

# 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)

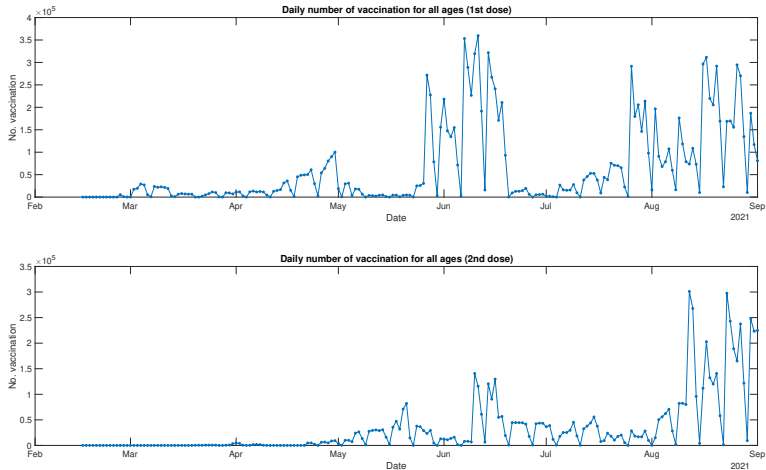


Figure 1: The daily number vaccination for 1st dose and 2nd dose from 2021/02/15 to 2021/09/01

# 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.

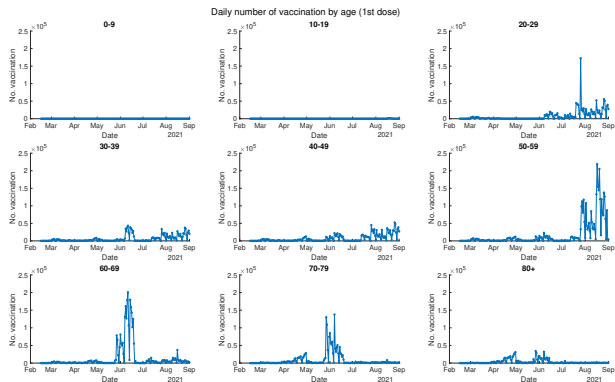


Figure 2: The daily number vaccination for 1st dose by age from 2021/02/15 to 2021/09/01

## 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.

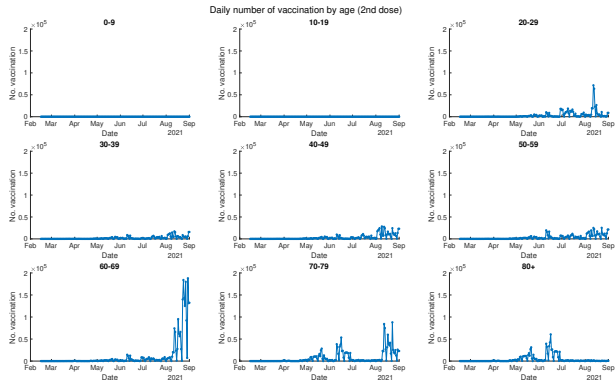


Figure 3: The daily number vaccination for 2nd dose by age from 2021/02/15 to 2021/09/01

## 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

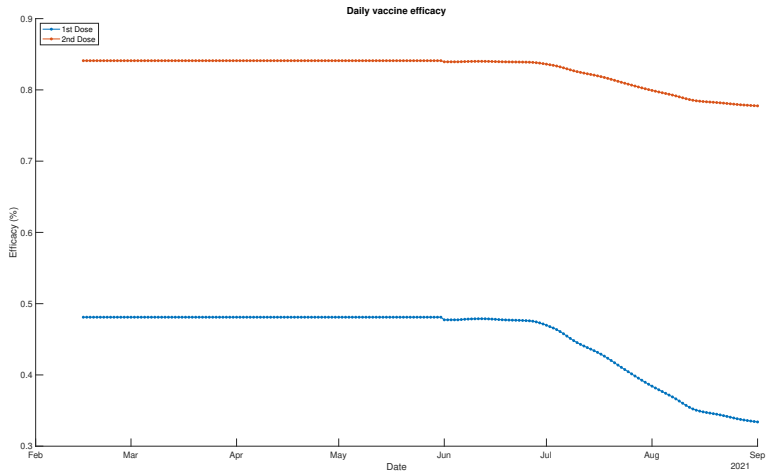


Figure 4: The estimated daily vaccine efficacy for 1st dose and 2nd dose.

## 4. Proportion of $\delta$ variant

Date	$\delta$ proportion (%)
6월 1주차	2.4
6월 2주차	1.4
6월 3주차	2.5
6월 4주차	3.3
6월 5주차	9.9
7월 1주차	23.3
7월 2주차	33.9
7월 3주차	48.0
7월 4주차	61.5
8월 1주차	73.1
8월 2주차	85.3
8월 3주차	89.6
8월 4주차	94.3
9월 1주차	97.0

Table 2: 질병관리청에서 보도된  
검출된 델타 변이 비율

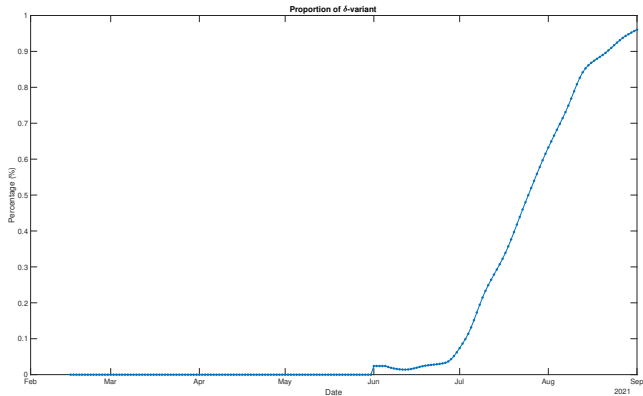


Figure 5: Estimates of proportion of  $\delta$  variant.



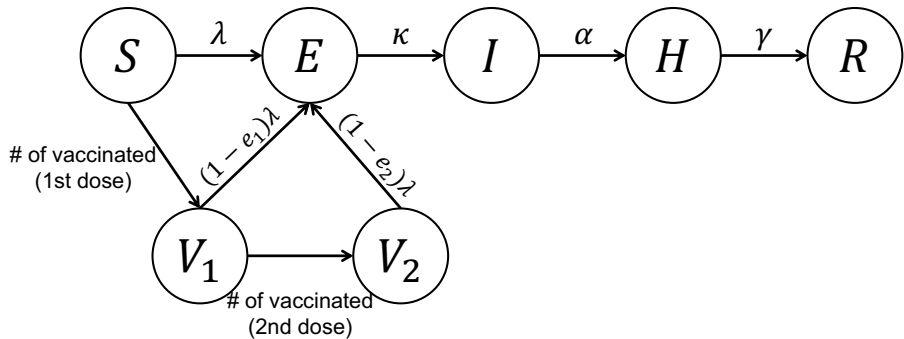


Figure 6: Diagram of age-structured model for SARS-CoV-2.

Notation	Interpretation
$S$	Susceptibles
$E$	Exposed
$I$	Infectious
$H$	Hospitalized
$R$	Removed (or recovered)
$V_1$	Vaccinated (1st dose)
$V_2$	Vaccinated (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 3: Definition of states and parameters.

### Social distance level

- ▶ 0.5단계 감소: transmission rate 전단계 대비 40% 증가
- ▶ 0.5단계 증가: transmission rate 전단계 대비 32% 감소

Date	Social distancing level	Change of transmission rate
2021/02/15-2021/06/30	2	
2021/07/01-2021/07/11	1.5	$\beta \times 1.4$
2021/07/12-2021/09/01 <sup>2</sup>	-	-

**Table 4:** 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	2단계
2	2단계	1.5단계	3단계
3	2단계	1.5단계	4단계

## Experiment 1: 2단계 (2021/07/12-2021/09/01)

▶  $\hat{\beta} = 0.0426$

Parameter	Initial	Estimate
$\delta$	2.0000e+00	1.5918e+00
Cost	3.9785e+04	1.5219e+04
Time	0.0000e+00	3.5082e+01

Table 5: Parameter estimates obtained by maximum likelihood estimation.

## Experiment 1: 2단계 (2021/07/12-2021/09/01)

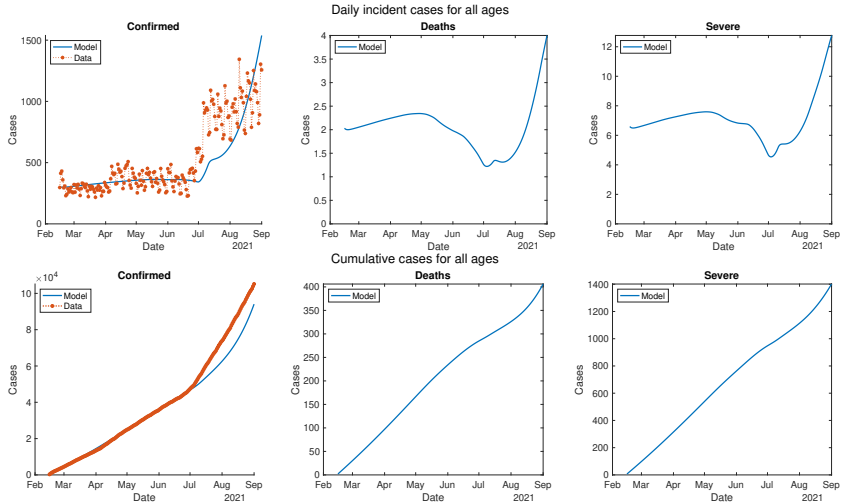


Figure 7: The model prediction and data for daily confirmed cases (top) and cumulative confirmed cases (bottom).

## Experiment 1: 2단계 (2021/07/12-2021/09/01)

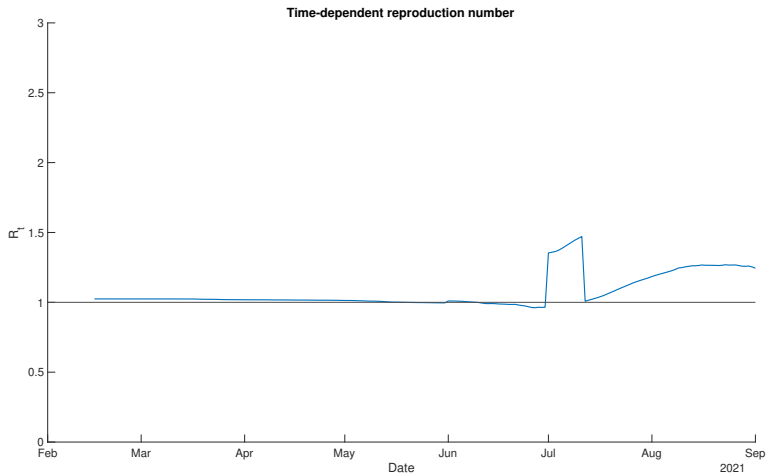


Figure 8: The estimated reproduction number from 2021/02/15 to 2021/09/01.



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

▶  $\hat{\beta} = 0.0426$

Parameter	Initial	Estimate
$\delta$	2.0000e+00	2.5105e+00
Cost	2.5828e+04	1.4278e+04
Time	0.0000e+00	3.7808e+01

Table 6: Parameter estimates obtained by maximum likelihood estimation.

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

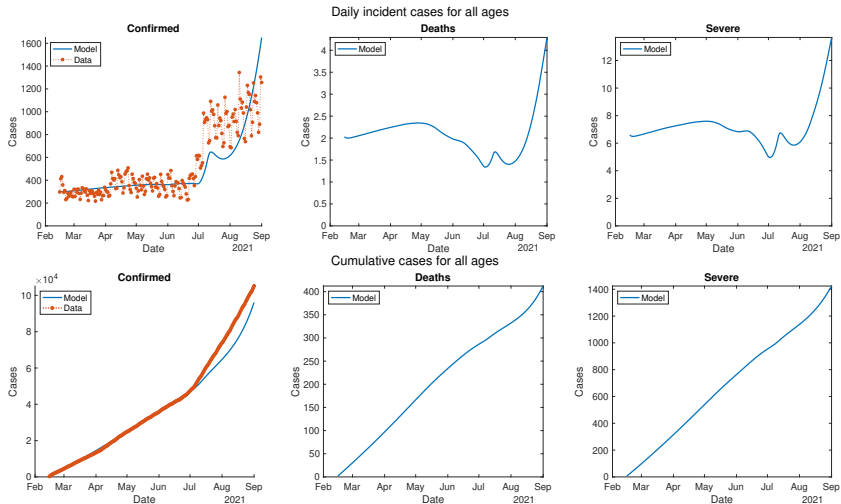


Figure 9: The model prediction and data for daily confirmed cases (top) and cumulative confirmed cases (bottom).

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

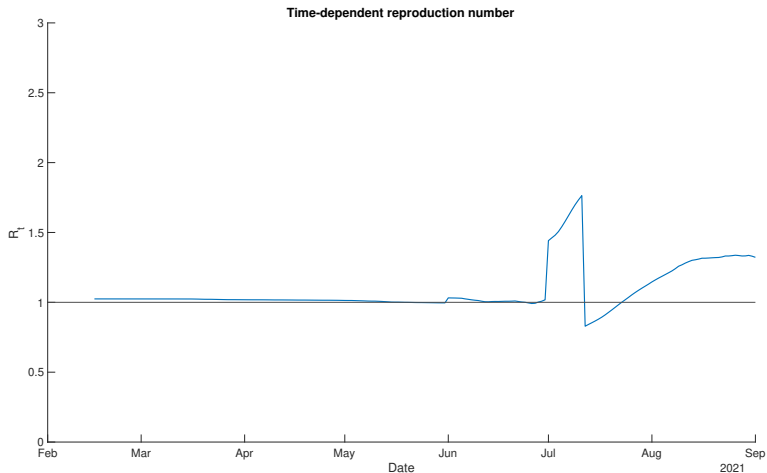


Figure 10: The estimated reproduction number from 2021/02/15 to 2021/09/01.

### Experiment 3: 4단계 (2021/07/12-2021/09/01)

▶  $\hat{\beta} = 0.0426$

Parameter	Initial	Estimate
$\delta$	2.0000e+00	3.7175e+00
Cost	6.6608e+04	1.2794e+04
Time	0.0000e+00	4.0059e+01

Table 7: Parameter estimates obtained by maximum likelihood estimation.

## Experiment 3: 4단계 (2021/07/12-2021/09/01)

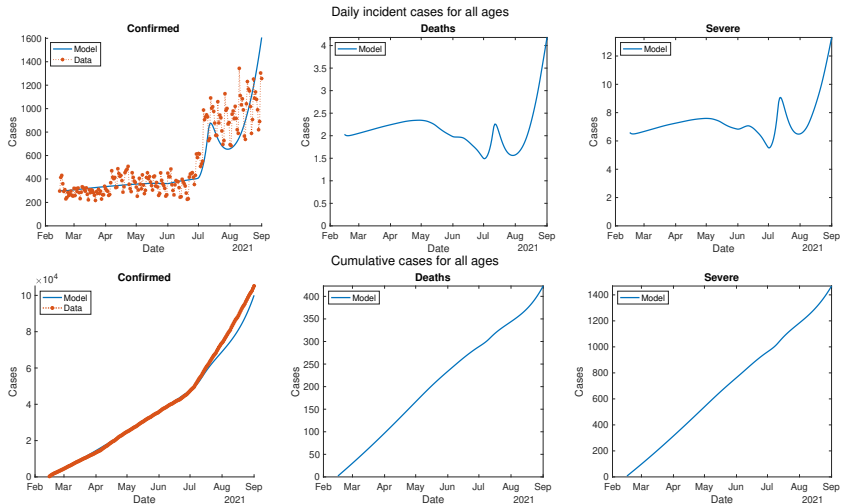


Figure 11: The model prediction and data for daily confirmed cases (top) and cumulative confirmed cases (bottom).

### Experiment 3: 4단계 (2021/07/12-2021/09/01)

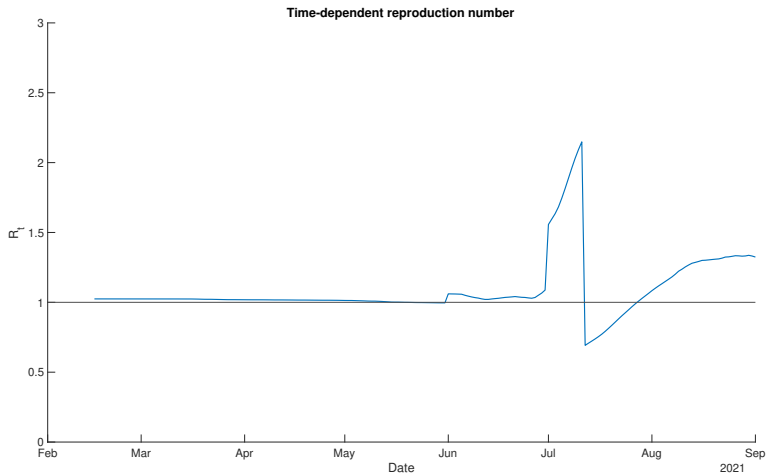


Figure 12: The estimated reproduction number from 2021/02/15 to 2021/09/01.