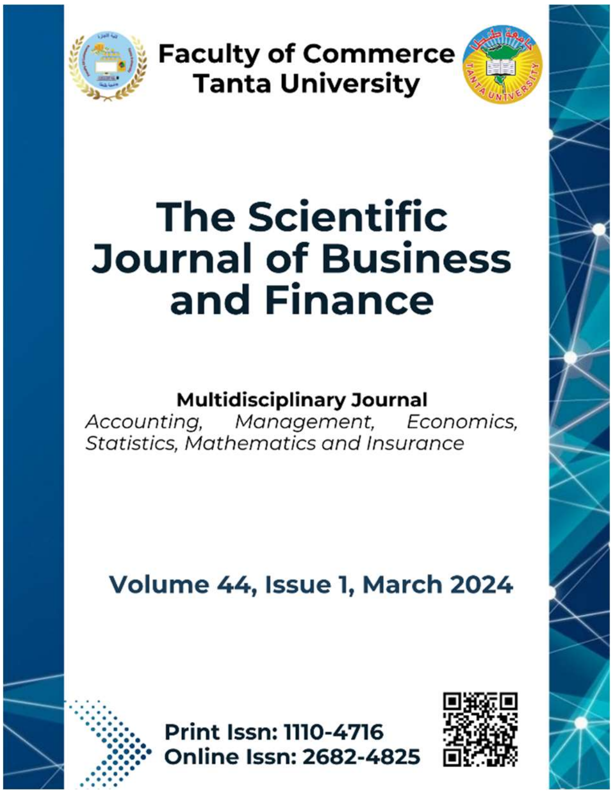

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Using the CUSUM control chart to monitor the reported deaths of COVID-19 in Egypt

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Abstract:

At the end of 2019, COVID-19 pandemic increased the reported deaths all over the world. It caused a worrisome state demands some tools to model and monitor the data of reported deaths of COVID-19.

This research aims to model the reported deaths of Covid-19 in Egypt using three distributions . The best-fit distribution will model the deaths number of COVID-19 in Egypt. In addition, three control charts based on the best fit distribution were designed to monitor the reported deaths. Also, there was a comparison between two charts designed with and without FIR using MLE estimator to know the importance of using FIR. Another comparison between the two charts designed with FIR using MLE and Bayesian estimators to identify which estimator gives better results. The results showed that Poisson distribution was the best to model the data. The superiority of the chart with FIR to detect shifts early was displayed, and the superiority of the chart was designed through Bayesian approach.

Key words : Goodness of fit ; COVID-19; CUSUM control chart ; FIR; Poisson distribution; Bayesian Approach ; MLE.

List of abbreviations

CUSUM	Cumulative sum
FIR	Fast initial response
MLE	Maximum likelihood estimator
SPC	Statistical process control
EWMA	Exponential weighted moving average

1-Introduction

In the late of 2019 , corona virus appeared in the Chinese city "Wuhan" and began to spread all over the world. This virus was causing great losses so the researchers should monitor its variables like number of deaths and new cases using control charts.
CUSUM control chart is one of the most important charts which can detect small and moderate shifts. It can be applied to a variety of fields, including industry and medical care processes to improve the quality of it (Montgomery, 2009).
CUSUM control chart has several types. It is divided into variable and attribute charts based on the type of data. It can be used with many distributions like normal, Gamma, and Poisson distributions (Provost and Murray, 2022). Poisson CUSUM control chart is one of the attributes CUSUM control charts. It can monitor counted data. To ensure good statistical performance using this chart, the data under study must follow Poisson distribution (Lucas, 1985). Also, Hawkins and Olwell (1998) showed the sensitivity of this chart to departure from the assumption of Poisson distribution. This chart is strong, simple to use and suitable for monitoring the counts of nonconformities in the process (Testik, 2007). A lot of studies in the field of quality control depends on the classical method of estimation (MLE) like Testik (2007) . Recently, these studies have shifted toward the Bayesian approach of estimation since it improves chart performance when the database of estimation is small, to get knowledge of practitioners and avoid the problems of estimation (Zhang et al., 2013).
Jones, Abdel-Salam, and Mays (2022) introduced the Bayesian approach to design CUSUM and EWMA control charts under some prior distributions and loss functions. This study compares the performance of classical charts and Bayesian charts then showed that the performance of Bayesian charts is better than classical when shift size is small but when shift size is large they achieve the same performance nearly.

Deming (2018) showed that a lot of healthcare, commercial and educational organizations depend on control charts to understand the behavior of their processes over time. In addition, Inkelas et al. (2021) showed that control charts have a lot of utilities in the field of public health, they are used to achieve the goals of public health in the pandemic of COVID-19 so this research will monitor the reported deaths of COVID-19 in Egypt using CUSUM control chart.

2-literature review

Braimah, Omaku, Saheed and Momo (2014) designed CUSUM and EWMA control charts to describe records data of outbreak of some diseases which was collected from "Edo State Civil Service Hospital" for the period, January 2006 to December 2010, then compared performance of two charts. The results revealed that, both of CUSUM and EWMA charts were able to detect shifts in diseases data, but CUSUM chart is slightly faster than EWMA chart. **Chikobvu and Sigauke (2020)** explained that Corona virus is a dangerous virus which caused a pandemic around the world. It is spreading very quickly. It has led to crisis in all aspects of life. It was the greatest challenge globally through the last 3 years. They modeled the reported COVID-19 deaths in south Africa from 27 March 2020 to 20 may 2020 into 4 models. Gamma distribution was the best fit distribution. **Odunayo, Nnamdi and oluwatosion (2020)** showed that CUSUM control chart is an efficient tool to monitor health care and rare diseases and analyzed some variables of COVID-19 data like confirmed cases and reported deaths in Africa. This study also applied several SPC tools like control charts, fish chart and pareto chart. This study confirmed that CUSUM control chart was more efficient than Shewhart chart to monitor small shifts in deaths rate especially when shift size is less than 2σ. **Inkelas et al. (2021)**, showed that; it was necessary to use several tools to monitor this epidemic, know when it exceeds the random level and find out the reasons to avoid them. Also, these tools can give decision makers signals for COVID-19 pandemic progress and recognize reasons of variation in COVID-19 rates which were the region, sub region and periods in study. **Adeoti and Adekeye (2023)** did goodness of fit tests for some distributions and recommended that gamma distribution is preferable to represent COVID-19 deaths in Nigeria for the period; 11^{th}April to 7^{th} September 2020. in addition, this study designed an upper sided gamma CUSUM control chart and an upper sided normal CUSUM control chart then, compared them. The first chart was the best in detecting signals, finally they interpreted the reason of consistent rise in COVID-19 reported deaths to the rainy season in Nigeria in the period of study. **Waqas, Anwar, Rasheed and Shabbir (2023)**, introduced a study aimed to select an optimal control chart in case of epidemiology to monitor variations in the deaths of COVID-19. This paper ,they were subjected to three phases,(pre-growth, growth, and post growth). They relied only on Shewhart charts($\bar{x}$,R,C) and EWMA charts. Finally, they recommended using EWMA chart in their study.

3-Research problem

To monitor and model reported deaths of COVID-19 in Egypt, this research will fit the data of reported deaths during the period of study to identify the best distribution that represents it. Then design CUSUM control chart to monitor the reported deaths of COVID-19. In addition, a lot of literature recommends using a Bayes estimator when the estimation database is small because it gives better results. Therefore, this research compares two charts designed using the MLE and Bayes estimator to prove this.

4-Research objective

This research aims to :

1-Fit the data of reported deaths of COVID-19 from 5-1-2021 to 6-9-2021 to recognize the suitable and best distribution can represent the data and model it.

2- Estimate the number of reported deaths through the period of study by MLE method.

3-Estimate the number of reported deaths through the period of study by Bayesian estimator using Gamma distribution as a prior distribution and quadratic loss function.

4- Design the upper sided poison CUSUM control chart with and without FIR through MLE and Bayesian estimators to detect a 25% of the increase in the reported deaths of COVID-19.

5- Plot the charts and monitor the number of reported deaths to detect times of positive shifts and analyze it .

6-Compare the results of two charts with and without FIR.

7-Compare the results of charts were designed by MLE and Bayesian estimators.

5-Research limits and data resource

This research deals with the reported deaths of COVID-19 in Egypt from 5/1/2021 to 6/9/2021.

Egypt: WHO Coronavirus Disease (COVID-19) Dashboard | WHO

6- Research methodology

CUSUM control chart

Page (1954) introduced this chart for the first time. It can detect small and moderate shifts quicker than Shewhart chart because it depends on the cumulative statistic. It can detect upward and downward shifts in the quality characteristic of interest**.**

Poisson CUSUM control chart

The Poisson CUSUM control chart is suitable for description the number of defects or nonconformities units in inspection region. This number follows Poisson distribution. In the most of research, Poisson CUSUM control chart is used to detect upward shifts in the number of defects because only this kind of shifts represents a problem, but the other type represents an improvement

Upper sided Poisson CUSUM control chart.

Let x is the number of defects in inspection area (j) follows Poisson distribution with parameter (θ)

, X=0,1,2,….. , $\theta > 0$ P(X=x)= $\frac{\theta^{x} e^{-\theta}}{x!}$

Is the mean and variance of Poisson distribution θ

θ_0 is the parameter of in- control distribution (there is no change in the process)

θ_1 is the parameter of out-of- control distribution(a change happened in the process leads to a change in the process)

$\theta_1 = \gamma * \theta_0$, γ is the shift size

Upper sided Poisson CUSUM control chart test statistic(with and without FIR respectively)

$$(1)\ U_i^{+} = \sum_{j=1}^{i} (x_j - k) = u_{i-1} + x_i - k \quad , U_0=0$$

$$(2)\ U_i^{+} = \sum_{j=1}^{i} (x_j - k) = u_{i-1} + x_i - k \quad , U_0= Hm/2$$

Chart parameters

K is the reference value=($\theta_1 - \theta_0)/log(\frac{\theta_1}{\theta_0})$ then we rounded it into two digits

Km=k*100

If the parameter θ_0 isn't known, it should be estimated by MLE or Bayes estimator through phase 1 data base.

The MLE estimator of $\theta_0$is the overall mean of samples ($\bar{\bar{\theta}} = \sum_{i=1}^{m} \hat{\theta}_i /m$) when $\hat{\theta}_i$ is the number of defects in sample (i) and m is the number of samples .

The Bayesian estimator when Gamma distribution is a prior distribution with parameter (α,β) equals (m $\bar{\bar{\theta}} + \alpha)/(m + \beta)$, when m=156 day in this research.
α=16 and β=5/8 (assume that in this research)
H_m is the upper control limit of chart which is calculated by determined the in-control ARL(in this research the in-control ARL=100) . It is calculated by R program and SPC package.
The lower control limit equals zero.
If chart statistics exceed the H_m control limit, the chart scores signal that there are special causes of variation need searching.

Application:
The data in this research is the reported deaths number of COVID-19 from 5/1/2021 to 6/9/2021. The raw data in this period was plotted in fig(1) that scored an increase in deaths number at the beginning of research period, then recorded a continuous decline. After that, the increase returned at the end of the period.

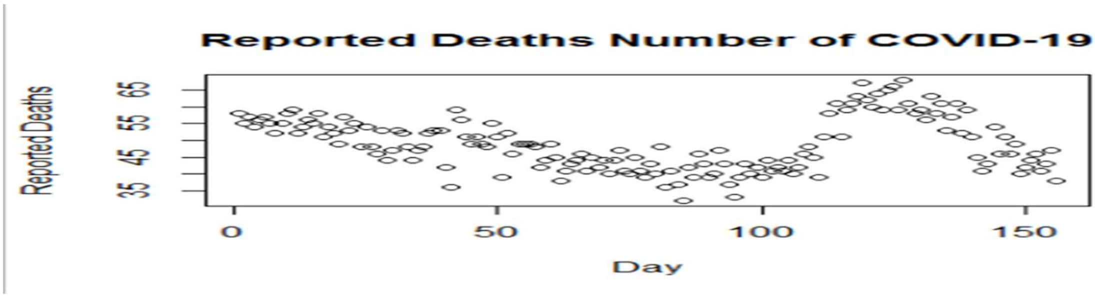

Fig1: The daily reported deaths number of COVID-19 between the 5th of January to the 9th of June 2021 .

Some descriptive statistics were calculated in table(1) using R program , *fitdistplus* package , descdist command. The minimum number of deaths was 32 cases while the maximum number was 68 cases . The average of reported deaths number was 49 cases/day. Also the number of reported deaths on 50% of days was less than 40 cases and on 50% of days was more than 40. The skewness is close to zero. The kurtosis value is less than 3 so that distribution is platykurtic, it means the tails are lighter than those of normal distribution.

Table1: Descriptive statistics of reported deaths number

Measurement	Value
Mean	48.92
Median	40
Min	32
Max	68
Skew	0.28
Kurtosis	2.31

The density of data is showed in fig(2). This density is different from normal density which is symmetric.

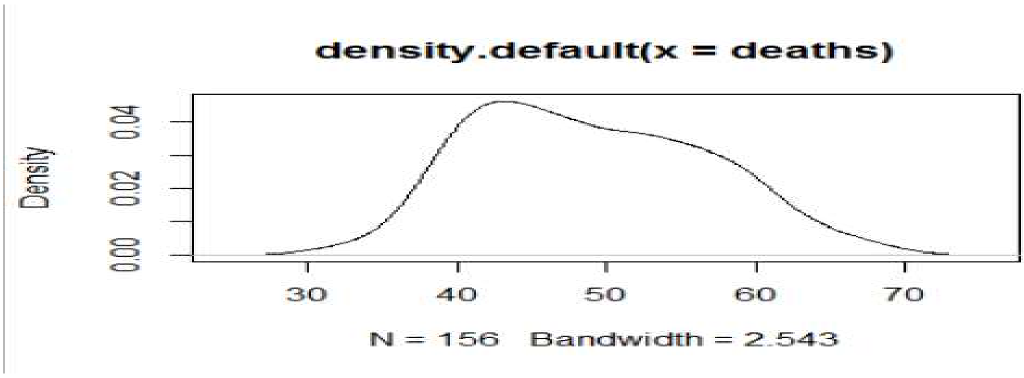

Fig2 : the denisty of reported deaths number of COVID-19

Best fit distribution for the research data

The data of research is counted data so this paper will fit Poisson, negative binomial, and geometric distributions to represent data. Table(2) indicates:

only Poisson and negative binomial distributions are significant to represent data, because p-value of both is greater than 0.05, so we cannot reject H_0 (H_0:the data follows Poisson or negative binomial or geometric).

Now which of two distributions is the best to represents data of research?. according to Akaike's Information criterion, negative binomial distribution is the best but according to Bayesian Information Criterion Poisson distribution is the best so we can use either of them to model data. In this research Poisson distribution models data.

Table 2: goodness- of- fit criteria

Test	Poisson	Negative binomial	Geometric
Chi-squared statistic	16.17871	11.26024	568.01
p-value	0.06	0.19	$1.53e^{-116}$
Akaike's Information criterion	1083.888	1082.553	1530.92
Bayesian Information Criterion	1086.938	1088.652	1530.97

fig(3) and fig(4) show that Poisson distribution and negative binomial distribution are suitable for representing data because the empirical distribution of data is almost the same as the theoretical distribution.

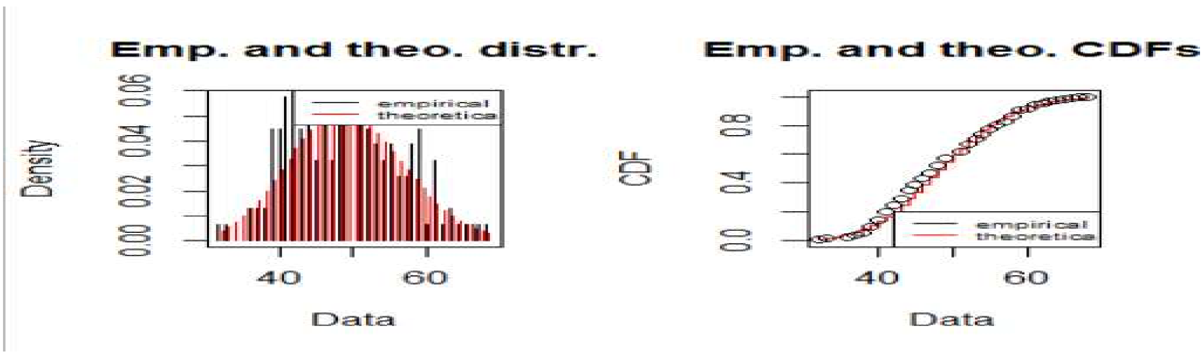

Fig 3: goodness-of-fit to Poisson distribution

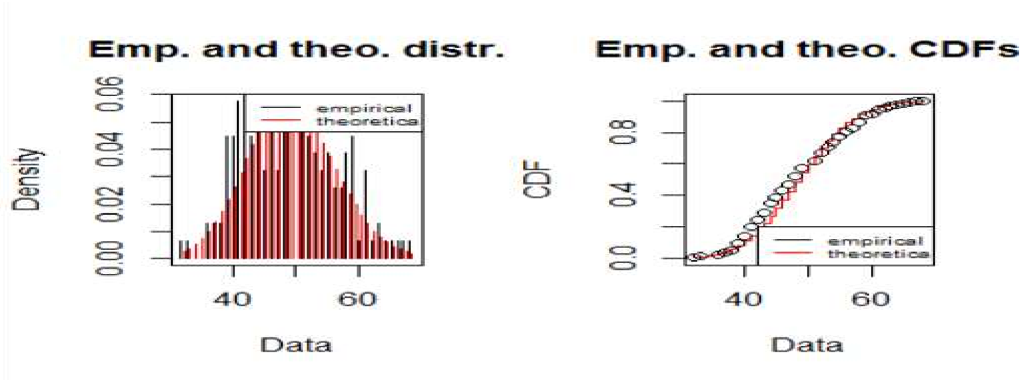

Fig 4: goodness-of-fit to negative binomial distribution

create the upper sided Poisson CUSUM control chart for reported deaths of COVID-19 through the period of research with and without FIR using MLE and Bayesian estimators **to detect a 25% increase in the reported deaths**, meaning that the shift size is 1.25.

Firstly, design the upper sided Poisson CUSUM control chart using MLE estimator and without FIR(c_0^+ =0)

The steps of creating this chart are:

1- Estimate θ_0 by MLE method

2-Determine the parameters of chart

θ_0 =48.92 on average , θ_1 =61.51 , km=5483 and Hm=1394

3-Calculate the chart statistic by **excel** program in table(1) in the appendix using this equation:

c_i^+=max(0,deaths*100-km+c_{i-1}^+) , i=1,2,…156

4-Plot these statistics by R program , ggplot2 package, ggplot function to create the chart in fig(5). This chart scored the first signal at 2/5/2021-the 118th day of research. The gatherings increased greatly during this period, which was the end of Ramadan month and the beginning of Eid al-Fiter days which increased the new cases of COVID-19 and the possibility of an increase in the reported deaths. See the web site (Egypt: WHO Coronavirus Disease (COVID-19) Dashboard | WHO)

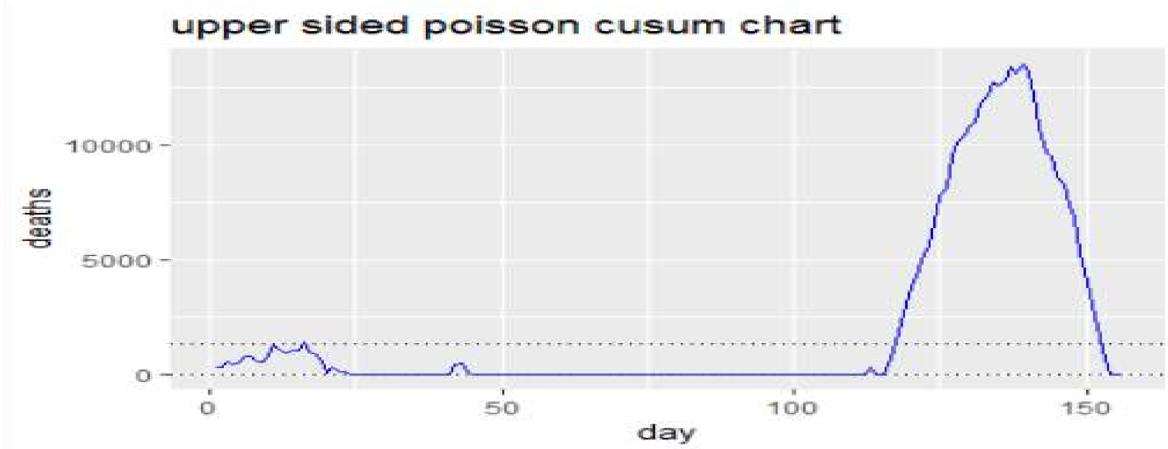

Fig 5: upper sided Poisson CUSUM control chart without FIR

Secondly, design the upper sided Poisson CUSUM control chart using MLE with FIR($c_0^+ = 697$)
follow the same last steps to create chart statistics but c_0^+ =697 instead of zero in table (2) in the appendix using excel program.
Plot these statistics by R program , ggplot2 package, ggplot function to create the chart in fig(6)which can detect upward shifts at the beginning of research period around 10/1/2021. It may be due to the gatherings resulting from New Year's Eve, which increased the chance of infection. Also, it detected the upward shifts at the end of period study at 2/5/2021 to 6/6/2021 like the chart in fig(5), but the chart in fig (5) can't detect the upward shifts at the beginning of research, and that means: the chart with FIR is better than the chart without FIR
.

Fig 6: upper sided Poisson CUSUM control chart with FIR=697 using MLE estimator.
Thirdly, design the upper sided Poisson CUSUM control chart using Bayesian estimator with FIR($c_0^+ = 697$)
The steps of creating this chart are:
1-Estimate θ_0 by Bayesian approach.
2-Determine the parameters of chart
$\hat{\theta}_0$=48.83 on average , θ_1 =61.03 , km=5470 and H_m=1394
3-Calculate the chart statistic by **excel** program in table(3)
=max(0,deaths*100-km+c_i^+) , i=1,2,…156c_{i-1}^+
4-Plot these statistics by R program , ggplot2 package, ggplot function to create the chart in fig(7)which can detect upward shifts more than the chart in fig(6). This chart scored 3 signals more than the last chart in 23/01/2021, 01/05/2021and 06/06/2021 as in table (3) in the appendix that means, the chart was designed by Bayesian approach is better than the chart was designed by MLE because it can detect the upward shifts faster.

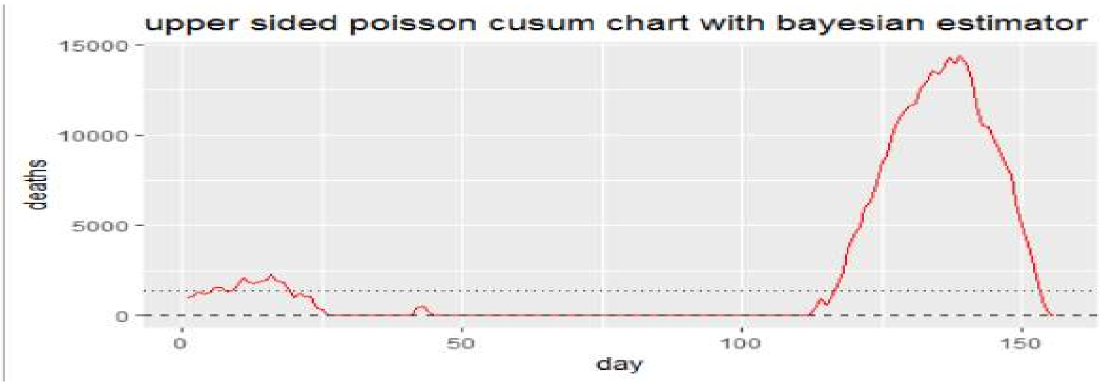

Fig 7: upper sided Poisson CUSUM control chart with FIR with Bayesian estimator.

7-Results

After modeling and monitoring the data the study scored these results

1-Poisson distribution is the best-fit-distribution to represent the reported deaths of COVID-19 in the study period.

2- The average of reported deaths by MLE is 48.92 case/day but the average of reported deaths by Bayesian estimator is 48.83 case/day .

3- The Upper sided Poisson CUSUM control chart with FIR can detect signal quicker than the other without FIR.

4- The upper sided Poisson CUSUM control chart with FIR was designed depending on Bayes approach is better than the other which constructed by MLE estimator.

5-Gatherings increase the virus cases and deaths even if temperature is high.

8-Conclution and future work

In this research, the reported deaths number of COVID-19 in Egypt extracted from "Egypt: WHO Coronavirus Disease (COVID-19) Dashboard | WHO" web site through the period 5thJanuary to 6thSebtember 2021 was modeled using some distribution. The best distribution to represent deaths data was Poisson distribution. Upper sided Poisson CUSUM control chart was designed with and without FIR through MLE and Bayesian estimators. The research results show that number deaths of COVID-19 consistently rise between the 118th day of study period to the 152th , showing that the deaths number of COVID-19 within this period was beyond the control limit(Hm) and requires investigations to determine the problem therein.

In addition, the performance of charts with FIR and without was compared and the results show the superiority of CUSUM control chart with FIR to detect an increase in deaths number in the 6th and 7th day of research period then increased again between the 9thday to the 18thday. Another comparison was constructed between the charts with FIR through MLE and Bayesian estimator. The results revealed that the importance of using FIR in case of instability conditions and the superiority of chart depends on Bayes approach in detecting shifts in the parameter than MLE estimator.

Future work : we suggest designing the upper sided negative binomial CUSUM control chart to monitor the reported deaths at the same period of study in Egypt and compare the results of two charts(Poisson and negative binomial).

we suggest also monitor another period of COVID-19 , another variable like new cases and it is possible applying these charts on another country in the same period of study and compare results between Egypt and this country.

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Appendix

Table 1:

upper sided Poisson CUSUM control chart statistics without FIR and using MLE

c+	Deaths	Day	Date	c+	Deaths	Day	Date
0	4400	29	02/02/2021	319	5800	1	05/01/2021
0	4700	30	03/02/2021	338	5500	2	06/01/2021
0	5300	31	04/02/2021	557	5700	3	07/01/2021
0	5200	32	05/02/2021	476	5400	4	08/01/2021
0	4800	33	06/02/2021	595	5600	5	09/01/2021
0	4400	34	07/02/2021	814	5700	6	10/01/2021
0	4700	35	08/02/2021	833	5500	7	11/01/2021
0	4800	36	09/02/2021	552	5200	8	12/01/2021
0	5200	37	10/02/2021	571	5500	9	13/01/2021
0	5300	38	11/02/2021	890	5800	10	14/01/2021
0	5300	39	12/02/2021	1309	5900	11	15/01/2021
0	4200	40	13/02/2021	1028	5200	12	16/01/2021
0	3600	41	14/02/2021	947	5400	13	17/01/2021
419	5900	42	15/02/2021	1066	5600	14	18/01/2021
538	5600	43	16/02/2021	1085	5500	15	19/01/2021
157	5100	44	17/02/2021	1404	5800	16	20/01/2021
0	4900	45	18/02/2021	1023	5100	17	21/01/2021
0	5100	46	19/02/2021	942	5400	18	22/01/2021
0	4900	47	20/02/2021	661	5200	19	23/01/2021
0	4800	48	21/02/2021	80	4900	20	24/01/2021
19	5500	49	22/02/2021	299	5700	21	25/01/2021
0	5100	50	23/02/2021	118	5300	22	26/01/2021
0	3900	51	24/02/2021	137	5500	23	27/01/2021
0	5200	52	25/02/2021	0	4800	24	28/01/2021
0	4600	53	26/02/2021	0	5400	25	29/01/2021
0	4900	54	27/02/2021	0	4800	26	30/01/2021
0	4900	55	28/02/2021	0	4600	27	31/01/2021
0	4900	56	01/03/2021	0	5300	28	01/02/2021
0	4100	104	18/04/2021	0	4800	57	02/03/2021
0	4400	105	19/04/2021	0	4200	58	03/03/2021
0	4000	106	20/04/2021	0	4400	59	04/03/2021
0	4200	107	21/04/2021	0	4900	60	05/03/2021
0	4600	108	22/04/2021	0	4500	61	06/03/2021
0	4800	109	23/04/2021	0	3800	62	07/03/2021
0	4500	110	24/04/2021	0	4100	63	08/03/2021
0	3900	111	25/04/2021	0	4300	64	09/03/2021
0	5100	112	26/04/2021	0	4400	65	10/03/2021
319	5800	113	27/04/2021	0	4600	66	11/03/2021

0	6100	114	28/04/2021	0	4100	67	12/03/2021
0	5100	115	29/04/2021	0	4500	68	13/03/2021
419	5900	116	30/04/2021	0	4200	69	14/03/2021
1038	6100	117	01/05/2021	0	4400	70	15/03/2021
1857	6300	118	02/05/2021	0	4000	71	16/03/2021
3076	6700	119	03/05/2021	0	4400	72	17/03/2021
3795	6200	120	04/05/2021	0	4700	73	18/03/2021
4314	6000	121	05/05/2021	0	4100	74	19/03/2021
5233	6400	122	06/05/2021	0	4000	75	20/03/2021
5652	5900	123	07/05/2021	0	4500	76	21/03/2021
6671	6500	124	08/05/2021	0	4100	77	22/03/2021
7790	6600	125	09/05/2021	0	3900	78	23/03/2021
8209	5900	126	10/05/2021	0	4300	79	24/03/2021
9528	6800	127	11/05/2021	0	4000	80	25/03/2021
10147	6100	128	12/05/2021	0	4800	81	26/03/2021
10466	5800	129	13/05/2021	0	3600	82	27/03/2021
10885	5900	130	14/05/2021	0	4100	83	28/03/2021
11004	5600	131	15/05/2021	0	3700	84	29/03/2021
11823	6300	132	16/05/2021	0	3200	85	30/03/2021
12142	5800	133	17/05/2021	0	4200	86	31/03/2021
12761	6100	134	18/05/2021	0	3900	87	01/04/2021
12580	5300	135	19/05/2021	0	4600	88	02/04/2021
12799	5700	136	20/05/2021	0	4300	89	03/04/2021
13418	6100	137	21/05/2021	0	3900	90	04/04/2021
13137	5200	138	22/05/2021	0	4000	91	05/04/2021
13556	5900	139	23/05/2021	0	4700	92	06/04/2021
13175	5100	140	24/05/2021	0	4300	93	07/04/2021
12194	4500	141	25/05/2021	0	3700	94	08/04/2021
10813	4100	142	26/05/2021	0	3300	95	09/04/2021
9632	4300	143	27/05/2021	0	3900	96	10/04/2021
9551	5400	144	28/05/2021	0	4300	97	11/04/2021
8670	4600	145	29/05/2021	0	4000	98	12/04/2021
8289	5100	146	30/05/2021	0	4200	99	13/04/2021
7408	4600	147	31/05/2021	0	3900	100	14/04/2021
6827	4900	148	01/06/2021	0	4400	101	15/04/2021
5346	4000	149	02/06/2021	0	4100	102	16/04/2021
4065	4200	150	03/06/2021	0	4200	103	17/04/2021
0	4300	154	07/06/2021	2984	4400	151	04/06/2021
0	4700	155	08/06/2021	2103	4600	152	05/06/2021
0	3800	156	09/06/2021	722	4100	153	06/06/2021

Table 2: the chart statistic of upper sided Poisson CUSUM control chart with FIR and using MLE

C+	Deaths*100	Day	date	C+	Deaths*100	Day	Date
996	5700	21	25/01/2021	1016	5800	1	05/01/2021
815	5300	22	26/01/2021	1035	5500	2	06/01/2021
834	5500	23	27/01/2021	1254	5700	3	07/01/2021
153	4800	24	28/01/2021	1173	5400	4	08/01/2021
72	5400	25	29/01/2021	1292	5600	5	09/01/2021
0	4800	26	30/01/2021	**1511**	5700	6	10/01/2021
0	4600	27	31/01/2021	**1530**	5500	7	11/01/2021
0	5300	28	01/02/2021	1249	5200	8	12/01/2021
0	4400	29	02/02/2021	1268	5500	9	13/01/2021
0	4700	30	03/02/2021	**1587**	5800	10	14/01/2021
0	5300	31	04/02/2021	**2006**	5900	11	15/01/2021
0	5200	32	05/02/2021	**1725**	5200	12	16/01/2021
0	4800	33	06/02/2021	**1644**	5400	13	17/01/2021
0	4400	34	07/02/2021	**1763**	5600	14	18/01/2021
0	4700	35	08/02/2021	**1782**	5500	15	19/01/2021
0	4800	36	09/02/2021	**2101**	5800	16	20/01/2021
0	5200	37	10/02/2021	**1720**	5100	17	21/01/2021
0	5300	38	11/02/2021	**1639**	5400	18	22/01/2021
0	5300	39	12/02/2021	1358	5200	19	23/01/2021
0	4200	40	13/02/2021	777	4900	20	24/01/2021
	4600	88	02/04/2021	0	3600	41	14/02/2021
0	4300	89	03/04/2021	419	5900	42	15/02/2021
0	3900	90	04/04/2021	538	5600	43	16/02/2021
0	4000	91	05/04/2021	157	5100	44	17/02/2021
0	4700	92	06/04/2021	0	4900	45	18/02/2021
0	4300	93	07/04/2021	0	5100	46	19/02/2021
0	3700	94	08/04/2021	0	4900	47	20/02/2021
0	3300	95	09/04/2021	0	4800	48	21/02/2021
0	3900	96	10/04/2021	19	5500	49	22/02/2021
0	4300	97	11/04/2021	0	5100	50	23/02/2021
0	4000	98	12/04/2021	0	3900	51	24/02/2021
0	4200	99	13/04/2021	0	5200	52	25/02/2021
0	3900	100	14/04/2021	0	4600	53	26/02/2021
0	4400	101	15/04/2021	0	4900	54	27/02/2021
0	4100	102	16/04/2021	0	4900	55	28/02/2021
0	4200	103	17/04/2021	0	4900	56	01/03/2021
0	4100	104	18/04/2021	0	4800	57	02/03/2021
0	4400	105	19/04/2021	0	4200	58	03/03/2021
0	4000	106	20/04/2021	0	4400	59	04/03/2021

0	4200	107	21/04/2021	0	4900	60	05/03/2021
0	4600	108	22/04/2021	0	4500	61	06/03/2021
0	4800	109	23/04/2021	0	3800	62	07/03/2021
0	4500	110	24/04/2021	0	4100	63	08/03/2021
0	3900	111	25/04/2021	0	4300	64	09/03/2021
0	5100	112	26/04/2021	0	4400	65	10/03/2021
319	5800	113	27/04/2021	0	4600	66	11/03/2021
0	6100	114	28/04/2021	0	4100	67	12/03/2021
0	5100	115	29/04/2021	0	4500	68	13/03/2021
419	5900	116	30/04/2021	0	4200	69	14/03/2021
1038	6100	117	01/05/2021	0	4400	70	15/03/2021
1857	6300	118	02/05/2021	0	4000	71	16/03/2021
3076	6700	119	03/05/2021	0	4400	72	17/03/2021
3795	6200	120	04/05/2021	0	4700	73	18/03/2021
4314	6000	121	05/05/2021	0	4100	74	19/03/2021
5233	6400	122	06/05/2021	0	4000	75	20/03/2021
5652	5900	123	07/05/2021	0	4500	76	21/03/2021
6671	6500	124	08/05/2021	0	4100	77	22/03/2021
7790	6600	125	09/05/2021	0	3900	78	23/03/2021
8209	5900	126	10/05/2021	0	4300	79	24/03/2021
9528	6800	127	11/05/2021	0	4000	80	25/03/2021
10147	6100	128	12/05/2021	0	4800	81	26/03/2021
10466	5800	129	13/05/2021	0	3600	82	27/03/2021
10885	5900	130	14/05/2021	0	4100	83	28/03/2021
11004	5600	131	15/05/2021	0	3700	84	29/03/2021
11823	6300	132	16/05/2021	0	3200	85	30/03/2021
12142	5800	133	17/05/2021	0	4200	86	31/03/2021
12761	6100	134	18/05/2021	0	3900	87	01/04/2021
8289	5100	146	30/05/2021	**12580**	5300	135	19/05/2021
7408	4600	147	31/05/2021	**12799**	5700	136	20/05/2021
6827	4900	148	01/06/2021	**13418**	6100	137	21/05/2021
5346	4000	149	02/06/2021	**13137**	5200	138	22/05/2021
4065	4200	150	03/06/2021	**13556**	5900	139	23/05/2021
2984	4400	151	04/06/2021	**13175**	5100	140	24/05/2021
2103	4600	152	05/06/2021	**12194**	4500	141	25/05/2021
722	4100	153	06/06/2021	**10813**	4100	142	26/05/2021
0	4300	154	07/06/2021	**9632**	4300	143	27/05/2021
0	4700	155	08/06/2021	**9551**	5400	144	28/05/2021
0	3800	156	09/06/2021	**8670**	4600	145	29/05/2021

Table 3: the chart statistic of upper sided Poisson CUSUM control chart with FIR and using Bayesian estimator.

C+	Deaths*100	Day	date	C+	Deaths*100	Day	Date
417	4800	24	28/01/2021	1027	5800	1	05/01/2021
347	5400	25	29/01/2021	1057	5500	2	06/01/2021
0	4800	26	30/01/2021	1287	5700	3	07/01/2021
0	4600	27	31/01/2021	1217	5400	4	08/01/2021
0	5300	28	01/02/2021	1347	5600	5	09/01/2021
0	4400	29	02/02/2021	**1577**	5700	6	10/01/2021
0	4700	30	03/02/2021	**1607**	5500	7	11/01/2021
0	5300	31	04/02/2021	1337	5200	8	12/01/2021
0	5200	32	05/02/2021	1367	5500	9	13/01/2021
0	4800	33	06/02/2021	**1697**	5800	10	14/01/2021
0	4400	34	07/02/2021	**2127**	5900	11	15/01/2021
0	4700	35	08/02/2021	**1857**	5200	12	16/01/2021
0	4800	36	09/02/2021	**1787**	5400	13	17/01/2021
0	5200	37	10/02/2021	**1917**	5600	14	18/01/2021
0	5300	38	11/02/2021	**1947**	5500	15	19/01/2021
0	5300	39	12/02/2021	**2277**	5800	16	20/01/2021
0	4200	40	13/02/2021	**1907**	5100	17	21/01/2021
0	3600	41	14/02/2021	**1837**	5400	18	22/01/2021
430	5900	42	15/02/2021	**1567**	5200	19	23/01/2021
560	5600	43	16/02/2021	997	4900	20	24/01/2021
190	5100	44	17/02/2021	1227	5700	21	25/01/2021
0	4900	45	18/02/2021	1057	5300	22	26/01/2021
0	5100	46	19/02/2021	1087	5500	23	27/01/2021
0	3700	94	08/04/2021	0	4900	47	20/02/2021
0	3300	95	09/04/2021	0	4800	48	21/02/2021
0	3900	96	10/04/2021	30	5500	49	22/02/2021
0	4300	97	11/04/2021	0	5100	50	23/02/2021
0	4000	98	12/04/2021	0	3900	51	24/02/2021
0	4200	99	13/04/2021	0	5200	52	25/02/2021
0	3900	100	14/04/2021	0	4600	53	26/02/2021
0	4400	101	15/04/2021	0	4900	54	27/02/2021
0	4100	102	16/04/2021	0	4900	55	28/02/2021
0	4200	103	17/04/2021	0	4900	56	01/03/2021
0	4100	104	18/04/2021	0	4800	57	02/03/2021
0	4400	105	19/04/2021	0	4200	58	03/03/2021
0	4000	106	20/04/2021	0	4400	59	04/03/2021
0	4200	107	21/04/2021	0	4900	60	05/03/2021
0	4600	108	22/04/2021	0	4500	61	06/03/2021
0	4800	109	23/04/2021	0	3800	62	07/03/2021

0	4500	110	24/04/2021	0	4100	63	08/03/2021
0	3900	111	25/04/2021	0	4300	64	09/03/2021
0	5100	112	26/04/2021	0	4400	65	10/03/2021
330	5800	113	27/04/2021	0	4600	66	11/03/2021
960	6100	114	28/04/2021	0	4100	67	12/03/2021
590	5100	115	29/04/2021	0	4500	68	13/03/2021
1020	5900	116	30/04/2021	0	4200	69	14/03/2021
1650	6100	117	01/05/2021	0	4400	70	15/03/2021
2480	6300	118	02/05/2021	0	4000	71	16/03/2021
3710	6700	119	03/05/2021	0	4400	72	17/03/2021
4440	6200	120	04/05/2021	0	4700	73	18/03/2021
4970	6000	121	05/05/2021	0	4100	74	19/03/2021
5900	6400	122	06/05/2021	0	4000	75	20/03/2021
6330	5900	123	07/05/2021	0	4500	76	21/03/2021
7360	6500	124	08/05/2021	0	4100	77	22/03/2021
8490	6600	125	09/05/2021	0	3900	78	23/03/2021
8920	5900	126	10/05/2021	0	4300	79	24/03/2021
10250	6800	127	11/05/2021	0	4000	80	25/03/2021
10880	6100	128	12/05/2021	0	4800	81	26/03/2021
11210	5800	129	13/05/2021	0	3600	82	27/03/2021
11640	5900	130	14/05/2021	0	4100	83	28/03/2021
11770	5600	131	15/05/2021	0	3700	84	29/03/2021
12600	6300	132	16/05/2021	0	3200	85	30/03/2021
12930	5800	133	17/05/2021	0	4200	86	31/03/2021
13560	6100	134	18/05/2021	0	3900	87	01/04/2021
13390	5300	135	19/05/2021	0	4600	88	02/04/2021
13620	5700	136	20/05/2021	0	4300	89	03/04/2021
14250	6100	137	21/05/2021	0	3900	90	04/04/2021
13980	5200	138	22/05/2021	0	4000	91	5/04/2021
14410	5900	139	23/05/2021	0	4700	92	6/04/2021
14040	5100	140	24/05/2021	0	4300	93	7/04/2021
6310	4000	149	02/06/2021	**13070**	4500	141	25/05/2021
5040	4200	150	03/06/2021	**11700**	4100	142	26/05/2021
3970	4400	151	04/06/2021	**10530**	4300	143	27/05/2021
3100	4600	152	05/06/2021	**10460**	5400	144	28/05/2021
1730	4100	153	06/06/2021	**9590**	4600	145	29/05/2021
560	4300	154	07/06/2021	**9220**	5100	146	30/05/2021
0	4700	155	08/06/2021	**8350**	4600	147	31/05/2021
0	3800	156	09/06/2021	**7780**	4900	148	01/06/2021

*The values colored in red are the statistics which exceed the upper sided control limit (H_m) and leads to signals in the chart. We should search for the reasons of signals in these days