cases

The data represent the condition of COVID-19 cases, the death rate, and the discharge rate in six different countries in the African region. These countries include Nigeria, Egypt, South Africa, Morocco, Kenya, and Tanzania, which have a high level of international economic optimism and a growing population pattern. The death rate and the discharge rates are sieved from COVID-19 cases in each selected country by taking a class of 10 cases inclusive for statistical distribution every week since it started in these countries. The cases are represented as the place in the distribution for the Petri net, in which the number of deaths in the classes or places in the Petri net is recorded as the transition for each country in Table 30.1.

Figs. 30.3 and 30.4 describe the first and second models of the COVID-19 death rate management in an interactive and separate mode. The first model showed that the interaction of the infected individual would have resulted in a more devastating effect on the selected society at large if the spaces existing within them were considerably small, unlike the separate interaction ensuring that transmissions of the pandemic diseases were managed in their respective countries. Space and time management in this scenario include interpersonal connectivity at an interval of time; these were maintained as the closure of the international airport at a particular expected time as well as closure of the land border at a scheduled time. The transition concerning the place is represented in the respective countries. However, as much as the location and transformation are the same for each Petri net model of separate and interactive mode, the terminating places are different from their respective transitions [57–60].

For example, $T1$ and $T4$ have the same distribution of the different numbers of death, as shown in Table 30.1 and Fig. 30.4. Table 30.2 the average total number of death rates each week 20. Thus, for the normal distribution of death rate for any chosen country, the probability of a death is 0.5321 across the four countries, with the average normal distribution of 0.3502, as shown in Table 30.2, interpreted by Table 30.1 of the Petri net, as against the normal flow of statistics for deaths and discharged cases in Table 30.3.

Table 30.1 shows the Petri net analysis of COVID-19 in six African countries as the cases were classed for a Petri net resultant diagram. The behavior of the data determined

Table 30.1 Petri net analysis of COVID-19 in six African countries.

	N	N	E	E	S	S	K	K	M	M	Ta	Ta
Case class	**Death rate**	**Discharge rate**	**Death rate**	**Discharge rate**	**Death rate**	**Discharge rate**	**Death rate**	**Discharge rate**	**Death rate**	**Discharge rate**	**Death rate**	**Discharge rate**
1–20	0	1	0	4	0	0	0	77	5	0	0	0
21–40	1	1	0	18	0	2	0	2	14	0	0	1
41–60	1	0	0	12	0	5	0	14	6	0	1	5
61–80	0	1	0	1	0	0	0	14	3	0	20	67
81–100	0	0	0	21	0	29	0	7	8	0	0	12
101–120	3	0	0	17	0	0	0	7	0	0	0	20
121–140	1	6	0	54	0	0	0	98	0	0	0	50
141–160	0	1	0	21	0	0	1	13	10	11	0	80
161–180	0	0	0	28	0	2	0	5	0	0	0	13
181–200	0	11	0	19	0	0	0	67	0	0	0	64
201–220	2	5	0	5	0	0	0	89	0	0	0	0
221–240	1	10	0	0	0	4	0	16	0	0	0	0
241–260	1	9	0	0	0	0	0	0	0	0	0	0
261–280	1	7	0	0	0	0	0	0	0	0	0	0
281–300	0	7	0	0	0	0	0	0	0	0	0	0
301–320	1	19	0	0	0	0	1	323	0	0	0	0
321–340	0	15	0	0	0	0	0	0	0	0	0	0
361–380	1	14	0	0	0	0	0	0	0	0	0	0
381–400	0	8	0	0	0	0	0	0	0	0	0	0
401–420	1	29	0	0	0	0	0	0	0	0	0	0
421–540	1	24	0	0	0	0	0	0	0	0	0	0
541–560	4	7	0	0	0	0	0	0	0	0	0	0
561–580	0	7	0	0	0	0	0	0	0	0	0	0
581–903	0	0	2	903	0	0	0	0	0	0	0	0

E, Egypt; *M*, Morocco; *N*, Nigeria; *Ta*, Tanzania.

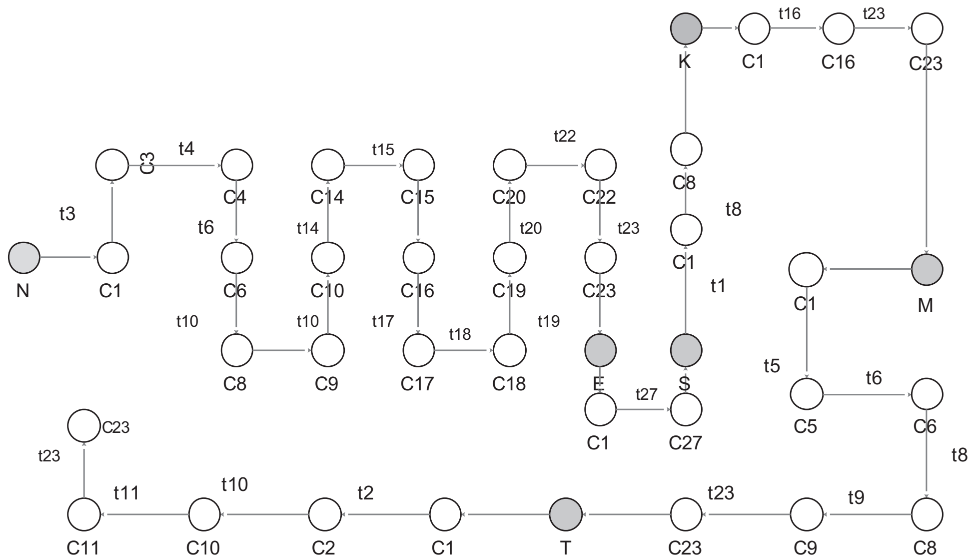

FIGURE 30.3 Petri net first model of COVID-19 death rate management.

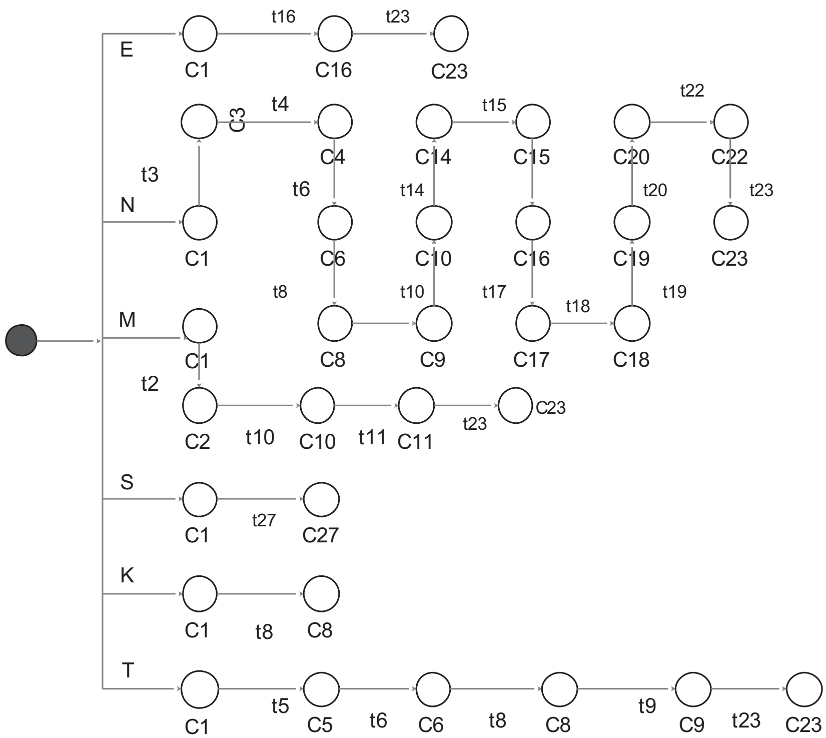

FIGURE 30.4 Petri net second model of COVID-19 death rate management.

Table 30.2 Petri net normal distribution of COVID-19 cases.

	Nigeria		Egypt		South Africa		Morocco		Kenya		Tanzania
T	**Death**	***T***	**Death**	***T***	**Death**	***T***	**Death**	***T***	**Death**	***T***	**Death**
1	1	27	2	—	—	16	2	1	5	3	1
2	1							2	14	4	20
6	3							3	6		
7	1							4	3		
11	2							5	8		
12	1							8	10		
13	1										
14	1										
16	1										
28	1										
20	1										
21	1										
22	1										
Total	16		2				2		46		21
Mean	1.23076		1				1		7.66666		10.5
Standard deviation	0.59914		1.41421				1.41421		15.4666		13.4350

T, Transition in Petri net.

Table 30.3 COVID-19 cases with death and discharge rate until April.

Location	**COVID-19 case**	**Death**	**Discharge**
Nigeria	6357	19	166
Egypt	3030	224	0
South Africa	3033	52	903
Morocco	261	1927	322
Kenya	2836	12	67
Tanzania	1038	43	11
Total	16,555	2277	1469
Mean	2759.167	379.5	244.8333
Standard deviation	2111.961	762.1603	343.9764

From www.worldometer.com and Nigerian Center for Diseases and Control.

the flow of the Petri net after it was classified. The classification of data for the Petri net analysis and behavior was in line with the analysis for optimum use against any foreseen pandemic case in West Africa. In these classes, the death rate, suspected rate, and discharge rate of cases were analyzed with the Petri net before the final statistical normal distribution was used for the final data analysis, which is ultimately useful for future forecasts against any pandemic disease.

Table 30.2 explains the result of the Petri net analysis, from which the death rate and discharge rate were sieved. According to the total death rate of each country, Kenya took the lead, whereas Egypt and Morocco had the fewest deaths. The rate of flow of transmission was also represented as transition T for each selected country in West Africa at the time of analysis. The corresponding means and standard deviations of the death rate were calculated, which suggested that Tanzania and Kenya need to take more physical proactive measures. The death and discharge rate for each selected country are shown in Table 30.3, which suggest that ultimately, the death rate almost doubled the discharge rate for the total cases modeled in Fig. 30.3. The economic activities of the chosen countries contributed to spread the diseases at the time interval before the land border and airport were closed and the total lockdown took place.

3.1 Discussion

The emergence of the pandemic disease COVID-19, which keeps many nations searching for a cure, needs a more predetermined approach by investigating the pattern and speed with which the disease is spread from one individual to another. According to Fig. 30.2, the general reasoning pattern of solving COVID-19 cases with a Petri net is a model that helps sieve the survival and death cases from suspected cases, in which a suspected case, P, could result in multiple instances if the chain of transition t is unbroken. However, if there is a break in interactive behavior between P and t in the case, provision $P(i+1)$ and $t(i+1)$ in the general reasoning pattern is provided for an immediate correction in the flow.

Open data from a different source, in social media and in a well-organized society and government, were used to model the accuracy of the research results of the Petri net; the model from which these data were fed were assumed to be useful for future purposes. Much-expected data after the pandemic subsides will be helpful for research to enable our environment to become safer and restored, and to grow in the future. This predetermining method can also be used to solve the future occurrence of such diseases. The predetermined approach is as good as a reasoning model for proactive measures. Thus, the Petri net was used as a predetermining model to ensure proactive measures for current and future control of the spread of deadly diseases such as COVID-19. To strengthen the Petri net argument for COVID-19, enabling function f_n for transitions, the normal distribution is fed into the modeled Petri net. In this work, function f_n is determined by collecting real and growing COVID-19 data from relevant institutions. The transition to a case is a pointer to the next instance of that distribution.

The pattern of data for each country is represented as random variables after the data are classified as fit into function f_n, which results in a normal distribution whose mean is 0, because a normal distribution is useful in statistics and is employed in many applications. The results of this general model are shown in Table 30.1 and Fig. 30.4. Whereas Table 30.3 shows the average total number of death rates in a week, the probability of death across the four countries, with their respective average normal distribution, are shown in Table 30.2 and interpreted in Table 30.1 with the Petri net, against the normal flow of statistics for deaths and discharged cases in Table 30.3. Results from this model proved that the number of suspected cases of COVID-19 is not a function of the death rate in the selected countries, but the discharge rate had a stronger effect on COVID-19 cases. The results of the normal statistical distribution of various instances of COVID-19 were compared with those of the Petri net; the results proved that the hybrid deterministic model is viable for future use for any pandemic disease. Moreover, this study presents a two-level deterministic reasoning model to curb the spread of COVID-19 in some populated and economically optimistic African countries.

This model shows that the projection for mitigating other pandemic diseases, as well as COVID-19 itself, will have a meager percentage, because the experience of every person who escapes the worst of COVID-19 should have suggested a new strategy curbing pandemic diseases in terms of deployment of biological and information technologies as far as the area is concerned. These technologies could inform individuals that the best approach to mitigate COVID-19 is based on analyzing information about it, and the best way to tackle this infectious disease is to analyze the previous incidence that might have taken place to solve current or future occurrences.

The awareness of the immediate closure of borders, adequate safety, and social distancing propagated through social media platforms, from the international and national communities to educate all levels of citizens in these countries shows that the number of cases needed some prompt actions. However, educational level and religion seem to show other discouraging factors, in that proper information about the growth of infection in these regions is not well-disseminated. Incentive programs might not have been in place to ensure adequate knowledge about the spread of COVID-19 and its impacts on the information age. Still, there have been some monetary donations to help ease the negative result of the “stay at home” campaign. In this situation, when COVID-19 incidences continue to grow and their number is increasing, there are available data in affected countries, both developing and developed.

4. Conclusion

This study has presented an improved Petri net model to analyze and curb the spread of the COVID-19 pandemic in African countries. The spread of COVID-19 is modeled with Petri net and normal distribution as a two-level reasoning pattern to curb the virus. Six countries in Africa (Nigeria, South Africa, Egypt, Kenya, Morocco, and Tanzania) were considered as case studies.

Data for the suspected cases were used universal data from which death and discharge data were sieved in the raw data collected. This work classified the first category of data by checking for the rate at which the three incidences occurred with the Petri net. On this basis, the average rate of the three occurrences were known for a normal flow or transition in the general occurrence of incidence. This flow resulted in the two general Petri net diagrams for statistical generalization of the occurrence of COVID-19 incidences. The results of the transition in the Petri net suggested various ways in terms of behavior and the spread of COVID-19 among people. Whereas the statistical normal distribution model suggested various ways in terms of numbers, COVID-19 spread among people. The pattern of the data for each country were represented as random variables after the data were classified to fit into function f_n, which resulted in a normal distribution of 1 and a normal distribution whose mean was 0, because a normal distribution is useful in statistics and is employed many applications. Thus, function f_n was determined by collecting real and growing COVID-19 data from relevant institutions.

Real data were gathered, studied, and modeled with Petri net to understand the rate at which people contracted COVID-19. The results from the Petri net suggests that some countries have a high rate at which people compared the extent of COVID-19 cases. Hence, two countries were suggested that high the rate social interactions might have caused increase in COVID-19 cases, though death rate would also increase. The Petri net result in Table 30.2 showed that the weekly growing death rate of patients, which at some point normalized, had risen; this behavior was also compared among the four selected high economically optimistic countries. The rate at which the suspected case growth was compared with the death rate by the Petri net showed that future caution need to be considered regarding how to respond quickly to pandemic diseases as severe as COVID-19. This work also suggests that there is a need for individuals, organizations, and the government to scale up their information technology and telecommunications against regional and global pandemic diseases.

References

[1] J. Segars, Q. Katler, D.B. McQueen, A. Kotlyar, T. Glenn, Z. Knight, E.C. Feinberg, H.S. Taylor, J.P. Toner, J.F. Kawwass, Prior and novel coronaviruses, Coronavirus Disease 2019 (COVID-19), and human reproduction: what is known? Fertil. Steril. 113 (6) (April 16, 2020) 1140–1149.

[2] J.F. Zhang, K. Yan, H.H. Ye, J. Lin, J.J. Zheng, T. Cai, SARS-CoV-2 turned positive in a discharged patient with COVID-19 arouses concern regarding the present standard for discharge, Int. J. Infect. Dis. 97 (March 19, 2020) 212–214.

[3] H. Lau, V. Khosrawipour, P. Kocbach, A. Mikolajczyk, H. Ichii, J. Schubert, J. Bania, T. Khosrawipour, Internationally lost COVID-19 cases, J. Microbiol. Immunol. Infect. 53 (3) (March 14, 2020) 454–458.

[4] H. Guo, Y. Zhou, X. Liu, J. Tan, The impact of the COVID-19 epidemic on the utilization of emergency dental services, J. Dent. Sci. 4 (5) (March 16, 2020) 115.

[5] E. Shim, A. Tariq, W. Choi, Y. Lee, G. Chowell, Transmission potential and severity of COVID-19 in South Korea, Int. J. Infect. Dis. 93 (March 18, 2020) 339–344.

[6] S. Lucas, Proving semantic properties as first-order satisfiability, Artif. Intell. 277 (December 1, 2019) 103174.

[7] L. Cohen, S.E. Shimony, G. Weiss, Estimating the probability of meeting a deadline in schedules and plans, Artif. Intell. 275 (October 1, 2019) 329–355.

[8] E. Driggin, M.V. Madhavan, B. Bikdeli, T. Chuich, J. Laracy, G. Biondi-Zoccai, T.S. Brown, C. Der Nigoghossian, D.A. Zidar, J. Haythe, D. Brodie, Cardiovascular considerations for patients, health care workers, and health systems during the COVID-19 pandemic, J. Am. Coll. Cardiol. 75 (18) (May 4, 2020) 2352–2371.

[9] K.V. Delgado, L.N. De Barros, D.B. Dias, S. Sanner, Real-time dynamic programming for Markov decision processes with imprecise probabilities, Artif. Intell. 230 (January 1, 2016) 192–223.

[10] V. Borodin, J. Bourtembourg, F. Hnaien, N. Labadie, Handling uncertainty in agricultural supply chain management: a state of the art, Eur. J. Oper. Res. 254 (2) (October 16, 2016) 348–359.

[11] M. Bourlakis, G. Maglaras, D. Gallear, C. Fotopoulos, Examining sustainability performance in the supply chain: the case of the Greek dairy sector, Ind. Market. Manag. 43 (1) (January 1, 2014) 56–66.

[12] M. Eskandarpour, P. Dejax, J. Miemczyk, O. Péton, Sustainable supply chain network design: an optimization-oriented review, Omega 54 (July 1, 2015) 11–32.

[13] V.B. Fedrigotti, C. Fischer, Sustainable development options for the chestnut supply chain in South Tyrol, Italy, Agric. Agric. Sci. Proc. 5 (January 1, 2015) 96–106.

[14] N.M. Galal, A.F.A. Moneim, Developing sustainable supply chains in developing countries, Proc. Cirp 48 (2016) 419–424.

[15] S.J. Ghoushchi, M.D. Milan, M.J. Rezaee, Evaluation and selection of sustainable suppliers in supply chain using new GP-DEA model with imprecise data, J. Ind. Eng. Int. 14 (3) (September 1, 2018) 613–625.

[16] K. Katsaliaki, N. Mustafee, S. Kumar, A game-based approach towards facilitating decision making for perishable products: an example of blood supply chain, Expert Syst. Appl. 41 (9) (July 1, 2014) 4043–4059.

[17] R.S. Rajan, R. Uthayakumar, Optimal pricing and replenishment policies for instantaneous deteriorating items with backlogging and trade credit under inflation, J. Ind. Eng. Int. 13 (4) (December 1, 2017) 427–443.

[18] T.H. Beach, Y. Rezgui, H. Li, T. Kasim, A rule-based semantic approach for automated regulatory compliance in the construction sector, Expert Syst. Appl. 42 (12) (July 15, 2015) 5219–5231.

[19] H.P. Lam, M. Hashmi, B. Scofield, Enabling reasoning with legal rule ML, in: J.J. Alferes, L. Bertossi, G. Governatori, P. Fodor, D. Roman (Eds.), Proceedings of the 10th International Web Rule Symposium, Springer, Stony Brook, April 2016, pp. 241–257.

[20] H.J. Genrich, K. Lautenbach, System modelling with high-level Petri nets, Theor. Comput. Sci. 13 (1) (January 1, 1981) 109–135.

[21] M.A. Marsan, G. Balbo, G. Conte, S. Donatelli, G. Franceschinis, Modelling with generalized stochastic Petri nets, Perform. Eval. Rev. 26 (2) (August 1, 1998) 2.

[22] A. Al-Ahmari, Optimal robotic cell scheduling with controllers using mathematically based timed Petri nets, Inf. Sci. 329 (February 1, 2016) 638–648.

[23] Y. Chen, Z. Li, K. Barkaoui, Maximally permissive liveness-enforcing supervisor with lowest implementation cost for flexible manufacturing systems, Inf. Sci. 256 (January 20, 2014) 74–90.

[24] M. Uzam, G. Gelen, T.L. Saleh, Think-globally-act-locally approach with weighted arcs to the synthesis of a liveness-enforcing supervisor for generalized Petri nets modeling FMSs, Inf. Sci. 363 (October 1, 2016) 235–260.

[25] W.M. Van Der Aalst, Making work flow: on the application of petri nets to business process management, in: In International Conference on Application and Theory of Petri Nets, Springer, Berlin, Heidelberg, June 24, 2002, pp. 1–22.

[26] F. Cheng, H. Li, Y.W. Wang, M. Skitmore, P. Forsythe, Modeling resource management in the building design process by information constraint Petri nets, Autom. ConStruct. 29 (January 1, 2013) 92–99.

[27] F.F. Cheng, Y.W. Wang, X.Z. Ling, Y. Bai, A Petri net simulation model for virtual construction of earthmoving operations, Autom. ConStruct. 20 (2) (March 1, 2011) 181–188.

[28] H. Li, Petri net as a formalism to assist process improvement in the construction industry, Autom. ConStruct. 7 (4) (May 1, 1998) 349–356.

[29] C. Molinero, M. Nunez, Planning of work schedules through the use of a hierarchical multi-agent system, Autom. ConStruct. 20 (8) (December 1, 2011) 1227–1241.

[30] B. Le, J. Andrews, Petri net modelling of bridge asset management using maintenance-related state conditions, Struct. Infrastruct. Eng. 12 (6) (June 2, 2016) 730–751.

[31] J.M. Leigh, S.J. Dunnett, Use of Petri nets to model the maintenance of wind turbines, Qual. Reliab. Eng. Int. 32 (1) (February 2016) 167–180.

[32] P.C. Yianni, D. Rama, L.C. Neves, J.D. Andrews, D. Castlo, A Petri-Net-based modelling approach to railway bridge asset management, Struct. Infrastruct. Eng. 13 (2) (February 1, 2017) 287–297.

[33] D. Zhang, H. Hu, C. Roberts, Rail maintenance analysis using Petri nets, Struct. Infrastruct. Eng. 13 (6) (June 3, 2017) 783–793.

[34] C. Girault, R. Valk, Petri Nets for Systems Engineering: A Guide to Modeling, Verification, and Applications, Springer Science & Business Media, March 14, 2013.

[35] I. Flores-Colen, J. de Brito, A systematic approach for maintenance budgeting of buildings façades based on predictive and preventive strategies, Construct. Build. Mater. 24 (9) (September 1, 2010) 1718–1729.

[36] F.M. Arain, L.S. Pheng, Knowledge-based decision support system for management of variation orders for institutional building projects, Autom. ConStruct. 15 (3) (May 1, 2006) 272–291.

[37] J.K. Wong, H. Li, Development of intelligence analytic models for integrated building management systems (IBMS) in intelligent buildings, Intell. Build. Int. 1 (1) (2009) 5–22. https://doi.org/10.3763/inbi.2009.0011.

[38] I. Flores-Colen, J.M.C.L. de Brito, V.P. de Freitas, On-site performance assessment of rendering façades for predictive maintenance, Struct. Surv. 7 (May 31, 2011) 26.

[39] P. Paulo, F. Branco, J. de Brito, A. Silva, Buildings life—the use of genetic algorithms for maintenance plan optimization, J. Clean. Prod. 121 (May 10, 2016) 84–98.

[40] I.M. Shohet, M. Paciuk, Service life prediction of exterior cladding components under standard conditions, Construct. Manag. Econ. 22 (10) (December 1, 2004) 1081–1090.

[41] A. Silva, P.L. Gaspar, J. De Brito, Durability of current renderings: a probabilistic analysis, Autom. Construct. 44 (August 1, 2014) 92–102.

[42] M. Duling, J. Jacobus, Towards the Development of Transition Probability Matrices in the Markovian Model for the Predicted Service Life of Buildings, Doctoral Dissertation, University of Pretoria, 2007.

[43] M.J. Kallen, J.M. Van Noortwijk, Statistical inference for Markov deterioration models of bridge conditions in The Netherlands, in: In Proceedings of the Third International Conference on Bridge Maintenance, Safety and Management (IABMAS), July 2006, pp. 16–19.

[44] J.D. Kalbfleisch, J.F. Lawless, The analysis of panel data under a Markov assumption, J. Am. Stat. Assoc. 80 (392) (December 1, 1985) 863–871.

[45] R. David, H. Alla, Discrete, Continuous, and Hybrid Petri Nets, Springer, Berlin, September 2005.

[46] J. Wang, Timed Petri Nets: Theory and Application, Springer Science & Business Media, December 6, 2012.

[47] W.G. Schneeweiss, Petri Net Picture Book: (An Elementary Introduction to the Best Pictorial Description of Temporal Changes), LiLoLe-Verl., 2004.

[48] J.L. Peterson, Petri nets, Comput. Surv. 9 (3) (1977) 223–252. https://doi.org/10.1145/356698.356702.

[49] F.D. Bowden, A brief survey and synthesis of the roles of time in Petri nets, Math. Comput. Model. 31 (10–12) (May 1, 2000) 55–68.

[50] C.V. Ramamoorthy, G.S. Ho, Performance evaluation of asynchronous concurrent systems using Petri nets, IEEE Trans. Software Eng. (5) (September 1980) 440–449.

[51] W.M. Zuberek, Timed Petri nets and preliminary performance evaluation, in: In Proceedings of the 7th Annual Symposium on Computer Architecture, May 6, 1980, pp. 88–96.

[52] M.K. Molloy, Izations of our main results, using a notion of eccentricity that is the maximum ratio of sides. Further work is needed to determine definitively the tradeoff be, IEEE Trans. Comput. (31) (September 9, 1982) 100.

[53] A.A. Marsan, G. Conte, G. Balbo, A class of generalized petri nets for the performance evaluation of multiprocessor systems, ACM Trans. Comput. Syst. 2 (2) (May 1984) 93–122.

[54] J.B. Dugan, K.S. Trivedi, R.M. Geist, V.F. Nicola, Extended Stochastic Petri Nets: Applications and Analysis, Wisconsin Univ-Madison Motor Behavior Lab, November 1984.

[55] M.A. Marsan, G. Chiola, On Petri nets with deterministic and exponentially distributed firing times, in: In European Workshop on Applications and Theory in Petri Nets, Springer, Berlin, Heidelberg, June 1, 1986, pp. 132–145.

[56] K.F. Man, K.S. Tang, S. Kwong, Genetic Algorithms: Concepts and Designs, Springer Science & Business Media, February 19, 2001.

[57] G. Morcous, Z. Lounis, Maintenance optimization of infrastructure networks using genetic algorithms, Autom. ConStruct. 14 (1) (January 1, 2005) 129–142.

[58] A. Silva, J.L. Dias, P.L. Gaspar, J. de Brito, Statistical models applied to service life prediction of rendered façades, Autom. ConStruct. 30 (March 1, 2013) 151–160.

[59] A. Silva, J. de Brito, P.L. Gaspar, Comparative analysis of service life prediction methods applied to rendered façades, Mater. Struct. 49 (11) (November 1, 2016) 4893–4910.

[60] K. Jensen, G. Rozenberg (Eds.), High-level Petri Nets: Theory and Application, Springer Science & Business Media, December 6, 2012.