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 δ variant

Data processing

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

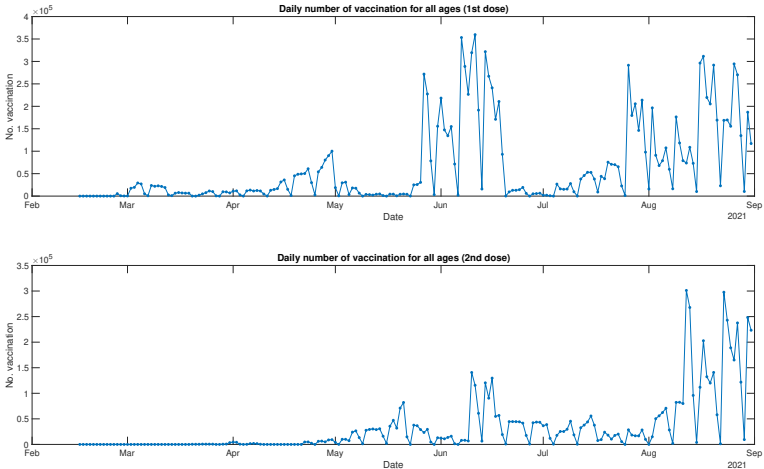


Figure 1: The daily number vaccination for 1st dose and 2nd dose from 2021/02/15 to 2021/09/01

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.

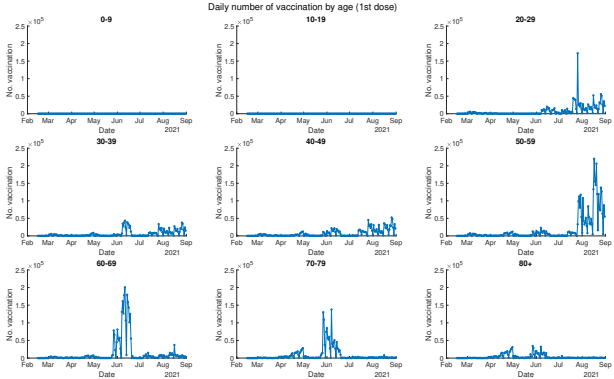


Figure 2: The daily number vaccination for 1st dose by age from 2021/02/15 to 2021/09/01

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.

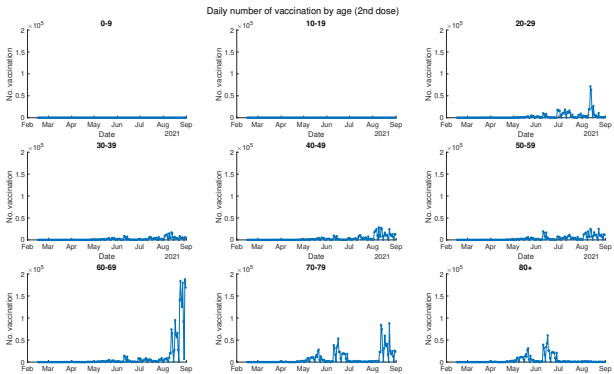


Figure 3: The daily number vaccination for 2nd dose by age from 2021/02/15 to 2021/09/01

3. Vaccine efficacy

- The vaccine efficacies for α variant and δ variant are different.[1]
- We use weighted sum of vaccine efficacies where weights are based on proportion of δ variant

	Dose	Astrazeneca	Pfizer
α variant	**1st dose**	48.7%	47.5%
	2nd dose	74.5%	93.7%
δ variant	**1st dose**	30.0%	35.6%
	2nd dose	67%	88%

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

[1] 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

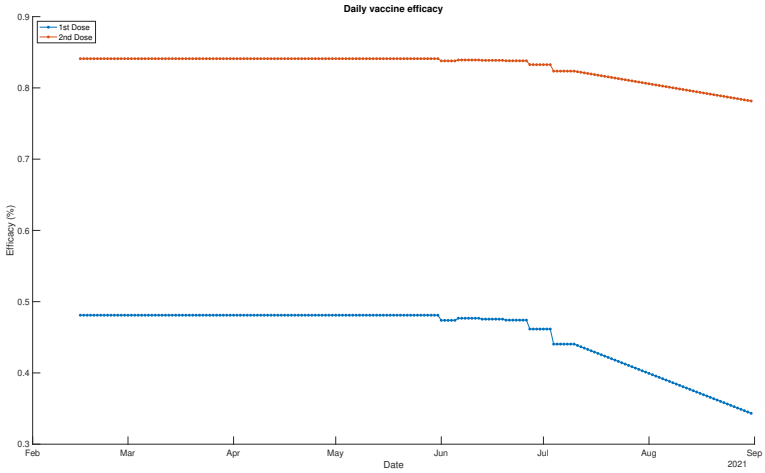
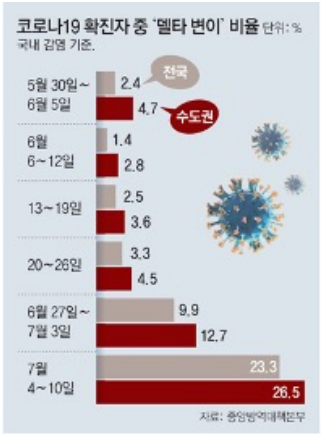


Figure 4: The estimated daily vaccine efficacy for 1st dose and 2nd dose.

4. Proportion of δ variant



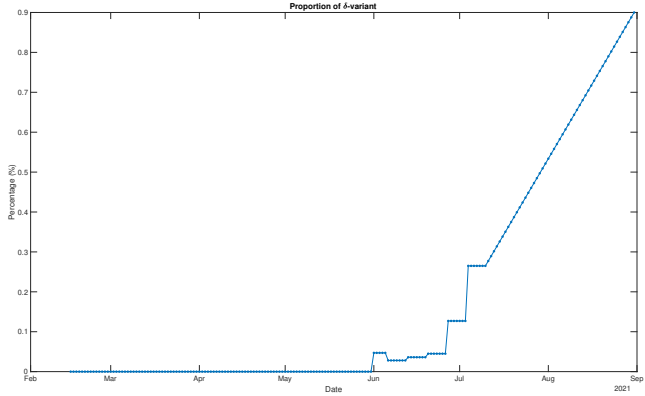


Figure 5: Estimates of proportion of δ variant.

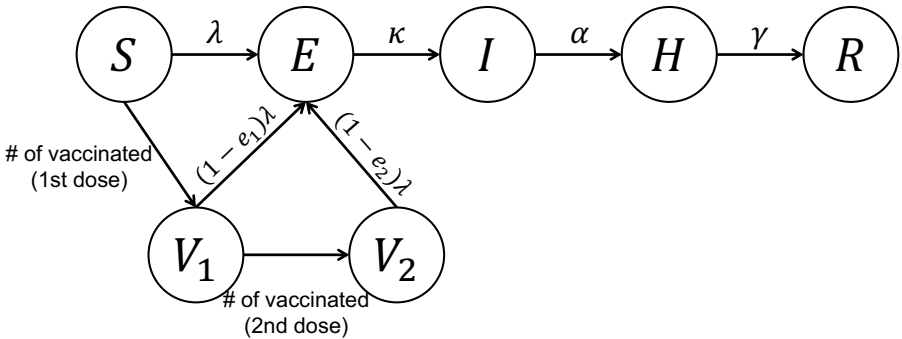


Figure 6: Diagram of age-structured model for SARS-CoV-2.

Notation	Interpretation
S	Susceptibles
E	Exposed
I	Infectious
H	Hospitalized
R	Removed (or recovered)
V	Vaccinated (between 1st dose and 2nd dose)
λ	Force of infection
κ	Latent period
α	Infectious period
γ	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[2]	-	-

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

[2]It will be changed according to the experiments.

Definition of λ

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 δ 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
δ	1.0000e+00	3.8549e+00
Cost	1.1696e+05	1.8366e+04
Time	0.0000e+00	5.2918e+01

Table 4: Parameter estimates obtained by maximum likelihood estimation.

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

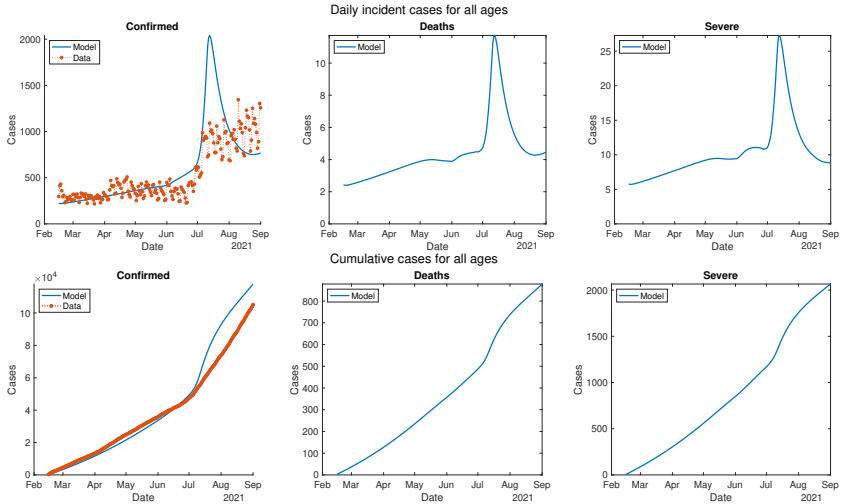


Figure 7: The model prediction and data for daily confirmed cases (top) and cumulative confirmed cases (bottom).

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

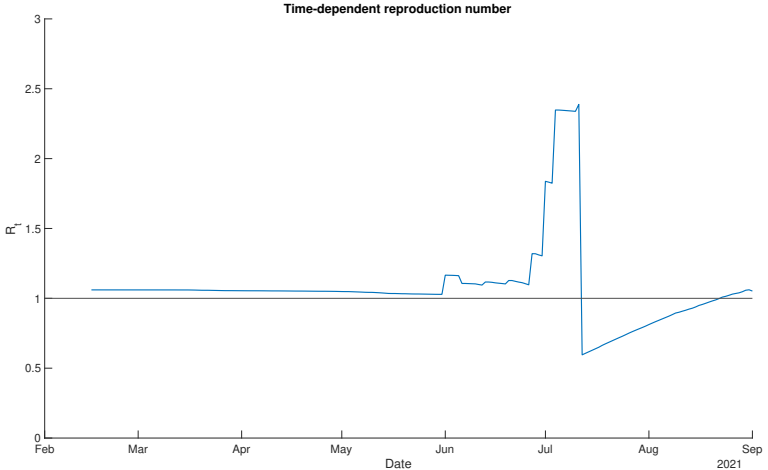


Figure 8: The estimated reproduction number from 2021/02/15 to 2021/09/01.

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

- $\hat{\beta} = 0.0433$

Parameter	Initial	Estimate
δ	1.0000e+00	2.9026e+00
Cost	9.3561e+04	1.3742e+04
Time	0.0000e+00	5.3264e+01

Table 5: Parameter estimates obtained by maximum likelihood estimation.

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

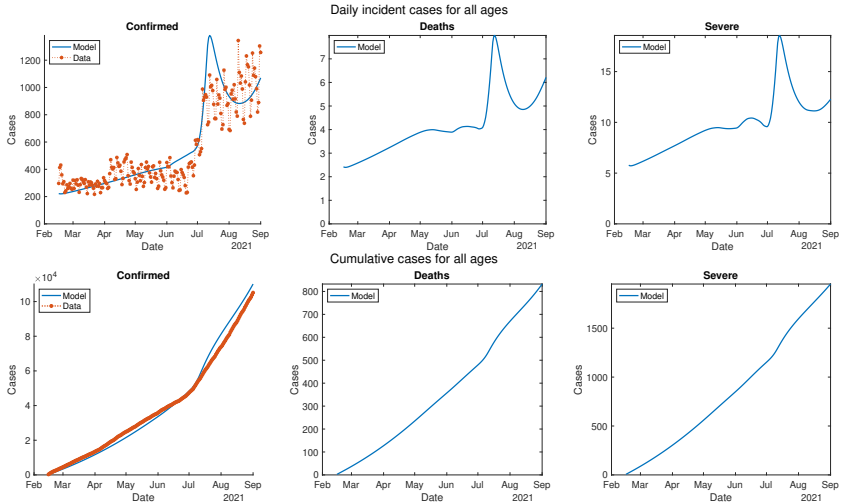


Figure 9: The model prediction and data for daily confirmed cases (top) and cumulative confirmed cases (bottom).

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

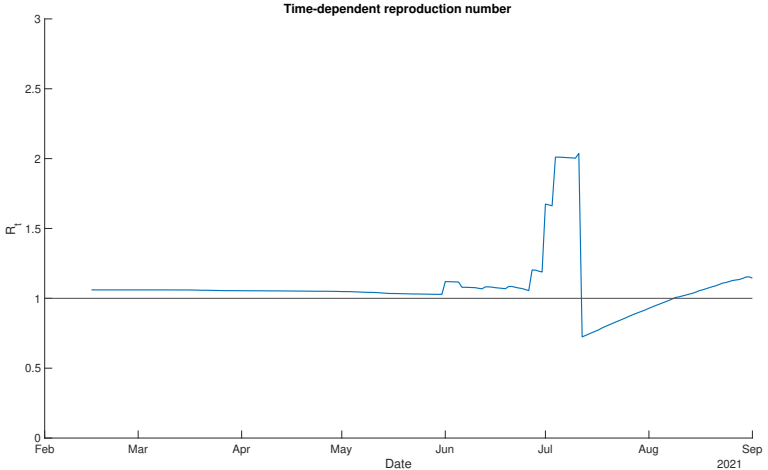


Figure 10: The estimated reproduction number from 2021/02/15 to 2021/09/01.

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

- $\hat{\beta} = 0.0433$

Parameter	Initial	Estimate
δ	1.0000e+00	1.9334e+00
Cost	5.4670e+04	1.2791e+04
Time	0.0000e+00	5.2448e+01

Table 6: Parameter estimates obtained by maximum likelihood estimation.

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

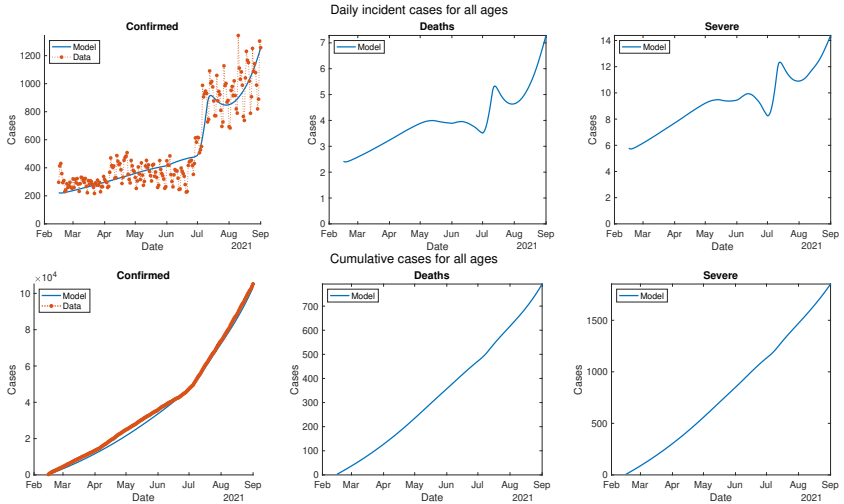


Figure 11: The model prediction and data for daily confirmed cases (top) and cumulative confirmed cases (bottom).

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

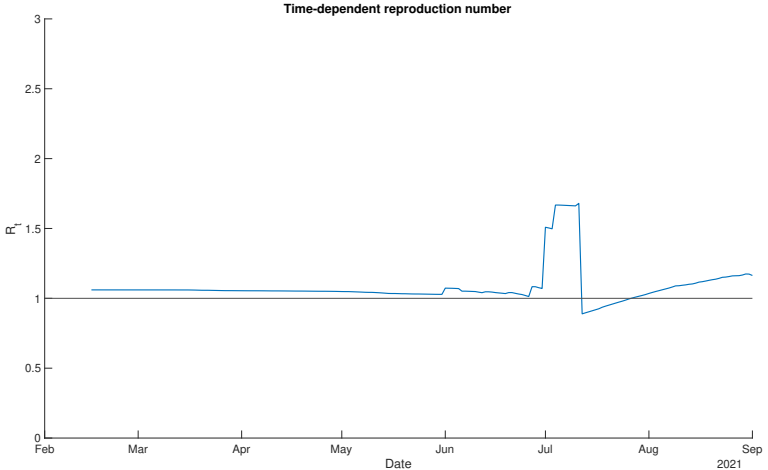


Figure 12: The estimated reproduction number from 2021/02/15 to 2021/09/01.

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

- $\hat{\beta} = 0.0433$

Parameter	Initial	Estimate
δ	1.0000e+00	1.3534e+00
Cost	2.4780e+04	1.3333e+04
Time	0.0000e+00	4.5986e+01

Table 7: Parameter estimates obtained by maximum likelihood estimation.

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

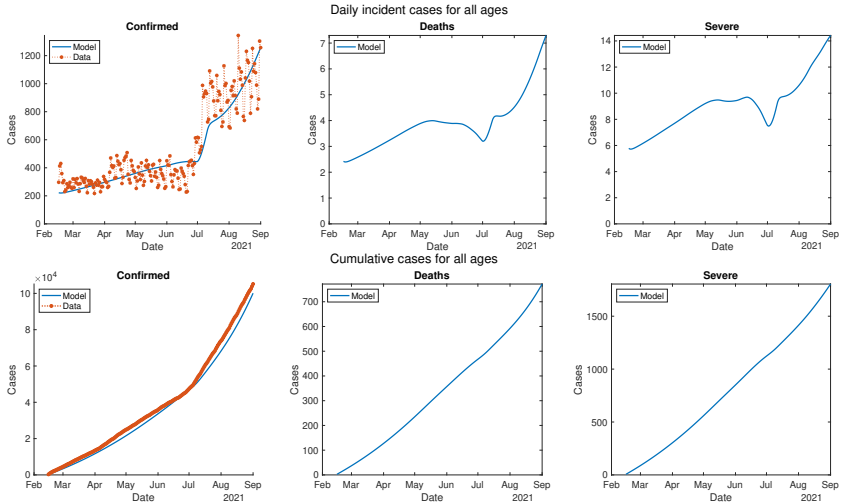


Figure 13: The model prediction and data for daily confirmed cases (top) and cumulative confirmed cases (bottom).

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

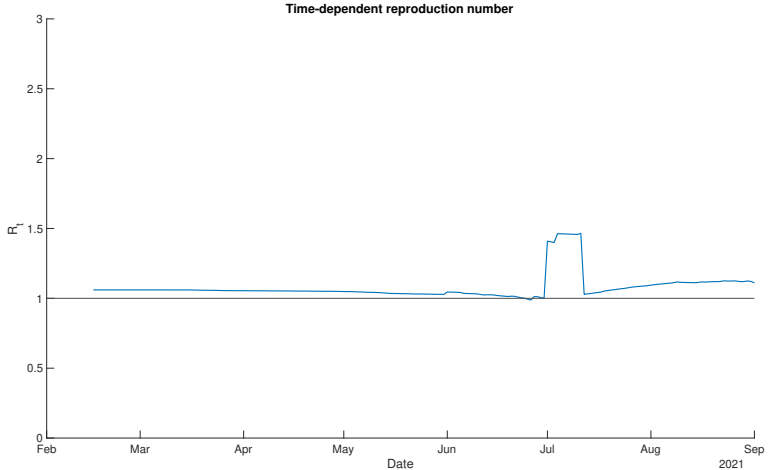


Figure 14: The estimated reproduction number from 2021/02/15 to 2021/09/01.