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COVID-19: What Intervention Policies Are Most Effective? A Brief Report Using Data from the Government of Bahrain

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Alireza Boloori
Michigan State University

Soroush Saghafian
Harvard Kennedy School

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COVID-19: What Intervention Policies Are Most Effective?
A Brief Report Using Data from Government of Bahrain

Alireza Boloori[1], Soroush Saghafian[2]

[1] Michigan State University (boloori@msu.edu)

[2] Harvard University (Soroush_Saghafian@hks.harvard.edu)

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1 Overview

To shed light on intervention policies that can be most effective in addressing the novel COVID-19, we have performed some preliminary analyses . Our analyses are based on (a) a compartmental analytical model, and (b) data that we have received from the government of Bahrain.[1] We have augmented this data by combining it with other sources, including data from Centers for Disease Control and Prevention (CDC), World Health Organization (WHO), other countries (e.g., China), and some related studies in the literature. The policies we have analyzed based on our conversations with the government of Bahrain are discussed in Table 1, and our data sources are briefly described in Table 2. In what follows, we first provide a brief overview of our analytical model. We then discuss our results on comparing the impact of following different intervention policies. We compare the impact of such policies on predicted values of (a) the number of people susceptible, exposed, infected, and recovered, (b) required hospital resources (common hospital beds, hospital ICU beds, and number of ventilators), and (c) number of deaths. Finally, we compare the impact of these policies by performing cost-effectiveness analyses.

2 A Brief Description of the Analytical Model

The epidemiology framework that we consider is based on a compartmental model known as SEIRS. This model considers susceptible, exposed, infected, recovered, and susceptible populations. One of the main assumptions in this model is that an immunity obtained upon recovery will not be life-long (i.e., it will *wane over time*). This could be the case for COVID-19 (see, e.g., Altmann et al. (2020)). Figure 1 illustrates this model.

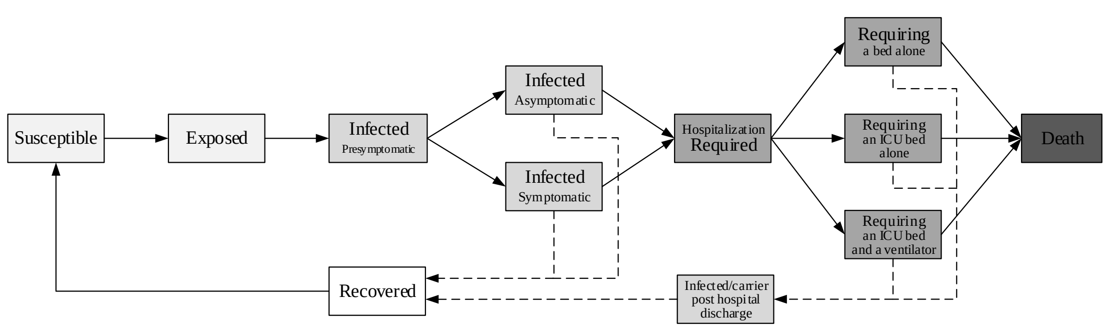


Figure 1: An illustration of a SEIRS model.

[1]We are grateful for the data provided to us by the government of Bahrain. In particular, we are thankful to Hamad Faisal Almalki (Undersecretary, National Economy, Ministry of Finance and National Economy), Manaf Husain Alsabbagh (Director, Planning and Economic Studies Directorate, Ministry of Finance and National Economy), and their team members for making this data available to us.

3 A Brief Description of the Results

In Figures 2-3, we show the predicted impact of different policies on the number of people susceptible, exposed, infected, and recovered. In Figures 4-5, we illustrate the impact of different policies on hospital resources (common hospital beds, hospital ICU beds, and number of ventilators). In Figures 6-7, we depict the predicted number of deaths. Finally, in Figure 5 we compare different policies from a *cost-effectiveness* standpoint. In particular, for each intervention policy, in Figure 8, we present the difference in costs and citizens' quality of life[2] between that policy and the no-intervention policy.

Table 1: Summary of intervention policies in Bahrain (and related parameters)

No	Policy description	Start date	Population impacted	Reduction in transmission rate (%)[†]
0	No intervention	02/24/2020[‡]	0	0.00
1	School closure	02/26/2020	300,000	2.02
2	No religious activities	02/29/2020	103,350	0.70
3	Suspension of cinemas/gyms, home delivery/takeaway food only	03/17/2020	1,000,000	6.74
4	50% of civil service work from home, No Friday prayers	03/19/2020	100,000	0.67
5	No prayers at Masjid	03/23/2020	237,600	1.60
6	Close malls and retails	03/24/2020	300,000	2.02
7	70% civil service work from home	04/02/2020	14,700	0.10
8	Online Gov services only, All faculty work from home	04/05/2020	18,000	0.12
9	Stop Construction	04/10/2020	150,000	1.01

[†] This reduction is compared to a baseline transmission rate.

[‡] The onset date of disease.

[2] For the quality of life, we use a measure called *quality-adjusted life years (QALY)*.

Table 2: Summary of parameters used in our analyses

Parameter	Value (Bahrain)	Value (benchmark)†
Initial population	1,483,756	—
# initially exposed	1% * 1,483,756	—
# initially susceptible	99% * 1,483,756	—
Incubation period (time between exposure and appearance of signs/symptoms of disease)	—	$x \in$ CI [8.2,15.6] days (Lauer et al., 2020)
Period between exposure and becoming infected presymptomatic (fraction of incubation period)	—	0.3*x days (see the row above)
Recovery period	CI [29.63,30.82] days‡	Range: (14,42) days (WHO, 2020)
Immunity/waning period	180 days (our notion)§	—
Length of stay (LOS) (when using a common bed)	CI [11.21,11.63] days¶	8 days (CDC, 2020a)
Length of stay (when using an ICU bed)	—	10 days (CDC, 2020a)
Length of stay (when using an ICU bed and a ventilator)	—	16 days (CDC, 2020a)
Baseline transmission rate (transmitting disease between a susceptible and an infectious individual)	9%-20% (Bahrain)	—
Probability of infection being asymptomatic	$x \in$ CI [69.49,78.14]%	y =25% (NPR, 2020) $y \in$ Range (4,80)% (CEBM, 2020)
Probability of infection being symptomatic	$(100 - x)$% (see the row above)	$(100 - y)$% (see the row above)
Rate of hospitalizations	CI [5.16,7.21]%	CI [20.7,31.4]% (CDC, 2020c)
Rate of hospitalizations who require common beds (λ_1)	$\lambda_1 = (100 - \lambda_2 - \lambda_3)$% = 90%	$\lambda_1 = (100 - \lambda_2 - \lambda_3)$%
Rate of hospitalizations who require ICU beds (λ_2)	$\lambda_2 + \lambda_3$ =10% (see the row below for λ_3)	$\lambda_2 + \lambda_3$ Range (26,32)% (CDC, 2020b) CI [4.9,11.5]% (CDC, 2020c) CI [31.13,31.27]% (IHME, 2020)
Rate of hospitalizations who require ICU beds and ventilators (λ_3) $\lambda_3 = (p/100 - p) * \lambda_2$, i.e., p% of ICU utilizations come with utilizing ventilators.	— $p = 70$% (our notion)	— $p = 51.34$% (Docherty et al., 2020) $p \in$ CI [90.44,90.58]% (IHME, 2020)
Rate of covid-related death (when hospitalized with common beds)	CI [0.13,1.51]%††	30% (Docherty et al., 2020)
Rate of covid-related death (when hospitalized with ICU beds)	2.0% (our notion, see the row above)	35% (Docherty et al., 2020)
Rate of covid-related death (when hospitalized with ICU beds and ventilators)	5.0% (our notion, see the row above)	50% (Docherty et al., 2020)
Vital dynamics–natural birth rate per day	13.60/365 (Bahrain) (KNOEMA, 2019a)	—
Vital dynamics–natural death rate per day	2.40/365 (Bahrain) (KNOEMA, 2019b)	—
Daily average of gross domestic product per capita	22,000/365 = 60.27 (USD) (Trading Economics, 2020a)	
Average employment rate: # people with employment/total population = 620,713/1,483,756 = 42.83% (Trading Economics, 2020b)		
Average (medical) cost of an ICU bed (without using a ventilator) per day $= \$3,164.33 * (1.0473)^{15} * 0.11 =$ \$696.21‡‡		
Average (medical) cost of an ICU bed (while using a ventilator) per day $= \$4,477 * (1.0473)^{15} * 0.11 = \$985.02$		
Average (medical) cost of a common bed per day $= \$696.21/5.85 = \$119.01$*		

† Benchmark values represent those values reported in other countries/studies. In our illustrations, we only use the benchmark value for the incubation period.

‡ CI: 95% confidence interval. For each CI, we use the corresponding mean value in our results.

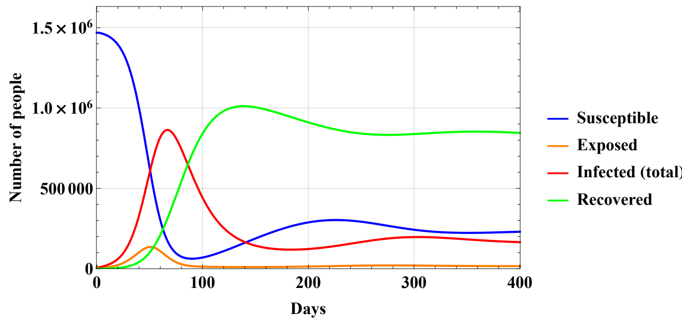
§ Although it is discussed in the literature (see, e.g., Altmann et al. (2020)), the duration of this period is yet to be known.

¶ In the Bahrain's data, we assume that LOS is the difference between hospital discharge date and date of test confirmation (i.e., admission date not available).
In this data, LOS is not adjusted based on different resources. Since the CI is very close to benchmark values by (CDC, 2020a), we use these values in our results.

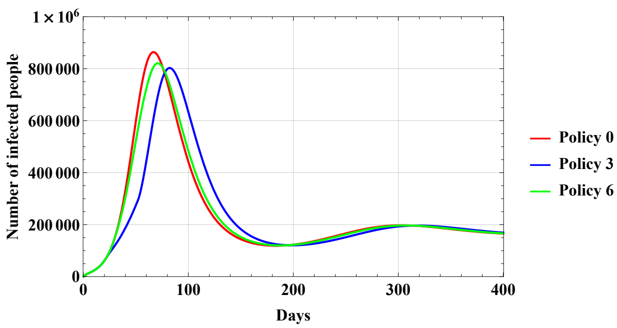
†† In the Bahrain's data, covid-related death rates are not reported with respect to resources involved.

‡‡ The value of \$3,164.33 is from 2005 (Dasta et al., 2005). We then use the US healthcare inflation rate from YCHARTS (2020) to compute the value for 2020.
Finally, we account for the ratio of Bahrain healthcare spending per capita to that of the US (\$1,099/\$9,870 = 0.11) obtained from Macro Trends (2020).
Of note, this is a back-of-the-envelope calculation, and may not reflect on the actual healthcare expenditures in Bahrain.

* Average ratio of cost of an ICU bed over that of a non-ICU bed is 5.85 (Norris et al., 1995).



(a) SEIR curves under policy 0



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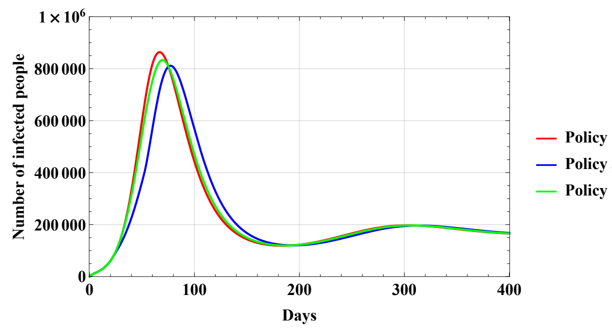

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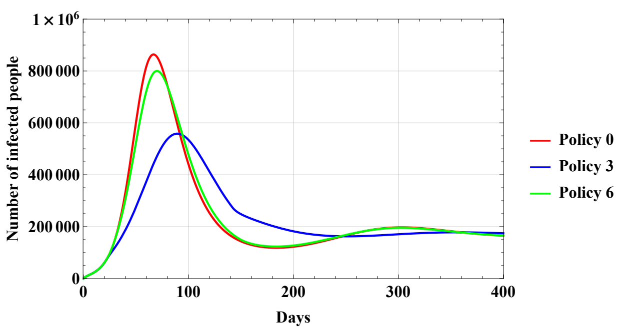

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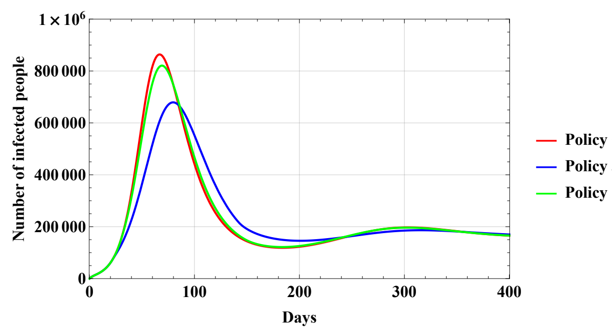
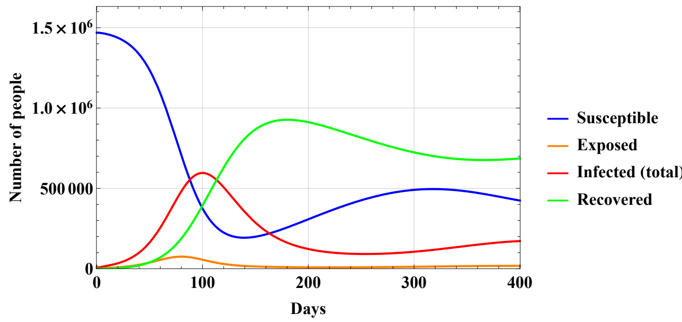


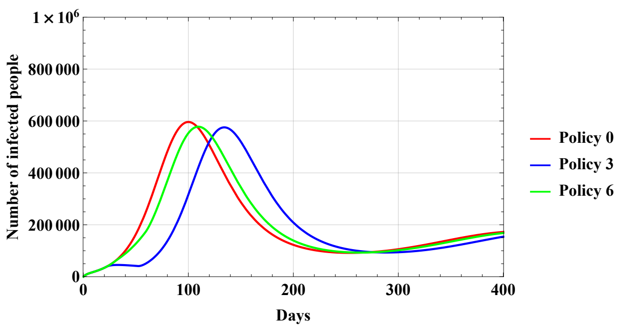
(e) Duration: 120 days, compliance: 70%

Figure 2: An illustration of epidemiological curves under three representative intervention policies **(baseline transmission rate: 15%)**.

Notes. See Table 1 for the description of policies. Parts (b)-(e) only illustrate the total number of infected people.



(a) SEIR curves under policy 0



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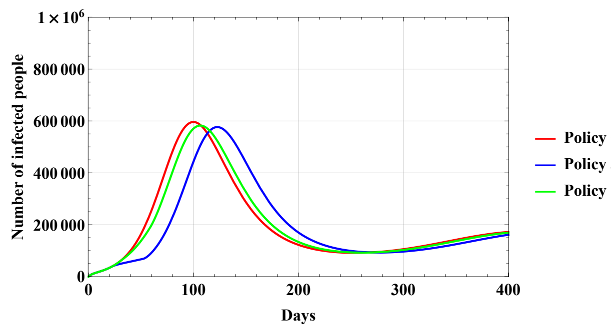

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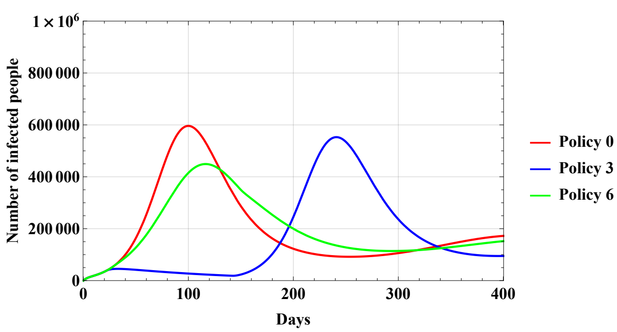

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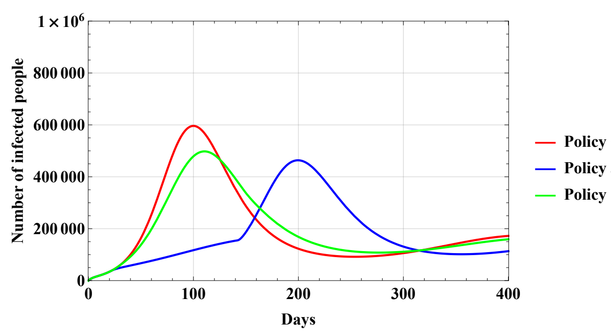
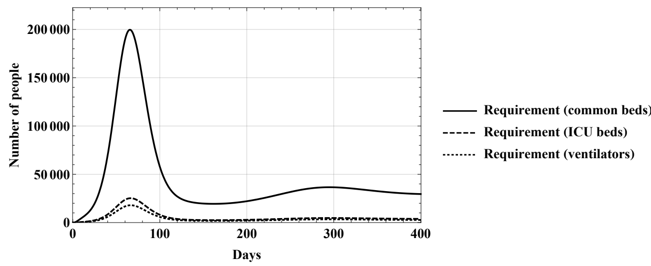


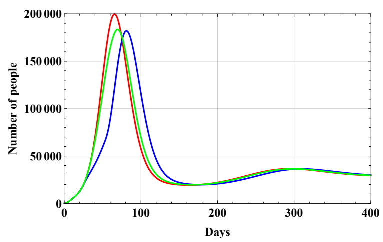
(e) Duration: 120 days, compliance: 70%

Figure 3: An illustration of epidemiological curves under three representative intervention policies **(baseline transmission rate: 9%)**.

Notes. See Table 1 for the description of policies. Parts (b)-(e) only illustrate the total number of infected people.



(a) No intervention policy



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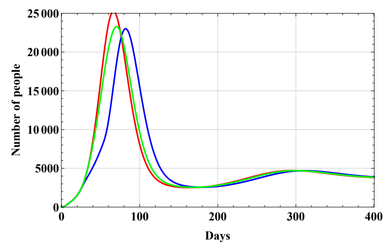

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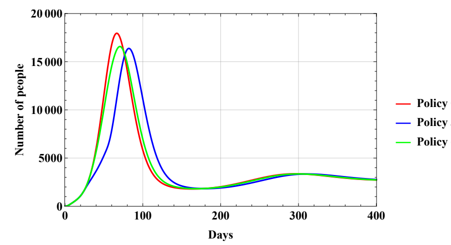

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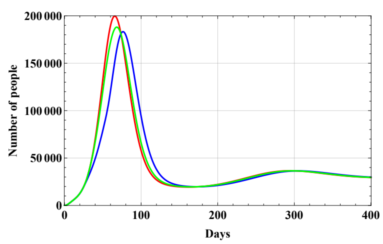

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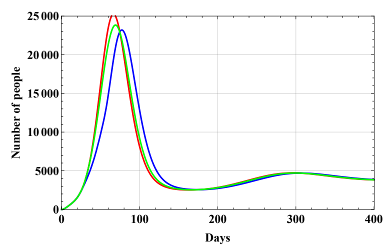

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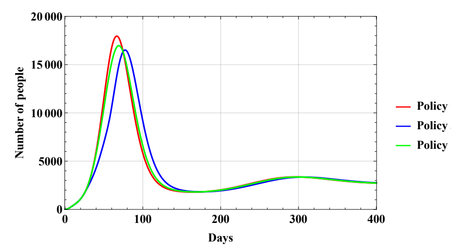
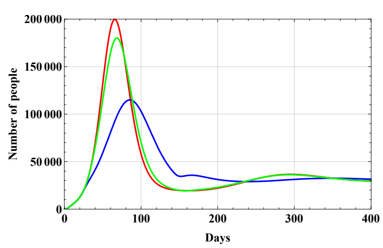
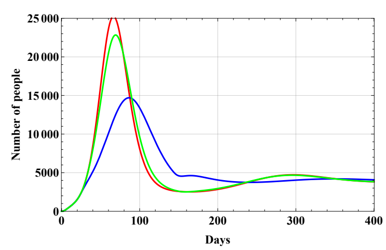


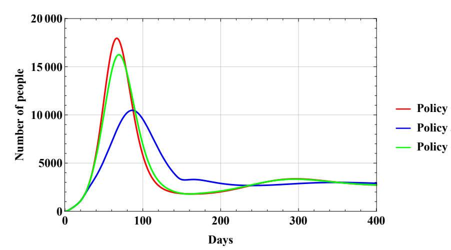
(g) Duration: 30 days, compliance: 70%



(h) Duration: 120 days, compliance: full



(i) Duration: 120 days, compliance: full



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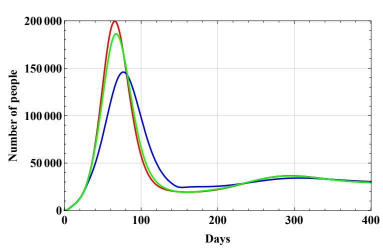

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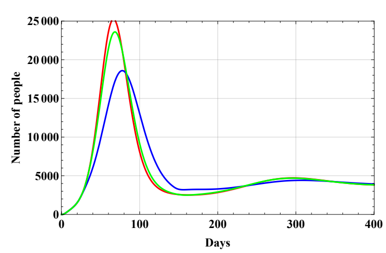

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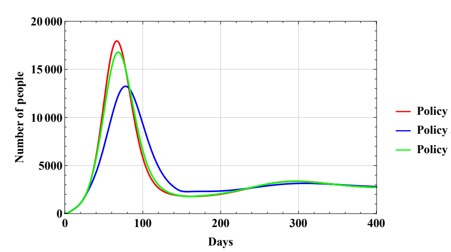
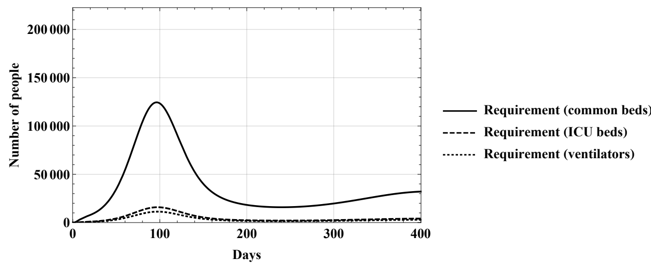


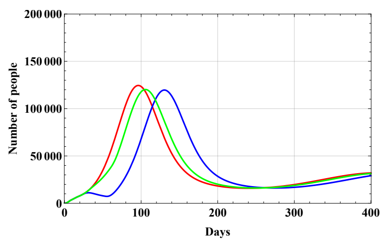
(m) Duration: 120 days, compliance: 70%

Figure 4: An illustration of resource utilization curves under three representative intervention policies **(baseline transmission rate: 15%)**.

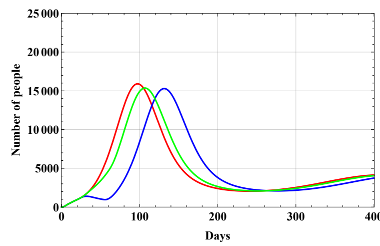
Notes. See Table 1 for the description of policies. Columns 1, 2, and 3 (from left to right) illustrate results for common beds, ICU beds, and ventilators, respectively.



(a) No intervention policy



(b) Duration: 30 days, compliance: full



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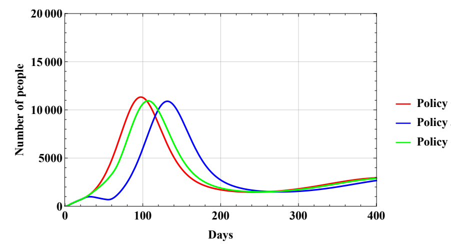

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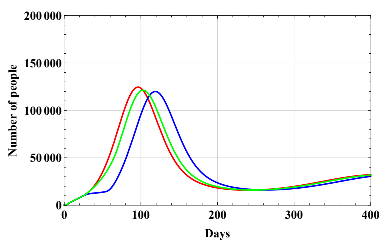

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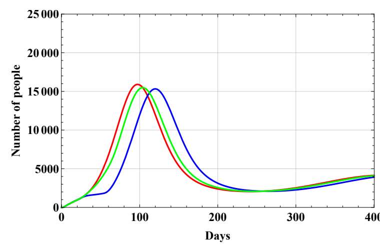

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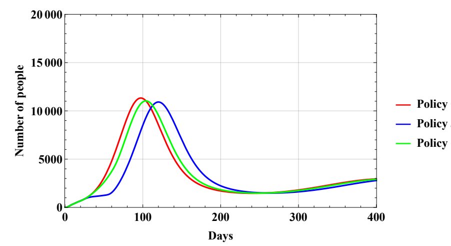

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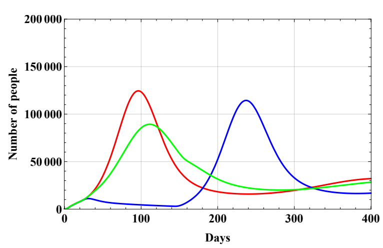

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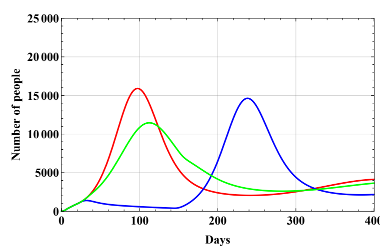

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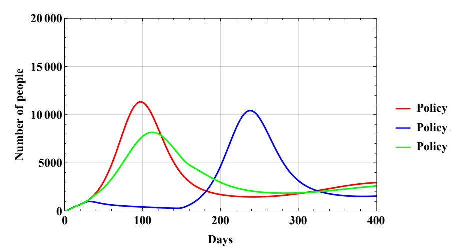

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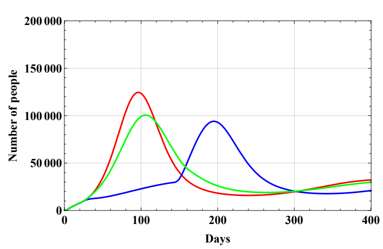

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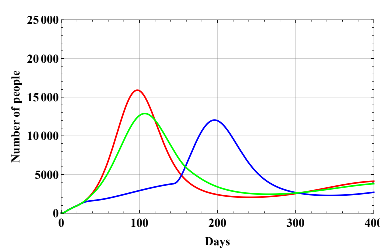

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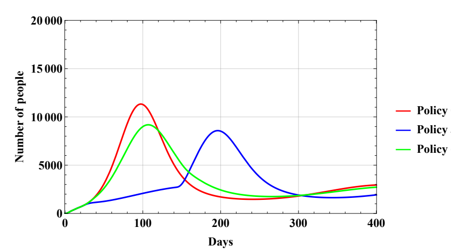
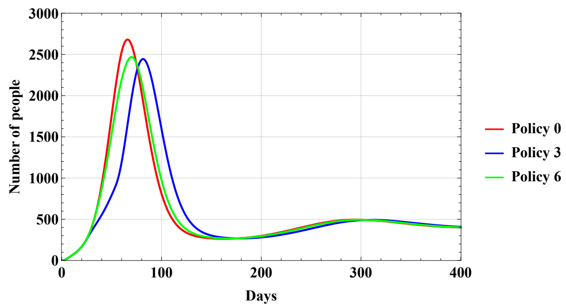


(m) Duration: 120 days, compliance: 70%

Figure 5: An illustration of resource utilization curves under three representative intervention policies **(baseline transmission rate: 9%)**.

Notes. See Table 1 for the description of policies. Columns 1, 2, and 3 (from left to right) illustrate results for common beds, ICU beds, and ventilators, respectively.



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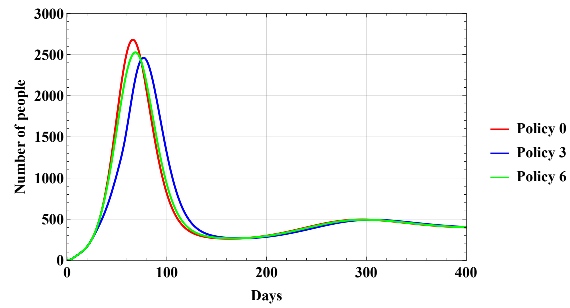

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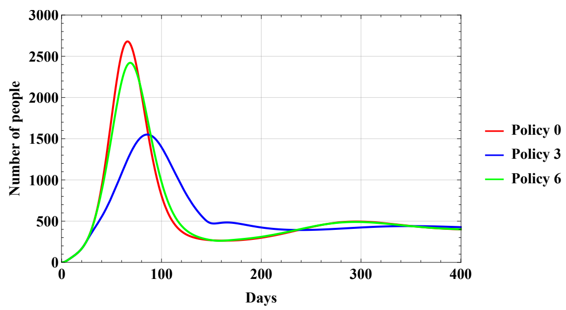

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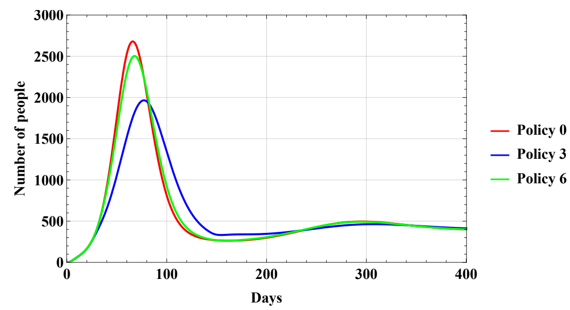
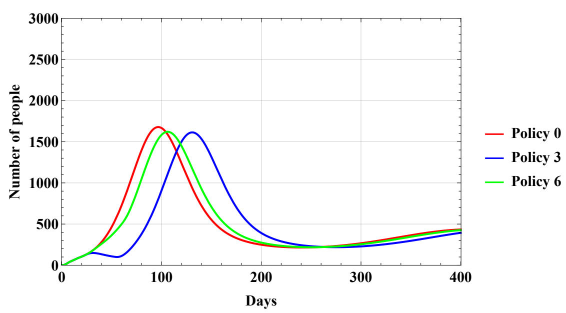


(d) Duration: 120 days, compliance: 70%

Figure 6: An illustration of number of deaths under three representative intervention policies. **(baseline transmission rate: 15%)**.

Notes. See Table 1 for the description of policies.



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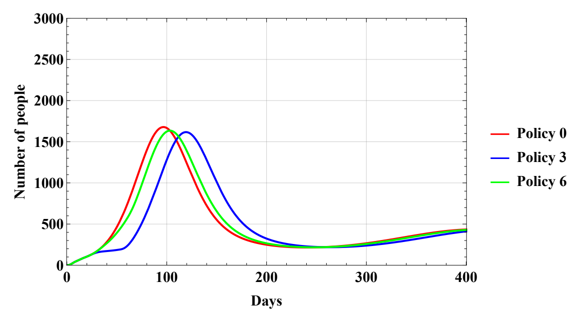

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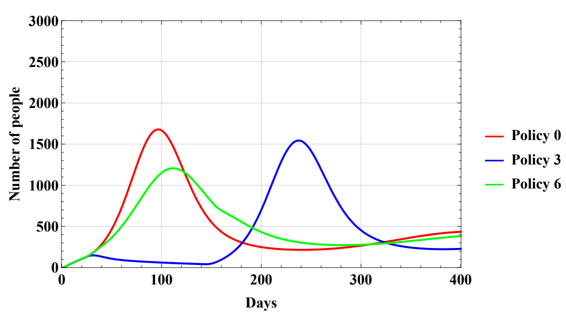

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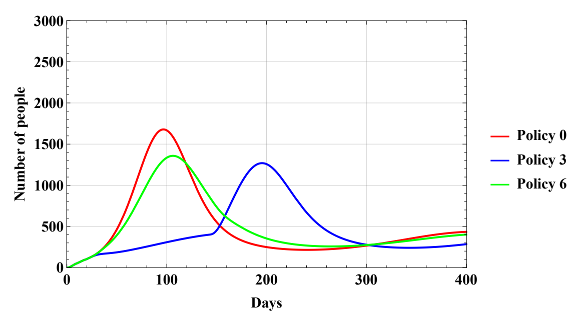
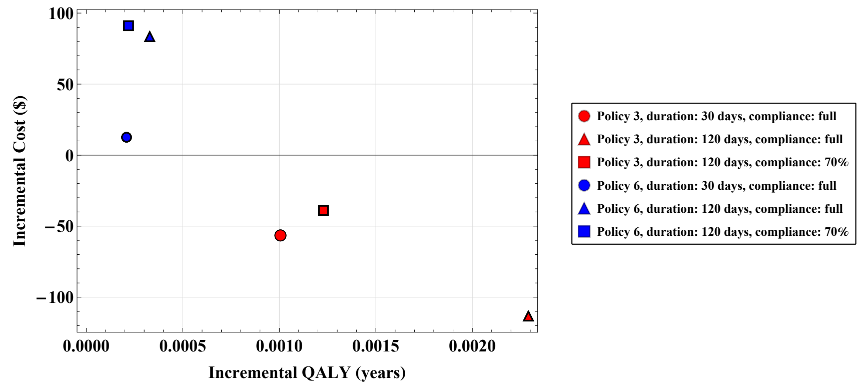


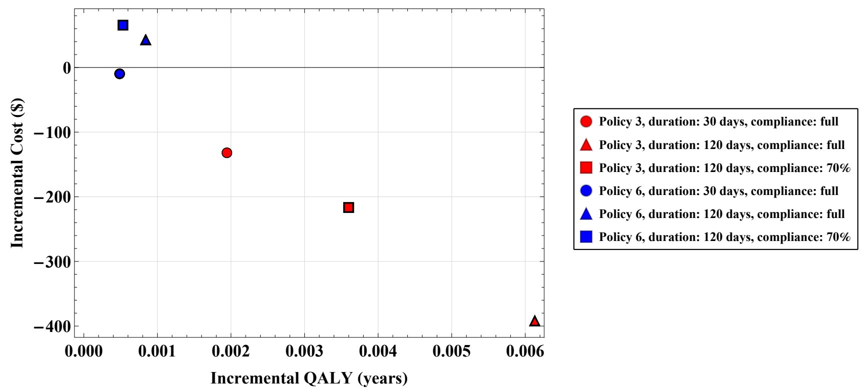
(d) Duration: 120 days, compliance: 70%

Figure 7: An illustration of number of deaths under three representative intervention policies. **(baseline transmission rate: 9%)**.

Notes. See Table 1 for the description of policies.



(a) baseline transmission rate: 15%



(b) baseline transmission rate: 9%

Figure 8: Difference between two representative intervention policies and the no-intervention policy in terms of quality-adjusted life years (QALY) and cost.

Notes. See Table 1 for the description of policies. Both QALY/cost values are averaged over the whole population over one year (i.e., illustrated values are per person per day).

We make the following observations from our results:

- There is always a tradeoff in cost versus quality of life as we increase the duration of each intervention policy. Specifically, as the duration increases so does the cost. But increasing the duration also improves the population's quality of life.
- Policy 3 generally performs better than policy 6 (i.e., yields higher QALY and lower costs).
- While compliance of people to intervention policies would have no impact on the cost (lost income), it will impact the quality of life (more compliance, higher QALY).

Disclaimer. Regarding the cost measurement, it is the sum of (1) indirect cost of intervention policies (i.e., cost of productivity loss or lost income for the employed population) and (2) direct cost of healthcare utilization. However, for the latter, we have only considered the cost of using common beds, ICU beds, and ventilators. Other direct costs such as cost of medications are not considered in this analysis.

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