

# Prediction of age-structured model for SARS-CoV-2 in Seoul and Gyeonggi

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# Data

1. Daily confirmed cases in Seoul and Gyeonggi
2. Vaccine
  - ▶ Daily number of vaccination for 1st dose (by age)
  - ▶ Daily number of vaccination for 2nd dose (by age)
  - ▶ Vaccine efficacy
3. Proportion of  $\delta$  variant

# Data processing

## 1. Daily number of vaccination for 1st dose (all ages)

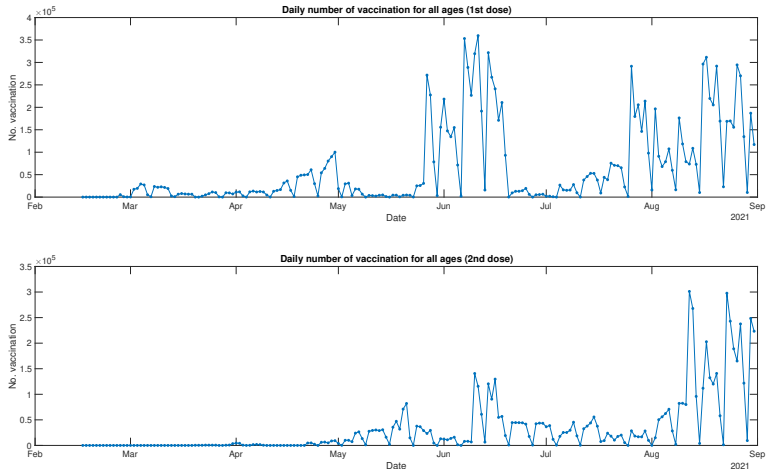


Figure 1: The daily number vaccination for 1st dose and 2nd dose from 2021/02/15 to 2021/09/01

## Data processing

### 1. Daily number of vaccination for 1st dose (by age)

- ▶ The daily number of vaccination by age is generated by the ratio between ages of vaccinated people.
- ▶ The ratio is based on KDCA reports.

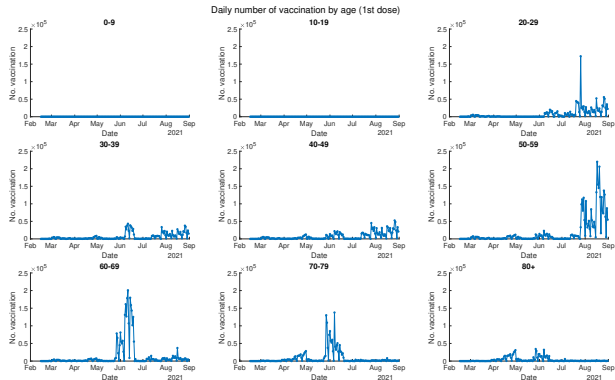


Figure 2: The daily number vaccination for 1st dose by age from 2021/02/15 to 2021/09/01

## Data processing

### 2. Daily number of vaccination for 2nd dose (by age)

- ▶ The daily number of vaccination by age is generated by the ratio between ages of vaccinated people.
- ▶ The ratio is based on KDCA reports.

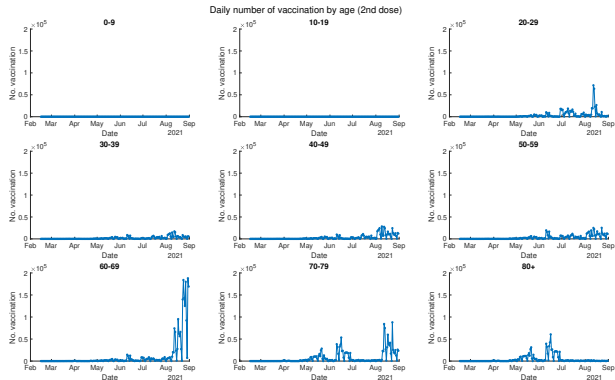


Figure 3: The daily number vaccination for 2nd dose by age from 2021/02/15 to 2021/09/01

## 3. Vaccine efficacy

- ▶ The vaccine efficacies for  $\alpha$  variant and  $\delta$  variant are different.<sup>1</sup>
- ▶ We use weighted sum of vaccine efficacies where weights are based on proportion of  $\delta$  variant

	Dose	Astrazeneca	Pfizer
$\alpha$ variant	1st dose	48.7%	47.5%
	2nd dose	74.5%	93.7%
$\delta$ variant	1st dose	30.0%	35.6%
	2nd dose	67%	88%

Table 1: The vaccine efficacies according to the vaccine type, variant and dose.

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<sup>1</sup>Jamie Lopez Bernal et al. (2021). “Effectiveness of Covid-19 vaccines against the B. 1.617. 2 (Delta) variant”.  
In: *New England Journal of Medicine*

## 3. Vaccine efficacy

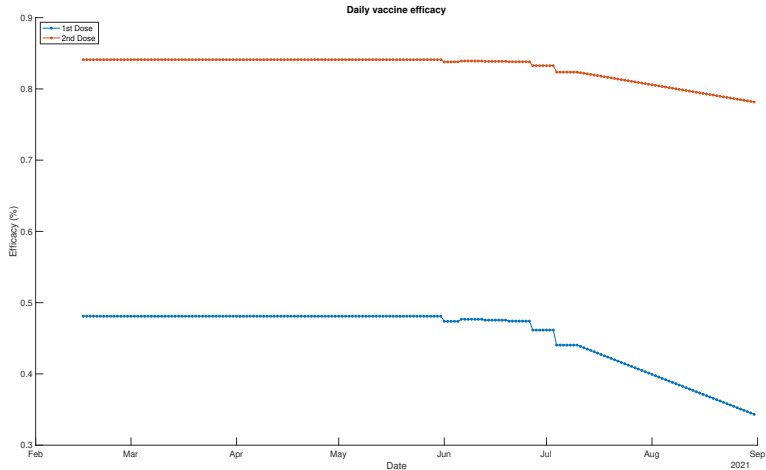


Figure 4: The estimated daily vaccine efficacy for 1st dose and 2nd dose.

## 4. Proportion of $\delta$ variant

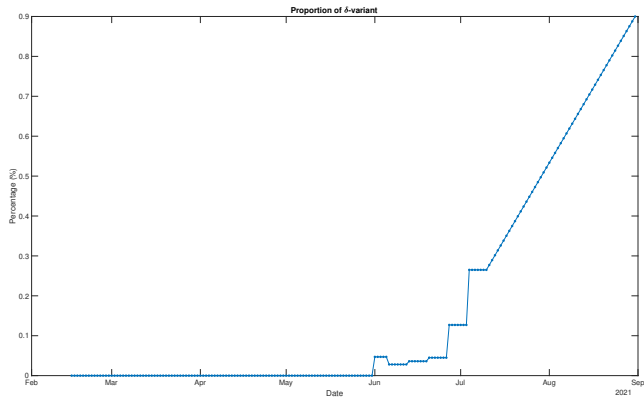
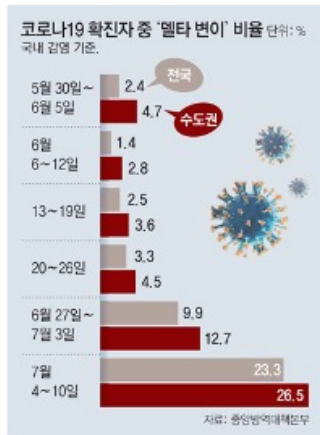


Figure 5: Estimates of proportion of  $\delta$  variant.



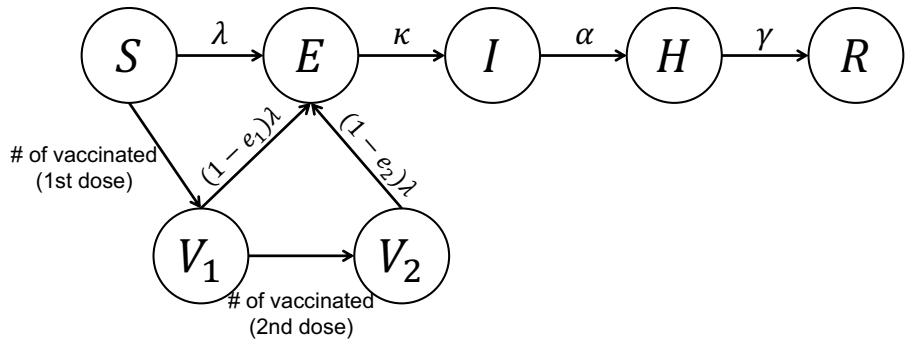


Figure 6: Diagram of age-structured model for SARS-CoV-2.

Notation	Interpretation
$S$	Susceptibles
$E$	Exposed
$I$	Infectious
$H$	Hospitalized
$R$	Removed (or recovered)
$V$	Vaccinated (between 1st dose and 2nd dose)
$\lambda$	Force of infection
$\kappa$	Latent period
$\alpha$	Infectious period
$\gamma$	Hospitalization period
$e_1$	Vaccine efficacy for 1st dose
$e_2$	Vaccine efficacy for 2nd dose

Table 2: Definition of states and parameters.

### Social distance level

- ▶ 0.5단계 감소: transmission rate 전단계 대비 41.61% 증가
- ▶ 0.5단계 증가: transmission rate 전단계 대비 30% 감소
- ▶ 1단계 증가: transmission rate 전단계 대비 65% 감소

Date	Social distancing level	Change of transmission rate
2021/02/15-2021/06/30	2	
2021/07/01-2021/07/11	1.5	$\beta \times 1.4161$
2021/07/12-2021/09/01 <sup>2</sup>	-	-

**Table 3:** The change of transmission rate according to the social distancing level from 2021/02/15 to 2021/09/01.

<sup>2</sup>It will be changed according to the experiments.

## Definition of $\lambda$

### Motivation

- ▶ In general,  $\lambda(t)$  is defined by  $W \times I(t)$  where  $W$  is the WAIFW matrix, and  $I(t)$  is the number of infectious at time  $t$ .
- ▶ To reflect the non-pharmaceutical intervention, we consider time-dependent  $W(t)$ .

### Definition of WAIFW matrix

Let  $p(t)$  and  $SD(t)$  be the proportion of  $\delta$  variant and proportionate of the corresponding social distancing level at time  $t$ . Let  $C(t)$  be the contact rate at time  $t$ .

- ▶  $W(t) = ((1 - p(t) + p(t)\delta) \times \beta \times SD(t) \times C(t)$

## Experiments

- ▶ The social distancing effects after 2021/07/12 are assumed differently in experiments.
- ▶ We assume that the number of contacts from 2021/07/01 to 2021/07/11 increases 41.61%.

No. Experiments	SD (2/15-6/30)	SD (7/1-7/11)	SD (7/12-9/1)
1	2단계	1.5단계	3단계
2	2단계	1.5단계	2.5-3단계
3	2단계	1.5단계	2.5단계
4	2단계	1.5단계	2단계

## Experiment 1: 3단계 (2021/07/12-2021/09/01)

▶  $\hat{\beta} = 0.0433$

Parameter	Initial	Estimate
$\delta$	1.0000e+00	3.6528e+00
Cost	1.1157e+05	1.9508e+04
Time	0.0000e+00	4.9572e+01

Table 4: Parameter estimates obtained by maximum likelihood estimation.

## Experiment 1: 3단계 (2021/07/12-2021/09/01)

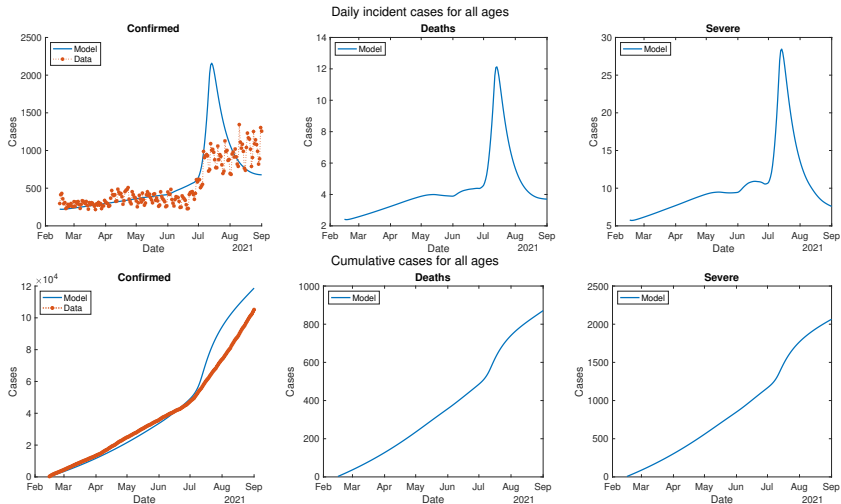


Figure 7: The model prediction and data for daily confirmed cases (top) and cumulative confirmed cases (bottom).

## Experiment 1: 3단계 (2021/07/12-2021/09/01)

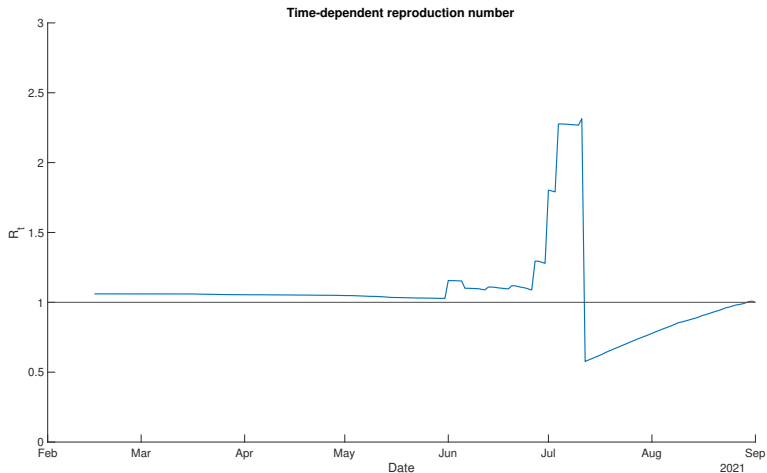


Figure 8: The estimated reproduction number from 2021/02/15 to 2021/09/01.



## Experiment 2: 2.5-3단계 (2021/07/12-2021/09/01)

▶  $\hat{\beta} = 0.0433$

Parameter	Initial	Estimate
$\delta$	1.0000e+00	2.7878e+00
Cost	8.8790e+04	1.4115e+04
Time	0.0000e+00	4.5544e+01

Table 5: Parameter estimates obtained by maximum likelihood estimation.

## Experiment 2: 2.5-3단계 (2021/07/12-2021/09/01)

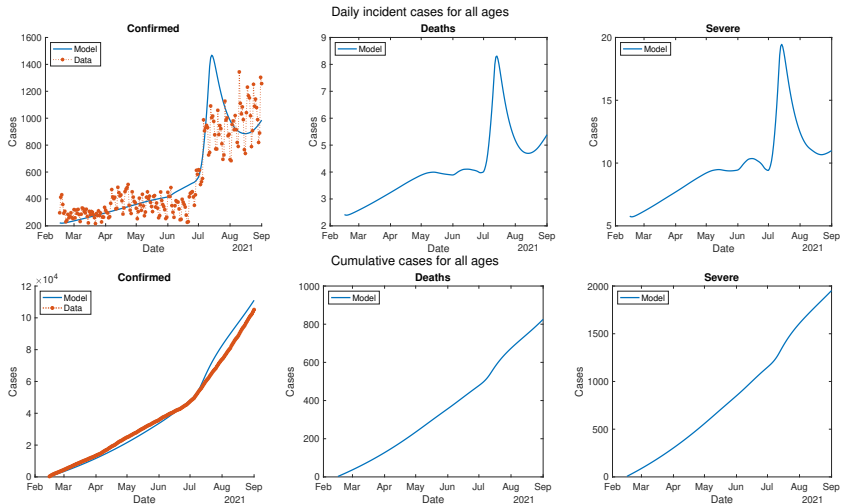


Figure 9: The model prediction and data for daily confirmed cases (top) and cumulative confirmed cases (bottom).

## Experiment 2: 2.5-3단계 (2021/07/12-2021/09/01)

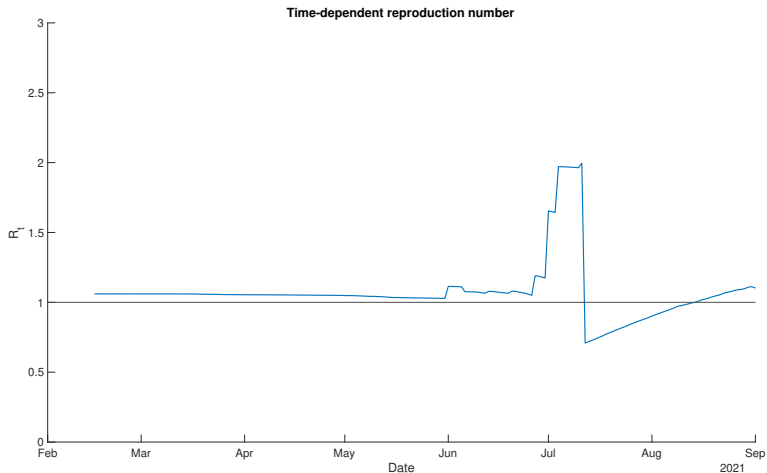


Figure 10: The estimated reproduction number from 2021/02/15 to 2021/09/01.

### Experiment 3: 2.5단계 (2021/07/12-2021/09/01)

▶  $\hat{\beta} = 0.0433$

Parameter	Initial	Estimate
$\delta$	1.0000e+00	1.8818e+00
Cost	5.1414e+04	1.2693e+04
Time	0.0000e+00	4.7774e+01

Table 6: Parameter estimates obtained by maximum likelihood estimation.

## Experiment 3: 2.5단계 (2021/07/12-2021/09/01)

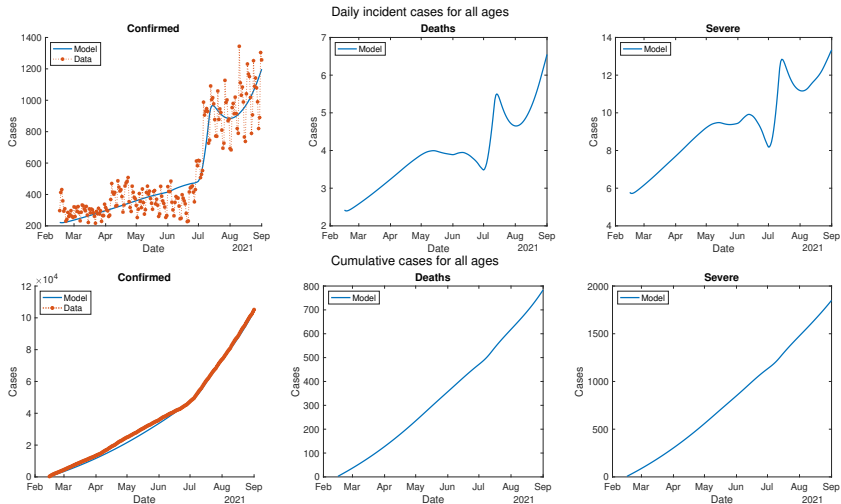


Figure 11: The model prediction and data for daily confirmed cases (top) and cumulative confirmed cases (bottom).

### Experiment 3: 2.5단계 (2021/07/12-2021/09/01)

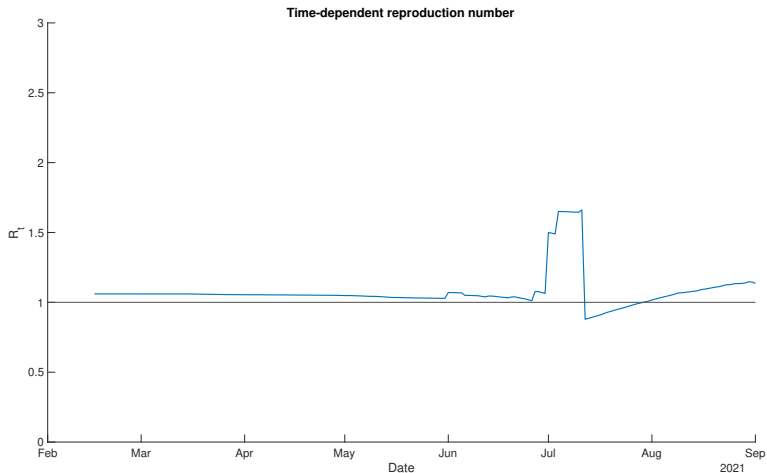


Figure 12: The estimated reproduction number from 2021/02/15 to 2021/09/01.

## Experiment 4: 2단계 (2021/07/12-2021/09/01)

▶  $\hat{\beta} = 0.0433$

Parameter	Initial	Estimate
$\delta$	1.0000e+00	1.3301e+00
Cost	2.3381e+04	1.3167e+04
Time	0.0000e+00	4.1814e+01

Table 7: Parameter estimates obtained by maximum likelihood estimation.

## Experiment 4: 2단계 (2021/07/12-2021/09/01)

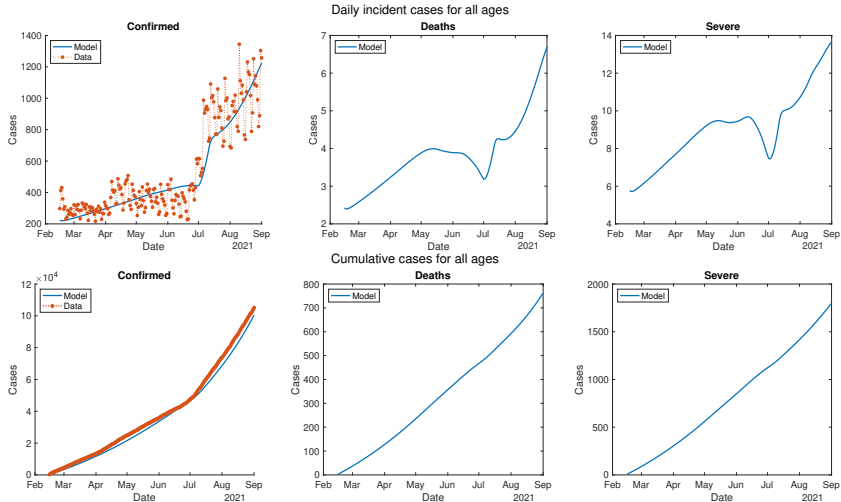


Figure 13: The model prediction and data for daily confirmed cases (top) and cumulative confirmed cases (bottom).



## Experiment 4: 2단계 (2021/07/12-2021/09/01)

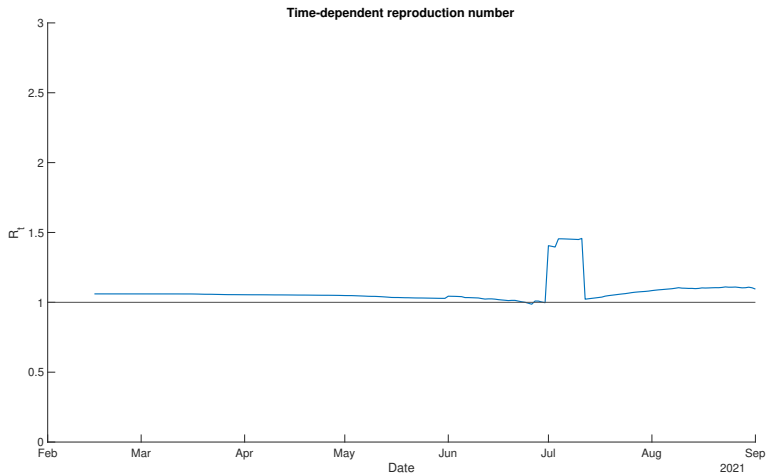


Figure 14: The estimated reproduction number from 2021/02/15 to 2021/09/01.