Implication of Inter-State Movement of Migrant Workers during COVID-19 Lockdown using Modified SEIR Model

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Abstract

A modified SEIR model is used in the paper to evaluate the effect of inter-state migrant worker transportation during the lockdown in India. The model considers different levels of COVID-19 transmission during travel, daily arrival rate and total migrant workers. Indian states with significant migrant workers are considered to estimate the rise in confirmed and active COVID-19 cases. It is observed that reduced daily arrival rate of migrant workers can help Uttar Pradesh and Bihar to lower the rise in confirmed and active cases. By the end of May, 2020, the daily arrival rate of migrant workers will have similar effect on Rajasthan. For the daily arrival rate of migrant workers considered, Madhya Pradesh may experience higher rise in confirmed and active cases. Maharashtra, on the other hand, may experience marginal rise in the confirmed and active cases. A stringent policy to screen migrant workers for possible trace COVID-19 virus prior to the travel and stricter isolation norm after reaching the destination state can be helpful in reducing the rise in confirmed and actives cases attributed to the migrant worker transportation.

Keywords: COVID-19; SEIR model; Migrant workers; Inter-state transportation; Indian states

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Introduction

The novel coronavirus, COVID-19 started at Wuhan, the capital city of Hubei province in mainland China and later widely spread all over the world, is recognized as pandemic by the World Health Organization. This outbreak has also created an alarming situation in India, where the first case was confirmed on January 30, 2020 in the state of Kerala. Till April 29, 2020 total 33,065 confirmed, 8,429 recoveries and 1,079 deaths are reported in India (MoHFW, 2020). The Indian government has adopted social distancing as a non-pharmaceutical infection prevention and control intervention. In this strategy, the large-scale population movement, which may accelerate the spread of contagious epidemic disease, is avoided or restricted. A 14-hour voluntary public curfew was arranged on March 20, 2020 and subsequently nationwide lockdown was implemented on March 24, 2020 to slow down the spread of COVID-19. The lockdown has since been extended twice, up until May 17, 2020, and is affecting the 1.3 billion population of India.

Analysts argued that absence of vaccine, social distancing is one of the effective prevention and control strategies. However, using lockdown to impose social distancing has immediate adverse effects on migrant workers, particularly those who are from the marginalized sections of the society and depends on their daily wages for living. These migrant workers are now stranded at various parts of the country with almost no source of income and no means to return to their respective native places. Documents submitted to the Supreme Court of India indicates approximately 10.55 million migrant workers are living in 22,567 shelters setup at various regions of India (Rawal et al., 2020). These migrant workers, staying away from their family, are insecure and emotionally disturbed. A recent incidence of mass gathering on April 14, 2020 (the last day of first phase of lockdown) near railway stations at Mumbai (Maharashtra) and Surat (Gujarat) signifies their strong desire to return to their native places (Joshi et al., 2020). These migrant workers are getting impatient and desperately exploring for opportunities to return, irrespective of the shelter and food arrangements (Gunjan, 2020).

Arranging transportation and allowing migrant workers to travel have its own risk of spreading COVID-19 not only among the traveling migrant workers but also within the community at their native places. The state government of Uttar Pradesh arranged transportation in the last week of April, 2020 to bring back students stranded in the state of Rajasthan. Similar arrangements are explored among states to transport the migrant workers. For this, the possible modes considered are bus and train. Each mode has its limitations and advantages in terms of capacity, speed and maximum possibility of infection. Various studies described the impact of lock-down on COVID-19 transmission in India (Singh and Adhikari, 2020; Chatterjee et al., 2020; Mukhopadhyay and Chakraborty, 2020). However, no study is available to measures the impact of migrant workers returning to their origin state. So, this paper attempts to estimate the possible impact in terms of additional confirmed and active cases of COVID-19 in the selective Indian states with high returning migrant workers. The estimation considered different level of COVID-19 transmission during travel, daily arrival rate of migrant workers and returning migrant workers. A modified SEIR model is used to predict the rise in confirmed and active cases of the states reviewed.

Literature Review

The epidemiological characteristics of COVID-19 can be mathematically studied using compartmental models such as SIR and SEIR. Mathematical modelling based on the differential dynamic formulations were able to provide a comprehensive information on the mechanism of the transmission of COVID-19 epidemic. Researchers developed different models to study the outbreak of the epidemic diseases (Tang et al., 2020; Quilty et al., 2019;
Shen et al., 2020; Tang et al., 2020; Nadim et al., 2019). Biao et al. (2019) and Chen et al. (2020) developed a generalized SEIR model to evaluate the transmission risk and predict the number of persons infected. This model classified the entire population of the affected region into two groups, the quarantined and the unquarantined people. This model was further extended to stimulate the period of incubation and recovery (Tang et al., 2020). Read et al. (2020) developed a SEIR model by assuming Poisson-distributed daily time increments. These data-driven mathematical models play an important role in predicting the outbreak of the disease and helps to plan the future remedial measures to control the epidemic.

In the SEIR models, population of the analysis region is one of the essential parameters. Hence, for this study, the migrant worker population expected to return to their origin state is an important information. The Office of the Registrar General & Census Commissioner, India maintain the record of Indian state population and migrant worker population. However, the most recent available data is from the 2011 census data (MoHA, 2020). Hence, the appropriate forecasting of the 2011 census data was warranted for this study. Models such as arithmetic increase method, geometric increase model, incremental increase method, decrease in growth rate method and logistic curve method are available for forecasting the population (Jensen, 1995). Arithmetic increase method is suitable to forecast population for large and old cities where there is moderate or no development; geometric method is suitable for new locations where the industrial development has just initiated; incremental increase method is suitable for places with normal conditions; decrease in growth method is used to forecast population of the places which undergoes extraordinary changes like epidemic, war, or any natural disaster; and logistic method can be used for the places with limited land space and economic opportunity (Jensen, 1995). So, a suitable method should be chosen based on the region of interest.

**Method**

In this paper, a modified SEIR model with time dependent quarantine rate, recovery rate and decease rate are considered. Analyses of quarantined, recovered and deceased population provide these time dependent empirical functions. The time-dependent functions could consider the reduction in COVID-19 related death, increment in recovery and faster identification of COVID-19 positive patients over time due to improvements and inventions in medical science. However, like any other SEIR model, this model does not consider the births and natural deaths. The SEIR model considered in this paper, as shown in Figure 1, divides the population at any time \( t \) into seven different compartments, i.e., susceptible \( S(t) \), exposed \( E(t) \), infected \( I(t) \), quarantined \( Q(t) \), recovered \( R(t) \), deceased \( D(t) \) and insusceptible or isolated \( P(t) \). The flow of individuals through these compartments is modeled using a set of differential equations shown in Table 1. The data related to confirmed, recovered and deceased are used to estimate the \( \alpha, \beta, \gamma, \delta_1, \delta_2, \lambda_1, \lambda_2, \kappa_1 \) and \( \kappa_2 \) values.

The model is initiated by assigning the start day data to the corresponding recovered, deceased and quarantined compartments, about 2000 times the total of quarantined, recovered and deceased cases to the susceptible compartment and the remaining state population without returning migrant workers to the insusceptible compartment. People of \( P \) compartment become
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Figure 1 Standard SEIR model for COVID-19

Table 1 Differential equations for the compartmental standard SEIR model

| Differential equation | Description |
|-----------------------|-------------|
| \( \frac{dS(t)}{dt} = -\beta \frac{S(t)I(t)}{N} + \alpha P(t) \) | Change in susceptible population |
| \( \frac{dI(t)}{dt} = \gamma E(t) - \delta(t)I(t) \) | Change in exposed population |
| \( \frac{dR(t)}{dt} = \lambda(t)Q(t) \) | Change in recovered population |
| \( \frac{dP(t)}{dt} = -\alpha P(t) \) | Change in deceased population |
| \( \lambda(t) = \lambda_1(1 - e^{-\delta_2 t}) \) | Rate of recovery |
| Where, \( S + E + I + Q + R + D = N \) | Total population |
| \( \alpha = \text{Rate of being susceptible} \) | |
| \( \beta = \text{Rate of exposure} \) | |
| \( \gamma = \text{Rate of being infected after exposure} \) | |

\( N \) = Total population
\( \delta(t) = \text{Rate of detection leading to quarantine} \)
\( \lambda(t) = \text{Rate of recovery} \)
\( \kappa(t) = \text{Rate of mortality} \)
\( \delta_1, \delta_2, \lambda_1, \lambda_2, \kappa_1, \kappa_2 = \text{Constants} \)

Susceptible and move to \( S \) compartment at the rate of \( \alpha \) when they defy isolation for various reasons. People of \( S \) compartment further become exposed to COVID-19 at the rate of \( \beta \) and eventually get infected at the rate of \( \gamma \) after interacting with an infected individual. These individuals are removed from the \( S \) compartment and added to the \( E \) compartment and subsequently to the \( I \) compartment. The removal rate of \( \gamma \) from the \( E \) compartment is equivalent to 1/incubation period or the latent time. Depending on the symptom and test protocol, certain people of the overall population are tested. If the tested person belongs to the \( I \) compartment, the test result is expected to be positive. These individuals are either hospitalized or isolated in the pre-designated quarantined center. For a particular COVID-19 positive patient, hospitalization or quarantine center is decided based on their morbidity, age, pre-existing condition, etc. At both locations, these infected individuals are assumed to be isolated from rest of the population and may stop spreading the virus. So, in this study, hospitalized patients and quarantined individuals are considered to be in \( Q \) compartment. The individuals from \( Q \) compartment either get cured or recovered and move to \( R \) compartment at \( \lambda \) rate or die at the mortality rate of \( \kappa \). Since, all the infected individuals cannot be identified
without testing the entire population, some infected individuals are expected to continue spreading the virus.

A SEIR model assumes constant population. So, in this study, prior to the inter-state transportation of migrant workers, the standard SEIR model have additional compartment of migrant workers. This compartment of migrant workers does not interact with any of the SEIR model compartments shown in Figure 1. However, when transportation for migrant workers are arranged, a suitable interaction between the compartment of migrant workers and some of the standard SEIR compartments is established. Hence, at the beginning the model parameters \( \alpha, \beta, \gamma, \delta_1, \delta_2, \lambda_1, \lambda_2, \kappa_1 \) and \( \kappa_2 \) are estimated considering the present state population without the returning migrant worker distributed among the \( S, E, I, Q, R, D \) and \( P \) compartments. A migrant worker not infected with COVID-19 can be part of \( P \) compartment. However, the migrant workers are not tested for COVID-19, only symptoms are monitored prior to boarding a train or a bus. In this process, an asymptomatic person and exposed individual cannot be detected. So, an asymptomatic person and exposed individual can board the bus or train and might become symptomatic prior to disembarking. The probability of someone being symptomatic depends on the location or the state they are currently residing. If the probability of being symptomatic and quarantined, estimated by considering the ratio of quarantined population and the total population of the region, in a particular state \( i \) is \( QR_i \), the number of expected symptomatic persons among the migrant worker population \( MW_{ij} \) traveling from state \( i \) to state \( j \) is \( QR_i \times MW_{ij} \). Based on some recent test results, about two-third of the symptomatic population is expected to be asymptomatic. Further, an asymptomatic traveling in a confined coach of a train or bus can expose many co-passengers. Hence, an elevated value of \( QR_i \) is considered to estimate the symptomatic number of migrant workers reaching state \( j \) from state \( i \). These symptomatic migrant workers are expected to be quarantined (in hospital or quarantine center) at their destination state. The co-passengers from the same compartment of the symptomatic passenger might be quarantined as well. Otherwise,
the migrant workers are expected to be in isolation for 14 days. The assumed situations of migrant worker at their origin and destination is shown in Figure 2. So, when the migrant workers arrive at their destination state, the SEIR model of the destination state is updated by assigning the symptomatic migrant workers to the $Q$ compartment, asymptomatic migrant to the $I$ compartment and remaining to the $P$ compartment. The updated SEIR model is shown in Figure 3. Note the migrant worker population did not interact with any compartments of a standard SEIR model until the first arrival date. Time required to transport all migrant workers to their destinations will depend on the daily arrival rate of migrant workers. In this analysis, various daily arrival rates are considered for review and comparison.

Figure 3 Modified SEIR model with migrant worker interactions

Data

The data compiled and provided by https://www.covid19india.org is used for the analysis (COVID-19 Tracker, 2020). This dataset contains daily information of “confirmed”, “recovered” and “death” cases for all Indian states since March 14, 2020. Data available till April 29, 2020 is used to develop the model. Minimum 10 confirmed cases are considered to initiate the analysis. So, certain states like Madhya Pradesh and Bihar, with late spread of infection, the analysis start day is sometime after March 14, 2020. The population considered in this model includes the state population and the returning migrant worker population of that state. The overall migrant population is forecasted considering the decadal growth factor of the population from the year 1981 to 2011 and the annual average growth of migrant population from the year 2001 to 2011. See Figure 4 for the process. Required information for it is acquired from the census data published by the Office of the Registrar General & Census Commissioner, India (MoHA, 2020). The current year population is forecasted using incremental increase method, shown in Equation 1, and the migrants growth rate is calculated using the annual average growth method, as shown in Equation 2. The overall migrant population is estimated considering both the growth rate of the migrant population and the overall population of the present year, as shown in Equation 3.

\[ P_{\text{op}} = P_{\text{op}_0} + n\bar{p} + \frac{n(n+1)}{2} \bar{q} \]  

(1)
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\[ \bar{r} = 100 \left( \frac{M_i}{M_f} \right)^{(1/y)} - 100 \]  
\[ M_n = \frac{\bar{r} \times \text{Pop}_n}{100} \]

where,
\[ \text{Pop}_n = \text{Population at n}^{\text{th}} \text{ year} \]
\[ \text{Pop}_0 = \text{Population of the last given decade} \]
\[ n = \text{No. of decades} \]
\[ \bar{p} = \text{Average increase in population} \]
\[ \bar{q} = \text{Average incremental increase in population} \]
\[ \bar{r} = \text{Annual average growth rate} \]
\[ M_i \& M_f = \text{Migrant population of the initial and latest given years} \]
\[ y = \text{Number of years for which the migrant population data is available} \]
\[ M_n = \text{Migrant population at n}^{\text{th}} \text{ year} \]

Input Multi decadal population data (Census India, 1981-2011)

Evaluate average increase in population over decades (\( \bar{p} \))

Estimate average incremental increase in population (\( \bar{q} \))

Forecast current population using Incremental increase method (\( \text{Pop}_n \)) (Eq. 1)

Input Multi decadal Migrants data (Census India, 1981-2011)

Estimate decadal growth rate of Migrants Population using annual average growth method (\( \bar{r} \)) (Eq. 2)

Estimate current migrants using decadal growth rate of migrants and states current population (\( M_n \)) (Eq. 3)

The states with significantly high in- and out-migration are considered in this study. It can be observed from Figure 5 that the states with higher number of in-migrants (i.e., the states where people migrated to) are Maharashtra, NCT of Delhi, Gujarat, Haryana, Uttar Pradesh and Karnataka, and states with higher number of out-migrants (i.e., the states from where people migrated) are Uttar Pradesh, Bihar, Rajasthan, Maharashtra and Madhya Pradesh. These states contribute more than 50% of the in- and out-migrants population of India. The number of in- and out-migrants forecasted for these states, for the year 2020, are shown in Table 2. It is assumed that the migrants residing for more than four years in a state probably have permanently settled in that state. It is also considered that despite the pandemic COVID-19, these migrants would prefer staying at their current location. Therefore, the migrant worker expected to travel is derived from the people migrated in the last four years. Further, the approximate data of migrant workers willing to travel to their home state are verified from the local government’s policies related to the migrant workers, news, and social media.
The migrant workers with high possibility of travel are daily wagers and workers with insecurity of food and shelter. States and union territories are identifying such people and providing the basic amenities. For instance, the Delhi Government with some social organizations arranged cooked food for 800,000 migrant workers (Mathur and Yadav, 2020); the Maharashtra government is supporting more than 650,000 migrant workers with food, shelter and basic medical facilities (Bose, 2020); the Karnataka government is providing relief for 440,000 migrant workers and the Haryana Government set up relief camps for 70,000 migrants (ET Bureau, 2020). As indicated earlier, these are some of the regions with the highest...
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In-migration compared to other Indian states. On the other hand, state governments with maximum out-migrants such as Uttar Pradesh and Bihar Governments may allow return of approximately 1 million migrant workers stranded in several other states (PTI, 2020; Kumar, 2020). When these information related to migrant workers are compared with the total migrant population presented in Table 2, it is noted that the migrant workers looking for transportation to return back to their origin state are between 3 and 12% (with an average of 10%) of the total people migrated to a state in the last four years. Therefore, in this study, it is assumed that 8-12% of the forecasted in-migrants (see Table 2) would return to their origin state.

Table 2 Migration in last four years estimated for year 2020

| States (Abbreviation) | In-migrants | Out-migrants |
|-----------------------|-------------|--------------|
| Maharashtra (MH)      | 7,018,877   | 1,573,486    |
| NCT of Delhi (DL)     | 6,352,546   | -            |
| Gujarat (GJ)          | 4,439,145   | -            |
| Haryana (HR)          | 3,507,625   | -            |
| Karnataka (KR)        | 5,439,221   | -            |
| Uttar Pradesh (UP)    | -           | 11,694,016   |
| Bihar (BR)            | -           | 8,446,304    |
| Rajasthan (RJ)        | -           | 3,498,803    |
| Madhya Pradesh (MP)   | -           | 3,367,641    |

Analysis and Results

As indicated earlier, the model parameters i.e., $\alpha$, $\beta$, $\gamma$, $\delta_1$, $\delta_2$, $\lambda_1$, $\lambda_2$, $\kappa_1$ and $\kappa_2$ are estimated using a standard SEIR model without migrant workers. The obtained parameters are shown in Table 3 and fitted trends for confirmed, active, recovered and deceased are shown in Figure 6. For all states except Bihar, the $\alpha$ value representing the rate of being susceptible indicates about 10% of the population can become susceptible even in the present lockdown. In Bihar this rate is however less (about 2%). Similarly, for all states except Uttar Pradesh, the $\beta$ values indicate susceptible people can become exposed immediately after interacting with infected person. It supports the high contagious characteristics of COVID-19. However, for Uttar Pradesh this rate is low and may need further review for better understanding. The $\gamma$ value indicating the rate of being infected after exposure is almost similar for all the states analyzed. In other words, the incubation time ($1/\gamma$) or latent time of COVID-19 is about 2 days. The other parameters are state specific and greatly depends on the confirmed, active, recovered and deceased cases recorded. The SEIR model used is a dynamic model with deterministic output and hence, the goodness of fit of the obtained trends is represented by RMSE values indicated in the corresponding plot.
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The obtained model parameters shown in Table 2 are used to predict the confirmed and active COVID-19 cases until May 31, 2020. It is the base scenario, representing the predicted number of confirmed and active cases in a particular state without the migrant workers. The migrant workers are assumed to start arriving at their respective destination state from May 5, 2020. Total 8 to 10% of the out-migrants in last four years are expected to return to their origin state. Considering the limited availability of the transportation modes, reduced capacity to maintain social distancing and the required infrastructure to screen migrant workers prior to boarding a train or bus and after disembarking the train or bus, it is assumed that per day 100,000 or less migrant workers would reach a particular destination state. Therefore, this study analyzed the daily arrival rate of 20,000 (20k) to 100,000 (100k) migrant workers per state. As reasons indicated earlier, these migrant workers are assumed to become symptomatic at a rate 10 to 100 times higher than their migrated state rate. All combinations of these three factors (total
number of migrant workers, daily arrival rate of migrant workers and rate to become symptomatic after reaching destination) are analyzed using the modified standard SEIR model shown in Figure 3. The respective compartments of the model are updated for each arrival day and the confirmed and active COVID-19 cases are predicted until May 31, 2020. These confirmed and active COVID-19 cases are adjusted for the base scenario to estimate the rise in confirmed and active COVID-19 cases in a state due to the arriving migrant workers. The range between the first and third quartiles, and the median values (second quartile) of the additional number of confirmed and active COVID-19 cases are presented in Figure 7. With stringent measures the rise in confirmed and active cases could be within the first quartile. However, in the worst situation, the rise in confirmed and active cases can go beyond the third quartile.

Table 3 Model parameters from standard SEIR model

| Parameters                                      | Values    |
|-------------------------------------------------|-----------|
| Population without migrant workers (N) in millions | MH        |
|                                                  | UP        |
|                                                  | BH        |
|                                                  | RJ        |
|                                                  | MP        |
| Population without migrant workers (N) in millions | 122.04    |
|                                                  | 233.24    |
|                                                  | 110.00    |
|                                                  | 76.44     |
|                                                  | 80.38     |
| \( \alpha \)                                      | 0.1       |
|                                                  | 0.1       |
|                                                  | 0.021     |
|                                                  | 0.1       |
|                                                  | 0.1       |
| \( \beta \)                                      | 0.92      |
|                                                  | 0.5       |
|                                                  | 1.2       |
|                                                  | 0.9       |
|                                                  | 1.0       |
| \( \gamma \)                                     | 0.6       |
|                                                  | 0.6       |
|                                                  | 0.4       |
|                                                  | 0.6       |
|                                                  | 0.6       |
| \( \delta_1 \)                                   | 1.0       |
|                                                  | 1.0       |
|                                                  | 0.18      |
|                                                  | 1.0       |
|                                                  | 1.0       |
| \( \delta_2 \)                                   | 0.039     |
|                                                  | 0.015     |
|                                                  | 0.1       |
|                                                  | 0.045     |
|                                                  | 0.055     |
| \( \lambda_1 \)                                  | 0.021     |
|                                                  | 1.0       |
|                                                  | 0.043     |
|                                                  | 1.0       |
|                                                  | 1.0       |
| \( \lambda_2 \)                                  | 0.066     |
|                                                  | 0.0       |
|                                                  | 0.1       |
|                                                  | 0.0012    |
|                                                  | 0.0009    |
| \( \kappa_1 \)                                   | 0.028     |
|                                                  | 0.002     |
|                                                  | 0.0006    |
|                                                  | 0.0016    |
|                                                  | 0.0054    |
| \( \kappa_2 \)                                   | 0.046     |
|                                                  | 0.0       |
|                                                  | 0.0       |
|                                                  | 0.0       |
|                                                  | 0.0       |

For a daily arrival rate of 20,000 migrant workers, Figures 7a and 7b represent the rise in confirmed and active cases, respectively. As expected, the confirmed cases in all the states are increasing till May 31, 2020 (see Figure 7a). However, as shown in Figure 7b, the rise in active cases for some states such as Rajasthan and Uttar Pradesh are either flattening or reducing in the last week of May, 2020. If the daily arrival rate of migrant workers increases to 100,000, among the states analyzed, Uttar Pradesh is expected to experience the largest rise in confirmed and active cases (see Figures 7c and 7d). However, the number of additional active cases in Uttar Pradesh are expected to drop in the last week of May, 2020 (see Figure 7d). Similar trend of reduction in active cases is observed for Rajasthan as well. Irrespective of the daily arrival rate of migrant workers considered, rise in confirmed and active cases in Madhya Pradesh are expected to rise at a higher rate till the end of analysis period. The effect of migrant workers returning to Maharashtra is nominal compared to all the states analyzed. The migrant workers leaving a particular state to return to their origin state is not adjusted in the present model. If adjusted, the rise in confirmed and active cases in Maharashtra are expected to be even lesser than the cases presented in this paper.
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The median values of additional active cases for daily arrival rates of 20,000, 40,000, 60,000, 80,000 and 100,000 migrant workers are presented in Figure 8. The rise in active cases in Uttar Pradesh and Bihar is considerably less when the daily arrival rate of migrant workers is 20,000. For all the states analyzed, by mid of May, 2020, the rise in active cases for the daily arrival rate of 60,000 and above are expected to be two to three times higher than the rise in active cases for the daily arrival rate of 20,000. Irrespective of the daily arrival rates considered, the rise in active cases in Rajasthan is expected to be almost same by the end of the analysis period. However, such trend is not observed for Uttar Pradesh, Bihar, Madhya Pradesh and Maharashtra.

Figure 7 Expected rise in confirmed and active cases till May 31, 2020

The median values of additional active cases for daily arrival rates of 20,000, 40,000, 60,000, 80,000 and 100,000 migrant workers are presented in Figure 8. The rise in active cases in Uttar Pradesh and Bihar is considerably less when the daily arrival rate of migrant workers is 20,000. For all the states analyzed, by mid of May, 2020, the rise in active cases for the daily arrival rate of 60,000 and above are expected to be two to three times higher than the rise in active cases for the daily arrival rate of 20,000. Irrespective of the daily arrival rates considered, the rise in active cases in Rajasthan is expected to be almost same by the end of the analysis period. However, such trend is not observed for Uttar Pradesh, Bihar, Madhya Pradesh and Maharashtra.
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Discussion

The population of migrant worker returning to their home state has significant impact on the expected number of confirmed and confirmed cases. Since lesser number of migrant workers are expected to return to Maharashtra, the rise in confirmed and active cases are predicted to be lower than the states analyzed. As indicated earlier, it may be even lower if the migrant workers leaving a state is considered. The daily arrival rate of migrant workers also affects the rise in confirmed and active cases. In spite of the highest number of migrant workers returning to Uttar Pradesh, maintaining a lower daily arrival rate can help Uttar Pradesh to keep the rise in confirmed and active cases low. The analysis reveals that Uttar Pradesh, Bihar and Madhya

Figure 8 Rise in active cases for different daily arrival rates
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Pradesh may experience higher rise in confirmed and active cases after the arrival of migrant workers. However, as indicated earlier, stringent measures in screening migrant workers prior to boarding and strict isolation after arrival can help to keep the rise in confirmed and active cases under control. Some of the state governments have planned for 14 to 21 days quarantine of the arriving migrant workers (Kumar, 2020). Alternatively, restarting industries with safe work environment might encourage the migrant workers to stay back. The Maharashtra and Karnataka state governments have started allowing a few industries, where migrant workers are generally employed, to operate (Poovanna, 2020). Such activities would help the migrant workers to earn livelihood and reduce the demand for travel. Moreover, it will help to sustain the economy (Sastry, 2020).

Conclusion

This study observes the implication of the inter-state migrant workers movement on the spread of pandemic COVID-19 at their native states of India. The modified SEIR model provided the additional confirmed and active cases of states analyzed. The daily arrival rate showed significant effect on the rise in the confirmed and active cases. The rise in confirmed and active cases in states like Uttar Pradesh, Bihar and Madhya Pradesh would be higher than Rajasthan and Maharashtra. The present study is limited to arriving migrant workers only. The migrant workers departing a state, migration of students and other inter-state movements are not considered.

This study reveals that the rise in confirmed and active cases would be low for lower daily arrival rate. However, lower daily arrival rate would take longer to complete the transportation of migrant workers. For example, about 50 days is required to transport 1 million migrant workers to Uttar Pradesh. Transportation infrastructure capacity, human resource availability, logistics for disinfection, etc. should be reviewed to decide the daily arrival rate. For example, Bihar is unable to facilitate adequate number of buses to transport migrant workers across India (FE Online, 2020) and the Indian Railways could operate only 115 “Shramik Trains” (special trains for transporting migrant workers) from May 01 to 06, 2020 to transport more than 100,000 migrant workers within India (PTI, 2020b).

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