

Evaluation of the Effectiveness of Movement Control Order to Limit the Spread of COVID-19

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Abstract. This study presents a prediction model based on Logistic Growth Curve to evaluate the effectiveness of Movement Control Order (MCO) on COVID-19 pandemic spread. The evaluation assesses and predicts the growth models. The estimated model is a forecast-based model that depended on partial data from the COVID-19 cases in Malaysia. The model is then studied together with the effectiveness of the three phases of MCO implemented in Malaysia. Evidence from this study suggests that results of the LGC prediction model match with the progress and effectiveness of the MCO to flatten the curve, thus helped to control the spike in number of active COVID-19 cases and spread of COVID-19 infection growth.

Keywords: COVID-19; Logistic Growth Curve; prediction; evaluation; Movement Control Order

1 Introduction

Corona (CO) Virus (VI) Disease (D) 2019 or in short COVID-19 (also known as “2019 novel coronavirus” or “2019-nCoV”), caused by the SARS-CoV-2 virus, is a highly contagious disease [1]. Recently we are anxiously witnessing the alarming spread of the disease throughout the most parts of the world. The COVID-19 has been recognized as an unforeseen disease that has exposed human frailty and inability to cope with the current pandemics [2]. Doctors and researchers are struggling to find the best way to contain the disease, let alone to recommend any effective treatment to work in a specific situation. However, it is very crucial to get this virus under control as quickly as possible, which can start with effectively minimizing the spread. Several studies are being conducted in the settings of various disciplines, including biology, medicine, computer science, artificial intelligence, for various predictions, monitoring, and countermeasures

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to tackle the spread of this epidemic [3]. Researchers are continuously trying to analyze the degree to which people are exposed to the disease and how to prevent it. Most of these researches target at estimating the number of cases expected as well as the final size of the coronavirus epidemic [4]. Researchers are also trying to analyze the effectiveness of isolation of cases and contact tracing in controlling SARS-CoV-2) [5]. The urgent need to understand what type of political, social, and economic interventions must be implemented to confront COVID-19 has prompted various countries to quickly take practical actions to limit the spread. However, more studies are required to analyze the effectiveness of these intervention actions. One major action that is enforced in most countries is locking down the whole area or city in controlling the spread of the pandemic. In general, lock down prohibits large gatherings, travelling abroad, restriction on tourists and visitors entering to a country, closure of schools, closure of businesses, closure of public and private offices [6]. Since COVID-19 may transmit from person-to-person through cough, sneeze, and touch by another infected person [7], lock down is a measure to slow down the spread of the disease by minimizing the possibilities of transmissions [2]. Movement Control Order (MCO) [8,9] is one such approach taken by the government of a country to prevent the spread of the disease. Lockdown is also referred to as Movement Control Order, Mandatory Control Order or Restricted Movement Order in different parts of the world. In this paper, we will be using the term Movement Control Order (MCO) and Malaysia's first three phases of MCO is taken as our case study. In this study, we explored and developed a prediction model at the early stage of the MCO and studied the model against the effectiveness of the three phases of MCO in Malaysia. We focused on the modeling of COVID-19 and its infection dynamics. In particular, we made short-term and long-term predictions of COVID-19 affected cases during different phases of MCO. We then compared the observed cases with the predictions in order to analyze the effectiveness of the MCO. We hope this study can be one of the MCO implementation references for policy-makers in addressing COVID-19 or future pandemic in a locality or country.

1.1 Purpose of the study

The purpose of this study was to assess the effectiveness of Movement Control Order (MCO) to minimize the spread of COVID-19 virus infection. As for the case study, this study focused on Malaysian COVID-19 virus infection data. This study focuses on two research questions as follows:

1. What is of the effect of MCOs to control the infection growth of COVID-19?
2. How do infection spreads without MCOs?

2 Literature Review

COVID-19 have quickly spread across so many countries since the first reported case in Wuhan, China. There is still no vaccine for the Corona Virus (COVID-19) and researchers everywhere are trying their best to estimate the impact of

the virus on our society. To measure its impact, researchers have taken the effort to collect data and provide analytics and visualization to be used by the public [10,11]. One notable work by researchers and the community at large is called CoronaTracker by [10], which received early recognition by World Health Organization (WHO). The data collected are useful for researchers to come up with predictive models, simulation, and analysis of the pandemic. A model to predict the effects of the COVID-19 is important, so that resources can be allocated, and national scale decisions can be made to slow down the spread of the infection through mandatory control order [12], that can be implemented to reduce the spread between individuals. In the past, researchers followed statistical and mathematical approaches in forecasting the spread of a virus. Chong, Zee and Wang used statistical methods [13], and later a Bayesian algorithm [14], to determine the arrival times of imported new cases. A common method used for modelling the pandemic is based on the SIR (Susceptible, Infectious, and Removed or Recovered) Model. This model has been used for predicting infection and spread of the human ectoparasites in Europe, Influenza and H1N1 by researchers in the past [15,16]. However, prediction of the COVID-19 have been rather elusive as prediction models and mitigation plans are designed to fit a specific time period that may not represent the long haul effects of the pandemic. The control strategies introduced by Prem et al. [17], and models introduced [18] are modelled based on Wuhan's historical data. Nonetheless, these are important precursor works for researchers to explore further, more general models. One of the approaches is taken by Wangping et al. [19] is to extend the SIR model predict the trend in Italy and compare it to cases in Hunan. Many researchers made a more complex model based on the SIR model called SEIR (Susceptible, Exposed, Infectious, and Removed or Recovered) model that adds the Exposed compartment as a variable [10,11,12,20,21]. Susceptible refers to individuals who can catch the infection and may become hosts if exposed [22]. The Exposed individuals are individuals who are already infected but are asymptomatic. Once the compartments of SIR or SEIR models are determined, modelling can be done using a variety of methods [23]. In [22], demographic information such as birth and death rates were added to the SEIR model. Nonetheless, it is uncertain that predicting COVID-19 requires a more complex model. Roda et al. [24] have described that building a complex model to predict COVID-19 may not give optimal results. In fact, most models are made to fit a certain timeframe and impact studies are made to fit into specific mitigation plans.

3 Methodology

Upon imposing an MCO, decision-makers need to analyze its effect on the growth of infections, and thereby, take the next strategic decisions. In this study, we investigated the effectiveness of an MCO by analyzing the actual growth of COVID-19 infections in comparison with the expected growth in situation where MCO is not imposed.

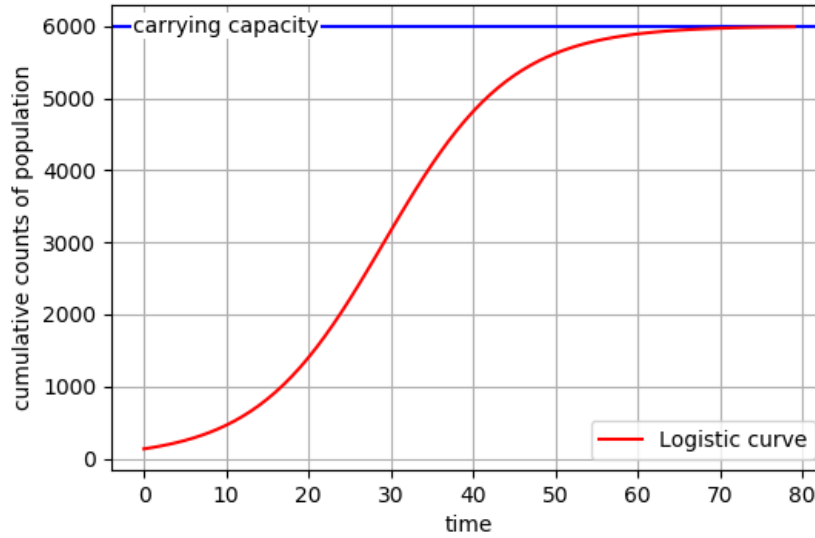


Fig. 1. A Logistic Growth Curve (LGC) showing the cumulative counts of the COVID-19 infections over time

In our analyses, we model the growth of infections by a Logistic Growth Curve (LGC) [25]. Several previous studies used LGC to forecast growth in different fields [26,27,28]. An LGC is an S-shaped sigmoidal curve that grows gradually at the beginning, rapidly at the middle, and slows down as the end as shown in Fig. 1. An LGC to model the infections in a country/locality can be expressed as

$$y = \frac{K}{1 + \exp(a + b \times x)} \quad (1)$$

where y is the total number of infections at a given time x . The parameters a and b help to shape the curve. K is known as the “Carrying Capacity”, which means the upper limit that a disease infection can grow [29,30]. To find the values for a and b , the curve is fitted on the available data based on a cost function. In this study, we adopt the Mean Squared Error (MSE) as the cost function, which is defined as

$$J(\theta) = \frac{1}{n} \sum_{i=1}^n (h_{\theta}(x^{(i)}) - y^{(i)})^2 \quad (2)$$

where θ is the parameter vector (a, b) to optimize, $y^{(i)}$ is the total number of infected cases at a given time $x^{(i)}$, n is the number of available data points, and $h_{\theta}(x^{(i)})$ represents the total number of infected cases predicted at a given time $x^{(i)}$ for a particular θ using Eq. 3. The target is to find a θ that gives the minimum cost value, i.e., when the values predicted by the curve are very close to the actual data points. Fig. 2 shows such an example. To accomplish this, we apply the gradient descent-based iterative method to try different potential values for θ , and select the most suitable one, yielding the least cost for the given data.

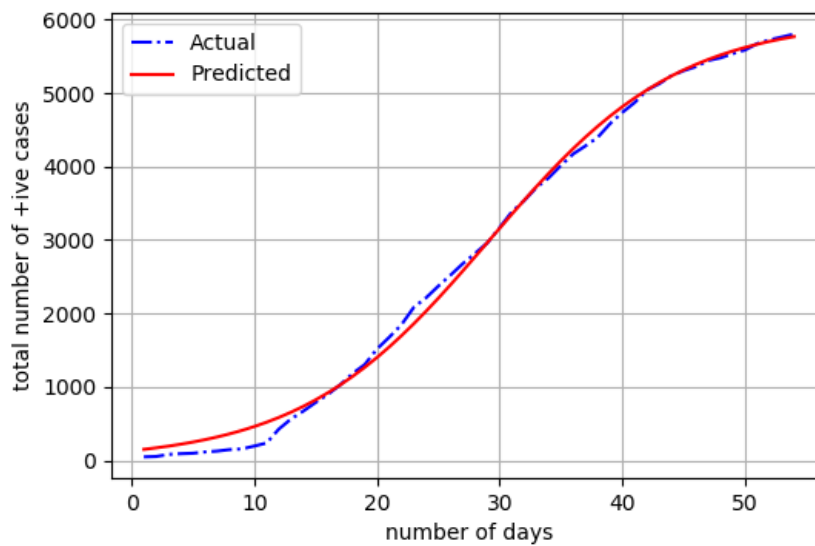


Fig. 2. An example of fitting LGC curve on a given data.

The value of the carrying capacity K is usually set at total population when the data for the whole targeted duration is known [31]. However, in the case of COVID-19, the number of infections is still in growing phases in most countries. Hence, the value of K is not readily available. So, along with a and b , we also include K in θ in the optimization/iteration process to search for a suitable value of K as well, which is somewhat similar to Meyer and Ausubel [32]. Thus, if a series of data is given, the model can forecast growth trend as well as the carrying capacity. Suppose that the cumulative counts of COVID-19 infections in a country for n days are available, where an MCO was declared on day m , where $m < n$. To analyze the effectiveness of the MCO, we first apply our procedure to fit the LGC curve to the data of the first m days. It gives us a set of values

6 Amiruzzaman, Abdullah-Al-Wadud, Mohd Nor, A. Aziz

for a , b , and K . Here the curve projects the infections for the days beyond m . We call this the “original projection”. This shows the prediction without having the MCO in place. Using the obtained value of K , we then apply our procedure again to fit the curve on n data points. Here we optimize the values of a and b only. This curve shows the prediction with the MCO in place, and we name the curve “logistic projection”. Upon having the two projections, we can analyze the effect of the MCO focusing on the values on the curve for the days after m .

4 Experimental Analysis

In this work, we focused on the growth of COVID-19 disease in Malaysia. The first four cases diagnosed with positive COVID-19 in Malaysia were reported on January 25, 2020 [33]. When positive COVID-19 cases began to increase, the government imposed the MCO on March 18, 2020, which was followed by three more phases of the MCO on March 31, and April 14, and April 29, 2020. Thus, the case of Malaysia perfectly fits with our work of analyzing the effectiveness of the MCO. In this section, we first describe the dataset we used in our analysis, and then we present the experimental results and analysis of our approach to study the effectiveness the MCO in Malaysia.

4.1 The Dataset

Data from the Malaysian Ministry of Health (MOH) were referred to for compilation in this study. The Director General of the MOH makes daily official press statement on the overall status and statistics of COVID-19 in the country. Figures on the number of new cases for positive COVID-19, number of recovered or discharged cases, number of patients in ICU, those on ventilation support, and new death cases for each day are updated. An overall total of positive COVID-19, a total of recovered cases, total death, and a total of active cases (which is the total of positive cases minus the sum of total recovered and total death cases) are also reported. These series of press statements with statistical data are made available to the public on the MOH website <https://www.moh.gov.my/index.php/pages/view/2274>, and detail of the statistics are referred to another MOH related site at [34]. Additionally, we also collected data about daily new infections, deaths, recoveries, and the total number of infections from <https://www.worldometers.info/coronavirus/country/malaysia/>.

We compiled the data from the abovementioned resources from March 4, 2020, till April 26, 2020, for this research. Thus, the dataset comprises data of 53 days showing day by day total number of infections. The daily progress data are plotted as in Fig. 3. The red line represents the total number of active COVID-19 cases while the green line represents the total number of cases recovered. The yellow line indicates the total accumulation positive cases, which, like in many other countries, is still ongoing.

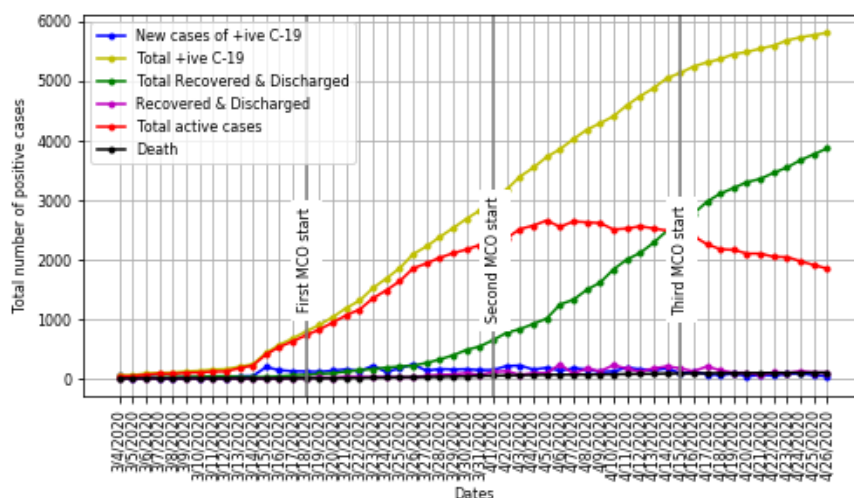


Fig. 3. Progress of COVID-19 cases in Malaysia during the Movement Control Order (MCO) phase 1 to phase 3.

5 Results and Analysis

In this work, our approach was to fit a Logistic Growth Curve (LGC) on the available dataset so as to make the predictions. We analyzed the first three phases of the MCO in Malaysia. The first phase of MCO in Malaysia was imposed on March 18, 2020. To analyze the effectiveness of this, we focused on the data for the first 15 days, i.e., from March 4, 2020, to March 18. We applied the iterative algorithm to fit the LGC on this data. The outcome is shown in Fig. 4. Here the algorithm predicts the carrying capacity to be 5901, which would be reached in 120 days as shown by the red line. This shows the trend of the growth of infection if no MCO were imposed. However, due to the MCO, the actual infections, which are shown by the blue line in Fig. 4 and Fig. 3, are much less. This shows the effectiveness of the MCO.

The curve in Fig. 4 was based fitted on a very small amount of datapoints. Specifically, the actual data for the initial tail of the S-shaped LGC curve were available. Moreover, this data also does not reflect the exponential growth of the infections of a pandemic like COVID-19 since this portion represent the few initial cases only. Hence, the fit the tail of the LGC curve to these datapoints the carrying capacity K was predicted as very large, which might look like not that realistic. To fit the curve and prediction better, we tried to apply our procedure on the whole dataset of 53 days. This yields the green dotted curve in Fig. 6. The carrying capacity predicted in this case was more realistic than that predicted in Fig. 5. We used this value of carrying capacity to make predictions based on the data for the three phases of MCO.

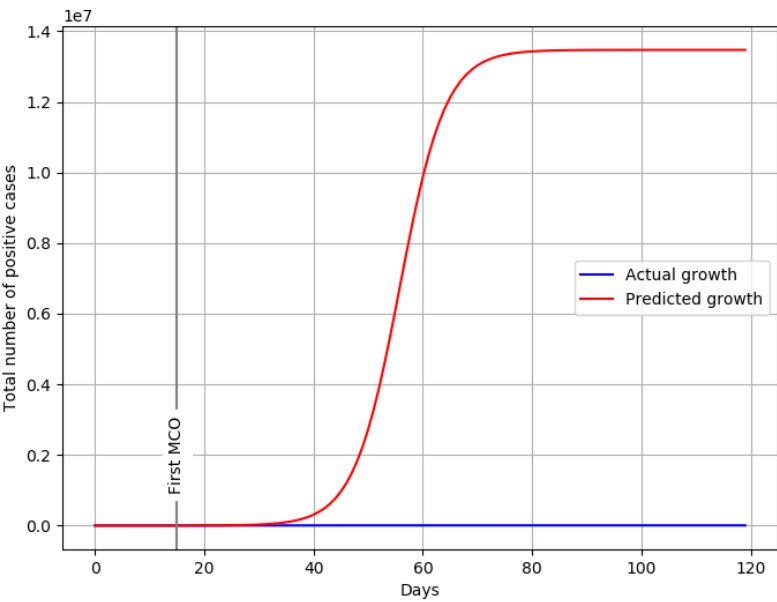


Fig. 4. The actual growth of COVID-19 infection and the predicted growth based on the data before the first phase of MCO in Malaysia

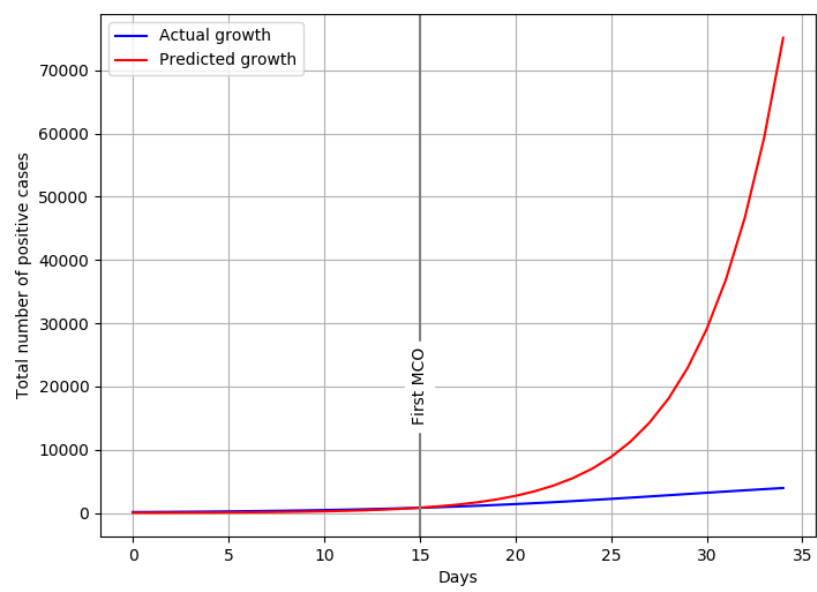


Fig. 5. A zoomed in view of the plots in Fig. 4

We eliminated all the data points after the first phase of MCO and computed a and b parameters to fit the LGC. This time we knew the K value, as we computed that for the whole dataset earlier. In Fig. 4, the solid red line shows the actual infection growth upto the first phase MCO, and the black dotted line shows the predicted growth if there was no MCO in place. Fig. 6 shows that the growth would have been dramatically different than the actual infection growth if there was only one phase of MCO.

After analyzing the infection growth rate of first phase MCO, we explored the second phase of MCO infection growth rate. So, this time we removed all the datapoints after the second phase of MCO and computed the a and b values for the LGC model. In Fig 6, the solid magenta line shows the actual infection growth upto the second phase of MCO, and the light cyan line shows the predicted growth if only the first phase of MCO was in place. However, due to the second phase of MCO, the actual growth was below the predicted curve. This indicates that the second phase of MCO was also effective to minimize the growth of COVID-19 infections.

Finally, to analyze the infection growth rate of first three phases of MCO, we removed all the datapoints after the third phase MCO and computed the a , and b values for the LGC model. In Fig 6, the solid green line shows the infection growth upto the third phase MCO, and the green dotted line shows the predicted growth after the first, second, and third phases of MCO assuming that there were only three phases of MCO in place. Obtained results of our study indicated that with three phases of MCO, then the predicted growth and actual follows the same LGC.

In summary of our first analysis, the results indicated that the first phase of MCO, which was announced on March 18, 2020, had a greater impact on the infection control than other phases of the MCO. However, our results also show that the second and third phases of MCO helped to flatten the curve further (see Fig. 6). More specifically, evidence from our study suggests that if different phases of MCOs were not in place, then the rate of infection would have gone higher than the present infection rate.

6 Discussion and Conclusion

Evidence from this study suggest that MCO is one of the factors that helped to minimize the mass spread of COVID-19 infection in Malaysia. The enforcement of three phases of MCO had prevented the worst case of the pandemic to take its course. It has assisted the Government of Malaysia in flattening the curve of the infection with the cooperation of various agencies and the public. It is important to note that MCO is not meant to end COVID-19 entirely but it is to flatten the curve, reduce a spike (or tall curve) in infections or the number of active confirmed COVID-19 cases. This is to ensure the health services are protected and able to cope with the pandemic in a country. In the Malaysian context, by the end of the third phase of MCO (42nd day) the curve had started to flatten further, and situations are in control. The health services at MOH hospitals have

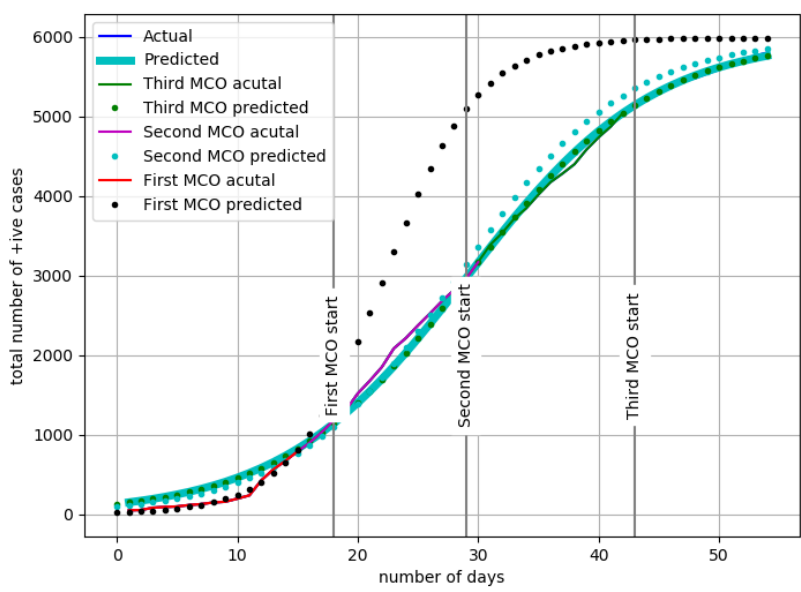


Fig. 6. Predict the peak of growth and analyze the effectiveness of MCOs

excess capacity of resources such as the number of beds for COVID-19 patients including for ICU cases and the number of ventilators. Frontlines also have some breathing space to take leave on rotational basis.

At the same time, it is important to note that the battle against COVID-19 has not ended in Malaysia and in many parts of the world, after their implementation of MCO. It is vital for the public to continue to maintain social distancing, stay at home and leave home only for essential matters and must maintain high levels of personal hygiene at all times, as in the health advisory on COVID-19 by the Malaysian Ministry of Health [35]. Evidence from our study indicates that working together among the country leaders, front lines from the medical team, public safety enforcement, relevant logistics and food service providers and the society at large to fight pandemic like COVID-19 could help control the fast spread of infections. Abiding to the Movement Control Order is an excellent example.

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14 Amiruzzaman, Abdullah-Al-Wadud, Mohd Nor, A. Aziz

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