School Closure Response to an Influenza Epidemic in AISD

Bryce van de Geijn

Introduction

Influenza epidemics cause costs to society in a number of ways. Work hours are lost directly when infected adults stay home from work and indirectly when infected kids miss school, forcing their parents to miss work. Infections also lead to a number of medical costs as well as costs in the form of deaths. The closing of schools is often used as a method to reduce the spread of epidemics. Closing schools reduces the contacts between kids and therefore reduces the number of infections. In this way the cost of the epidemic can be greatly reduced. However, closing schools is also very costly. When schools are closed, many adults are forced to miss work for child care. An optimal response to an outbreak of influenza minimizes the cost of influenza plus the cost of school closure. Araz et al develops a method of determining optimal school closure based on data for the entire state of Texas. However, the model they use divides the population into just two classes, adults and kids. Transmission is based on one giant pool for the whole state and closing schools means closing every school in the state. However, in practice there may be a spatial element to the epidemic, with certain areas having higher proportions infected. By associating the population with schools, this I allow the closing decision to be made on a school by school basis. This will allow for a more efficient selection of school closure policy.

The Model

The model splits the population into kids and adults associated with each school in the Austin Independent School District. The size of the kid population for each school is based on 2009 enrollment data. The associated adult population is determined by multiplying the kid population by the statewide ratio of kids to adults (1 : 2.64) based on Federal Statistics from 2009. Each group is then subjected to a deterministic SEIR model of difference equations. An individual is classified as susceptible, exposed, infected or recovered. Most start out susceptible, with a few exposed depending on the initial conditions. Susceptible individuals become exposed at a rate beta when they come in contact with an infected individual. These contacts can be intraschool and interschool. Exposed individuals become infected at a rate epsilon. Infected individuals recover at a rate gamma.

$S_{n,x}$	Number of x susceptible on day n. These are people that may become infected in the future
$E_{n,x}$	Number of x exposed on day n. These are people that have been infected but are not yet contagious.
$I_{n,x}$	Number of x infected on day n. People who are infected and contagious
$R_{n,x}$	Number of x recovered on day n. People who have previously been infected and are therefore immune.
ε	Rate at which those exposed become infected.
γ	Rate at which those infected become recovered
c_{xy}	Number of contacts on those of type y from those of type x
beta_{xy}	Rate those of type y are infected by those of type x
pop_{x}	Population of type x.
$\text{distance}_{x,y}$	Distance between school x and school y
$\alpha_1, \alpha_2, \delta$	Parameters for the gravity model.
$\text{Contacts}_{x,y,z}$	The contacts of class x between school y and school x. Based on the gravity model.

$S_{n+1} = S_n -$ (intraschool exposures + interschool exposures)

$E_{n+1} = E_n +$(intraschool exposures + interschool exposures) $- \varepsilon * E_n$

$I_{n+1} = I_n + \varepsilon * E_n - \gamma * I_n$

$R_{n+1} = R_n + \gamma * I_n$

Intraschool contacts are based on a mass action model similar to that used in Araz et al.

Intraschool kid exposures = $c_{kk} * \mathrm{beta}_{kk} * S_{n,k} * I_{n,k} / \mathrm{pop}_k + c_{ak} * \mathrm{beta}_{ak} * S_{n,k} * I_{n,a} / \mathrm{pop}_a$

Intraschool adult exposures = $c_{ka} * \mathrm{beta}_{ka} * S_{n,a} * I_{n,k} / \mathrm{pop}_k + c_{aa} * \mathrm{beta}_{aa} * S_{n,a} * I_{n,a} / \mathrm{pop}_a$

Interschool contacts are based on a modified gravity model as described in Viboud et al.

$\mathrm{Contacts}_{k,\mathrm{school1},\mathrm{school2}} = \mathrm{pop}_{k,\mathrm{school1}}{}^{\alpha 1} * \mathrm{pop}_{k,\mathrm{school2}}{}^{\alpha 2} / (1+\mathrm{distance}_{\mathrm{school1},\mathrm{school2}})^{\delta}$

$\mathrm{Contacts}_{a,\mathrm{school1},\mathrm{school2}} = \mathrm{pop}_{a,\mathrm{school1}}{}^{\alpha 1} * \mathrm{pop}_{a,\mathrm{school2}}{}^{\alpha 2} / (1+\mathrm{distance}_{\mathrm{school1},\mathrm{school2}})^{\delta}$

Contacts between kids and adults associated with different schools are assumed to be negligible.

In this model the contact numbers are symmetric, i.e. $\mathrm{Contacts}_{k,\mathrm{school1},\mathrm{school2}}$ is equal to $\mathrm{Contacts}_{k,\mathrm{school2},\mathrm{school1}}$. Since the αs should sum to 1, they are both 0.5. Since the distances between schools in AISD are small with some being less than 1, (1 + distance) is used in the denominator of the gravity model. This makes intraschool contacts equal to an interschool contact between two identical schools with 0 distance between them. δ is varied during the simulations.

Interschool kid exposures = $\Sigma_{\text{other schools}}$ (β_{kk} *

$S_{n,k,school}/pop_{k,school}*I_{n,k,school}/pop_{k,otherschool}*contacts_{k,school,otherschool}$)

Interschool adult exposures = $\Sigma_{\text{other schools}}$ (β_{aa} *

$S_{n,a,school}/pop_{a,school}*I_{n,a,school}/pop_{a,otherschool}*contacts_{a,school,otherschool}$)

In order to make the cost calculations easier, a number of values are kept during the simulation and are summed each simulated day.

Adult sick days – the number of adults x the fraction adults sick each day

Healthy adults with sick kids days – the number of kids x the fraction kids sick x the fraction of adults healthy each day

Healthy adults with healthy kids closed days – the number of kids x the fraction of kids healthy x the fraction of adults healthy only on closed days

Model parameters

The parameters used in the model are taken from Araz et al. Estimates of the β parameters are based on a formula from Kelling and Rohani and an reproductive rate (R_0) of 1.3. Contact numbers were formed using data in Mossong et al. Estimates of γ and ε are based on Gojovic et al.

β_{kk}	.3091
β_{ak}	.1671
β_{ka}	.2688
β_{aa}	.1453
$c_{kk,\ open}$	10/16
$c_{kk,\ closed}$	2/16

c_{ak}	1/8
c_{ka}	6/16
c_{aa}	7/8
ε	1/3
γ	1/6
α_1, α_2	0.5

Cost Calculations

As described in the introduction, the cost of a particular policy will be based on the cost of schools closing as well as the cost due to infection. These costs consist of a number of components, based on the cost calculations in Araz et al. They assume a 40 hour work week.

The lost wages due to the work missed by sick adults: This starts with the number of days that adults are sick. It is then multiplied by the employment rate to yield the total days of work missed by adults. Finally, it is multiplied the average wage earned in a day to yield dollars lost.

Adult Sick Days* employment*wage *hours per week/7

The cost of healthy adults missing work due to sick kids: This starts with the number of days that sick kids have healthy adults. It is then multiplied by the percentage of adults that stay home when they have sick kids and then the employment rate to yield days missed by healthy adults due to sick kids. This is multiplied by average daily wage to yield dollars lost.

Healthy Adults Sick Kid Days * %adults stay home with sick kids * employment * wage * hours per week/7

The cost of healthy adults with healthy kid due to school closure: This starts with the number of days that healthy adults have to stay home for healthy kids due to school closure. It is then multiplied by employment rate to yield days missed. This is finally multiplied by average daily wage to yield dollars lost.

Healthy Adult Healthy Kid during closure days * %adults stay home with closure * employment * wage * hours per week/ 7

The medical costs of kids: This is the cumulative kids infected times the average medical cost of infected based on hospitalization and non-hospitalization costs.

Total Kids Sick * (Kid Hospitalization Rate * Kid Hospitalization Cost + (1-KHR) * Kid non-Hospitalization Cost)

The medical costs of adults: This is calculated similarly to that of kids.

Total Adults Sick * (Adult Hospitalization Rate * Adult Hospitalization Cost + (1-AHR) * Adult non-Hospitalization Cost)

The cost of kid mortality: This is the cumulative infected times the mortality rate to yield total kid mortalities. This is then multiplied by the kid cost of life.

Total Kids Sick * Mortality Rate * Cost of Kid Lost Life

The cost of adult mortality: This is calculated similarly to that of kids.

Total Adults Sick * Mortality Rate * Cost of Adult Lost Life

Values for Costs:

Values for calculating the policy costs are also taken from Araz et al. Weekly wage and employment rates are based on Federal Statistics 2009. The rate at which adults stay home during school closures is based on Lempel et al. The rates at which those infected seek medical care and the costs are based on a survey by Thomas Reuters Healthcare. Finally, the costs of mortality are based on Lee et al.

Weekly Wage	$739
Employments rate	.93
Adults stay home with sick kid	1.0
Adults stay home with closure	.14
Kids Seek Medical Care	.005
Kids Avg. Medical Care Cost	$150
Kid non-Medical Care Cost	$25
Adult Seek Medical Care	.0023
Adult Avg. Medical Care Cost	$150
Adult non-Medical Care Cost	$25
Kid Lost Life Cost	$936,319
Adult Lost Life Cost	$873,046

Results

Two initial infections from each school:

The first initial conditions that we consider has 2 infected kids in each school. Figures 1, 2, and 3 plot the costs of responses versus mortality rate for δ equal to 3, 3.5, and 4 respectively.

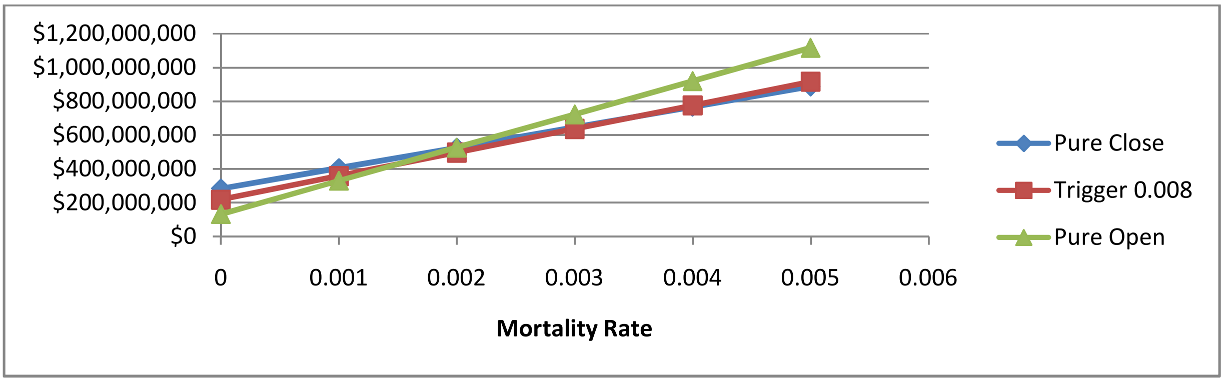


Fig. 1: δ = 3

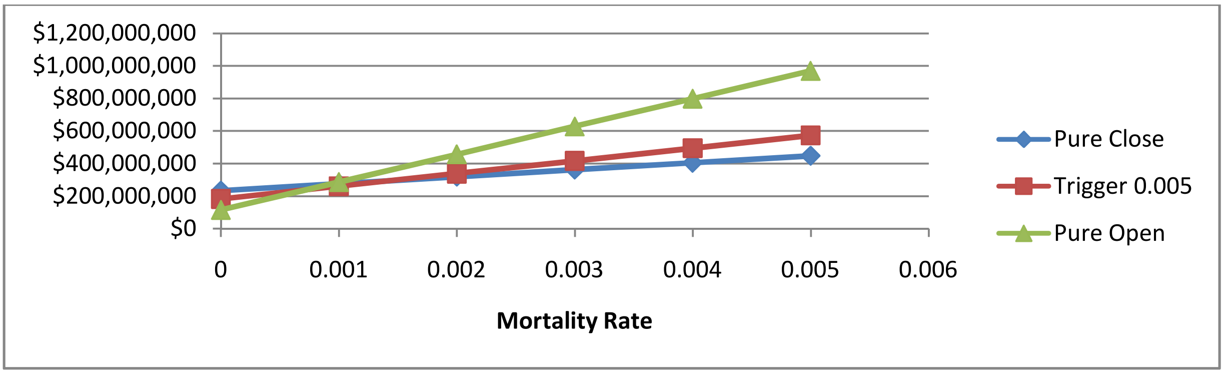


Fig. 2: δ = 3.5

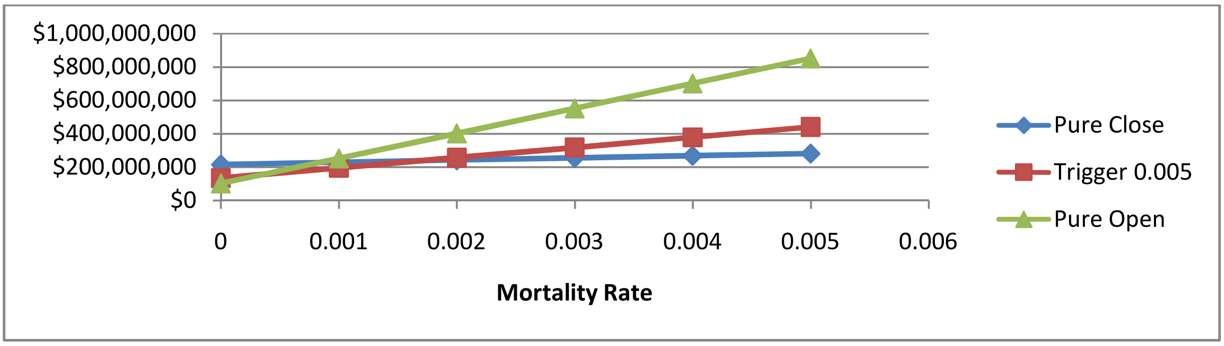


Fig. 3: δ = 4

Figure 1 shows the costs of response versus mortality rate for a δ of 3. Without mortality, the optimal response is to allow schools to remain open. However, closing at a low trigger becomes the best option for mortality rates above 0.2%. At higher rates, pure closure becomes optimal. Using a radius does not provide a significant benefit. A pure open policy results in infection in about 75% of kids and 70% of adults over the 180 day period. When δ is increased to 3.5, the optimal response without mortality remains to leave schools open. There is a small stretch where closing at a low trigger is best, but pure closure is best for mortality rates above 0.15%. Using a radius does not provide a significant benefit. Cumulative infections under pure open policy results in 65% kids and 61% adults infected. For a δ of 4, the optimal responses are similar to that for the δ of 3.5. Pure closure becomes optimal above a mortality rate of 0.2%. Using a radius does not provide a significant benefit. Cumulative infections are 55% of kids and adults infected.

Two Initial Infections from a Centralized School:

The first scenario is somewhat unlikely as the infection must start from multiple sources throughout the district. What is more likely is that the infection starts with a handful of individuals associated with one school. We now consider this situation, starting with a centralized school (Pease Elementary School). Figures 4, 5, and 6 plot the costs against mortality rate again for a δ of 3, 3.5, and 4 respectively.

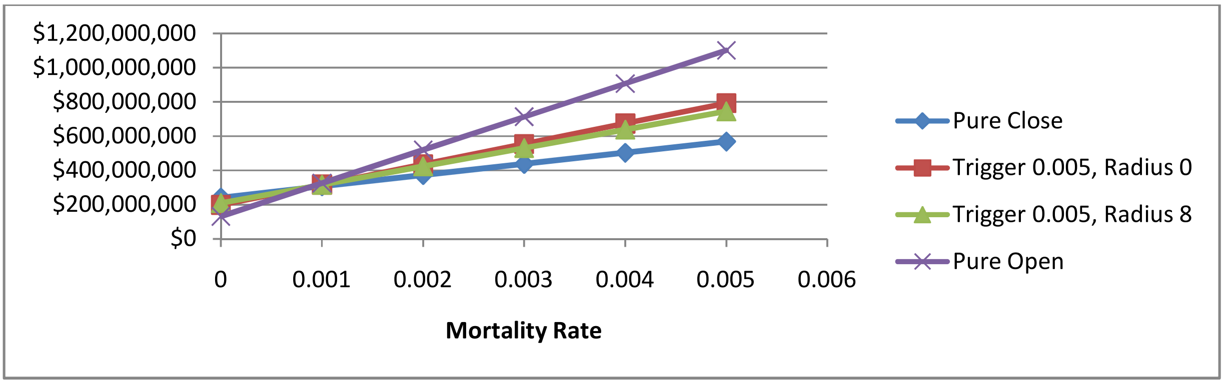


Fig. 4: δ = 3

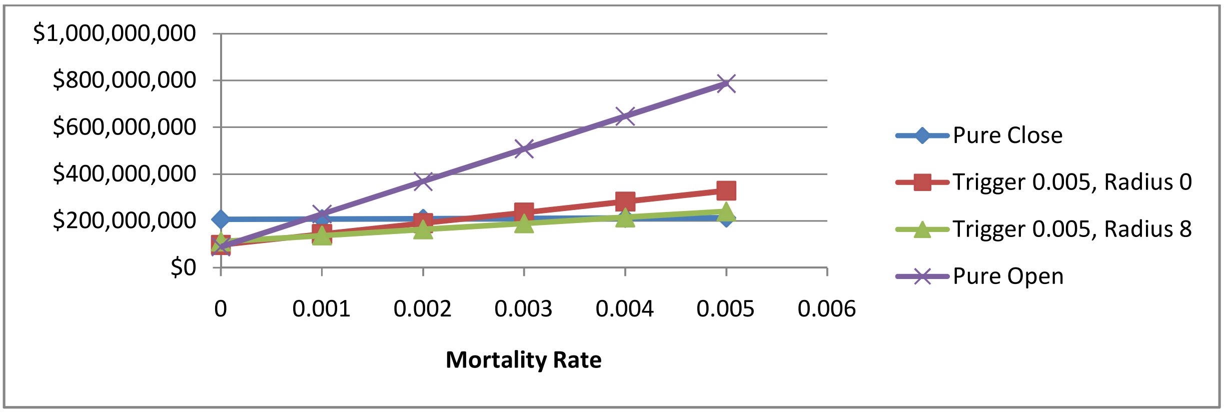


Fig. 5: δ = 3.5

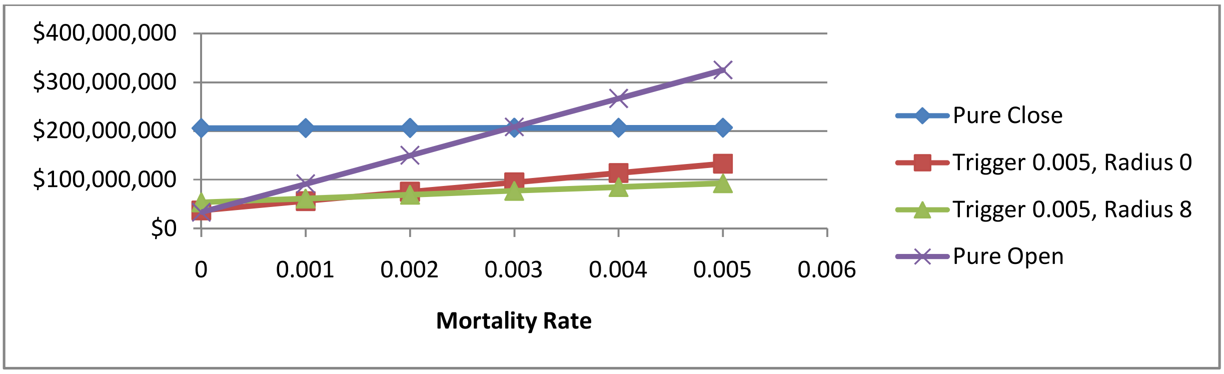


Fig. 6: δ = 4

Figure 4 plots the costs of response versus mortality rate for a δ of 3. Pure open is the optimal response again for low mortality rate. However, pure closure immediately becomes optimal when mortality rate exceeds 0.1%. Using a radius provides some benefit, but only when pure closure is the best choice anyway. Cumulative infections are 75% for kids and 69% for adults. With a δ of 3.5, pure open is only optimal when there is no mortality. A low trigger is best for intermediate mortality rates. Interestingly, using a closing radius of 8 outperforms not using a radius. Cumulative infection under pure open policy is 54% for kids and 50% for adults. These effects are maintained with a δ of 4. Pure open is only optimal when there is no mortality. A low trigger is best for other mortality rates. Again, using a closing radius of 8 outperforms not using a radius. Cumulative infection under pure open policy is 22% for kids and 21% for adults.

Two Initial Infections in a Non-Central School:

We also consider the situation where the epidemic starts in a non-central school (Menchaca Elementary School). Figures 7, 8, and 9 plot the costs against mortality rate in this case.

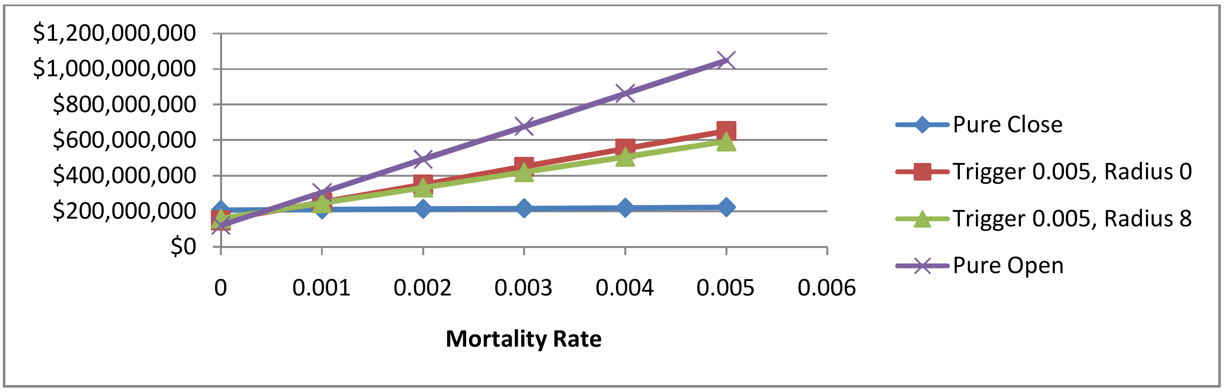


Fig. 7: δ = 3

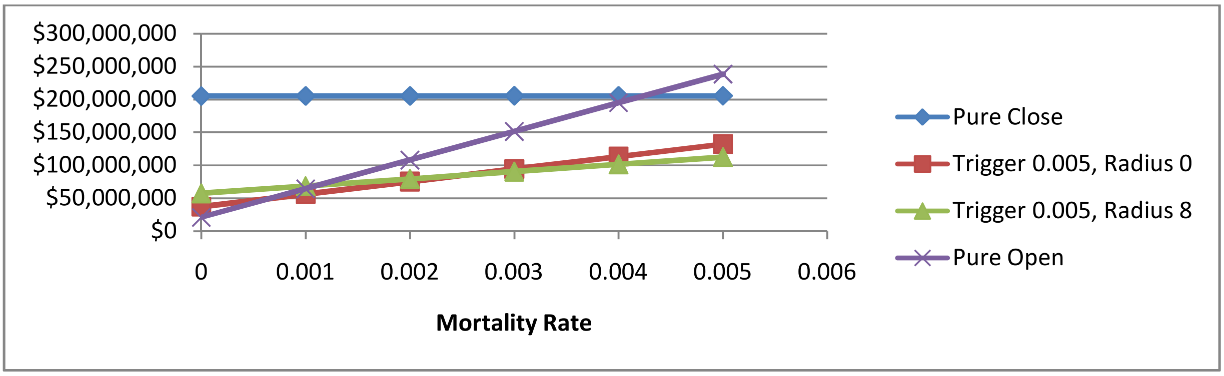


Fig. 8: δ = 3.5

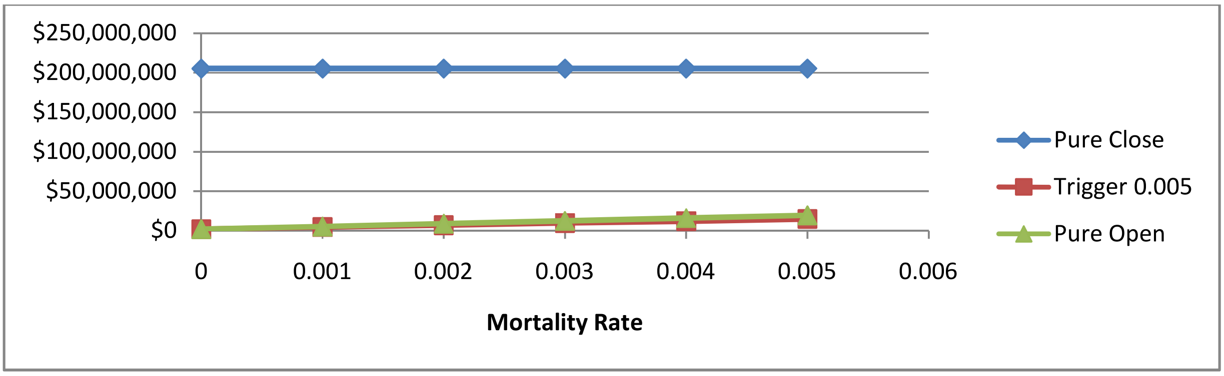


Fig. 9: δ = 4

Figure 7 displays the costs of response versus mortality rate for a δ of 3. Pure closure quickly becomes the best policy as mortality rate increases. Cumulative infections are 73% for kids and 66% for adults. For a δ of 3.5, pure open is only optimal when there is very low mortality. A low trigger is best for intermediate mortality rates. Using a closing radius of 8 outperforms not using a radius. Cumulative infection under pure open policy is 18% for kids and 15% for adults. A δ of 4 is far less interesting, as shown in Fig. 9. The infection never spreads beyond Menchaca, making a pure open policy cost very little.

Conclusions

The first step in developing conclusions is determining plausible parameter values, namely which δ fits the model best. Based on cumulative infections, the δ of 3 comes out high, with infected at almost 75%. Similarly, the simulations with δ of 4 come out low, with almost no infection resulting from starting in a fringe school as well as the low infections starting centrally. Therefore, the δ of 3.5 makes most sense with cumulative infected around 50% with a pure open policy. These are close to the 42% kids and 45% adults cumulative infected in the pure open case from the Araz et al. paper.

As discussed earlier, the simulations that started the infection at each school is not as interesting, since the epidemic is unlikely to have that many simultaneous starting points and by starting the infection evenly, the impact of the spatial nature of the model is reduced. When the infection is started in a central school and mortality rate below 0.4, using the lowest trigger (0.5% infected) and a closing all schools within 8 km of a triggered school is optimal. The fact that closing around a radius is optimal is somewhat surprising since this means that schools below the trigger are closed. Since closure only helps with intraschool infection, closing a school with few infections does not exactly make sense at first glance. However, the benefit is likely due to the fact that using an even lower trigger than 0.5% would be optimal and being close to a triggered school is a good indicator of having an infected rate of almost 0.5%. However, using a trigger lower than 0.5% is unlikely to be feasible since this represents one student in 200 sick and detecting an infection involving fewer students would be difficult. In this way, using a closing radius takes the place of allowing a lower trigger in a way that might be more feasible in practice. The only difference when the epidemic is started in Menchaca, a school that is distant from all others, is that there are low mortality rates where letting the epidemic run its course with a purely open policy is optimal. Again we see using the 0.5% trigger as optimal and the radius of 8 working, likely for the same reasons as before.

It is important to keep in mind the meaning of optimal policy. A decision that is optimal for the district might not be optimal for an individual school. For this paper, only the cost to the district is considered.

Based on this model, school closures can be used to substantially decrease the costs due to an influenza epidemic when costs of deaths are taken into account. If the school where the infection begins is closed early, the epidemic can be kept to a minimum and prevented from spreading to other schools, even when the first school is centralized. The cost to the single school is more than offset by the reduced infections district-wide. However, schools that are nearby those showing infection are likely to have elevated infections, even if they have not reached to threshold for detection. Closing schools nearby infected schools can be used to account for this and further decrease overall epidemic cost.

Further Work

Although the use of a closing radius around triggered schools turned out to be an improvement in some cases, it may not be the best way to utilize school location in policy. Further work should concentrate on this problem. One possibility might be to have different triggers based on the centrality of the schools. Schools that are more central would have a lower threshold, since they are most likely to spread infections to other schools. Since there are numerous methods for quantifying centrality, this direction contains many possibilities for study.

Special Thanks

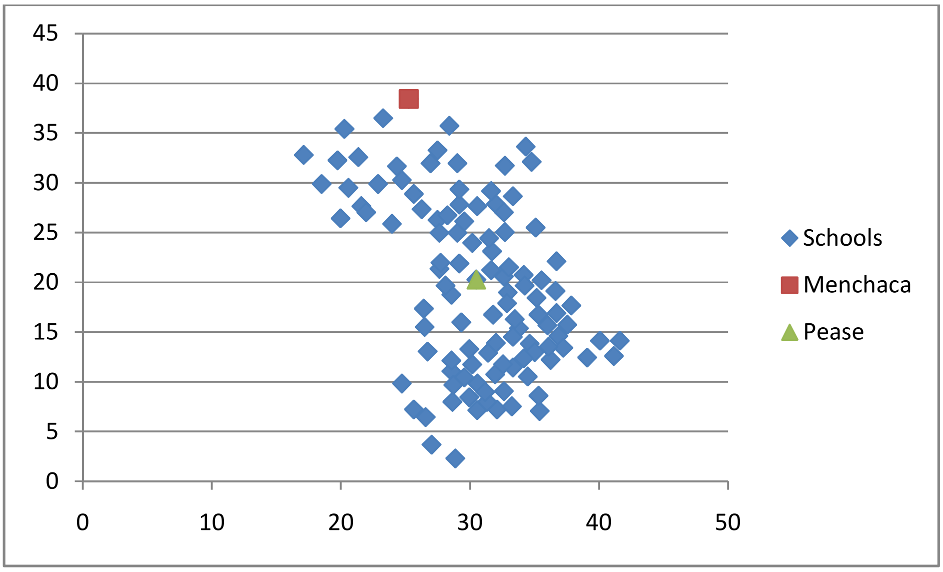
I would like to thank my advisor Prof. Lauren Ancel Meyers for her help with this paper. I would also like to thank Ozgur Araz and Sean Burke for their input and advice.

Works Cited

1) AISD Map 2010, Austin Independent School District (2010). http://www.austinisd.org/
2) AISD Membership Report 2009, Austin Independent School District (2009).
3) Araz O., Burke S., van de Geijn B., Damien P., Galvani A., Meyers L.A. (2010). A Decision Analytic Model for School Closure in Response to Pandemic Influenza.
4) FedStat, Federal Statistical Agency (2009). http://fedstats.gov/
5) Gojovic M.Z., Sander B., Fisman D., Krahn M.D., Bauch C.T. (2009). Modeling mitigation strategies for pandemic (H1N1) 2009. CMAJ 181 (10)
6) Keeling M.J., Rohani P. 2008. *Modeling infectious diseases in humans and animals*. Princeton University Press, New Jersey.
7) Lee V.J., Tok M.Y., Chow V.T., Phua K.H., Ooi E.E., Tambyah P.A., Chen M.I. (2009). Economic analysis of pandemic influenza vaccination strategies in Singapore. *PLoS ONE* 4(9).
8) Lempel H., Hammond R.A., Epstein J.M. Economic cost and health care workforce effects of school closures in the US. *PLoS Curr Influenza*. 2009 October 5: RRN1051
9) Mossong J., Hens N., Jit M. (2008). Social contacts and mixing patterns relevant to the spread of infectious diseases. PLoS Medicine 5(3):e74
10) Thomas Reuters Healthcare (2009). Few in U.S. see doctor or get medication for flu: study.
11) Viboud C., Bjernstad O., Smith D., Simonsen L., Miller M., Grenfell B. (2006). Synchrony, Waves, and Spatial Hierarchies in the Spread of Influenza. *Science*, Vol. 312, p. 447-451.

Supplemental Material

I) Map of AISD (axis in km)



II) Model Code

```
import math

days = 180
gamma = 1.0/6
epsilon = 1.0/3
atok = 2.64

#intraschool parameters
beta_aa = .1453
beta_kk = .3091
beta_ak = .1671
beta_ka = .2688
contact_kko = 10/16.0
contact_kkc = 2/16.0
contact_ka = 6/16.0
contact_aa = 7/8.0
contact_ak = 1/8.0

#gravity parameters
alpha_1 = .5
alpha_2 = .5
```

```
delta = 3.
theta = 1

def CreateSchoolSet():
   SchoolDict = [0]*len(Pops)
   for n in range(len(Pops)):
      SchoolDict[n] = School(Pops[n])
   return SchoolDict


class School():
   def __init__(self, pop):
      self.popk = pop
      self.popa = pop*atok
      if pop == 252:
         self.ks = float(pop - 2)
         self.ke = 2.0
      else:
         self.ks = pop
         self.ke = 0
      self.ki = 0.0
      self.kr = 0.0
      self.nks = 0.0
      self.nki = 0.0
      self.nkr = 0.0
      self.ads = pop*atok
      self.ae = 0.0
      self.ai = 0.0
      self.ar = 0.0
      self.nas = 0.0
      self.nai = 0.0
      self.nar = 0.0

def Poisson(lamb):
   m = 0
   #print lamb
   poi = random() - pow(math.e,-lamb)
   while(poi > 0):
      m = m+1
      poi = poi - (pow(math.e,-lamb)*pow(lamb,m))/math.factorial(m)
   return m

def Binomial(n, p):
   m = 0
   for a in range(n):
      if(random() < p):
         m = m + 1
   return m

def Step(school, SchoolDict, Connections, op):
   #intraschool infection
   new_kexp = 0
   new_aexp = 0
```

```
    if op:
        new_kexp = new_kexp +
contact_kko*beta_kk*SchoolDict[school].ks*SchoolDict[school].ki/SchoolDict[school].popk
        new_kexp = new_kexp +
contact_ak*beta_ak*SchoolDict[school].ks*SchoolDict[school].ai/SchoolDict[school].popa
        new_aexp = new_aexp +
contact_ka*beta_ka*SchoolDict[school].ads*SchoolDict[school].ki/SchoolDict[school].popk
        new_aexp = new_aexp +
contact_aa*beta_aa*SchoolDict[school].ads*SchoolDict[school].ai/SchoolDict[school].popa
    else:
        new_kexp = new_kexp +
contact_kkc*beta_kk*SchoolDict[school].ks*SchoolDict[school].ki/SchoolDict[school].popk
        new_kexp = new_kexp +
contact_ak*beta_ak*SchoolDict[school].ks*SchoolDict[school].ai/SchoolDict[school].popa
        new_aexp = new_aexp +
contact_ka*beta_ka*SchoolDict[school].ads*SchoolDict[school].ki/SchoolDict[school].popk
        new_aexp = new_aexp +
contact_aa*beta_aa*SchoolDict[school].ads*SchoolDict[school].ai/SchoolDict[school].popa
    #interschool infection
    for school2 in range(len(SchoolDict)):
        if school != school2:
            new_kexp = new_kexp +
beta_kk*SchoolDict[school].ks*SchoolDict[school2].ki*(theta*pow(SchoolDict[school].popk,alpha_1-
1)*pow(SchoolDict[school2].popk,alpha_2-1)/pow(Connections[school][school2]+1,delta))
            new_aexp = new_aexp +
beta_aa*SchoolDict[school].ads*SchoolDict[school2].ai*(theta*pow(SchoolDict[school].popa,alpha_1-
1)*pow(SchoolDict[school2].popa,alpha_2-1)/pow(Connections[school][school2]+1,delta))
    #exposed to infected
    new_kinf = SchoolDict[school].ke*epsilon
    new_ainf = SchoolDict[school].ae*epsilon
    #infected to recovered
    new_krecov = SchoolDict[school].ki*gamma
    new_arecov = SchoolDict[school].ai*gamma
    SchoolDict[school].nks = SchoolDict[school].ks - new_kexp
    SchoolDict[school].nke = SchoolDict[school].ke + new_kexp - new_kinf
    SchoolDict[school].nki = SchoolDict[school].ki + new_kinf - new_krecov
    SchoolDict[school].nkr = SchoolDict[school].kr + new_krecov

    SchoolDict[school].nas = SchoolDict[school].ads - new_aexp
    SchoolDict[school].nae = SchoolDict[school].ae + new_aexp - new_ainf
    SchoolDict[school].nai = SchoolDict[school].ai + new_ainf - new_arecov
    SchoolDict[school].nar = SchoolDict[school].ar + new_arecov

Triggers = [0,.005,.008,.011,.014,1]
Radius = [0,1,2,4,8]

for trig in Triggers:
    for radi in Radius:
        SchoolDict = CreateSchoolSet()
        aidays = 0
        acdays = 0
        aksick = 0
        for day in range(days):
```

```
        opens = len(Pops)*[1]
        for school in range(len(SchoolDict)):
            if(SchoolDict[school].ki/SchoolDict[school].popk>trig):
                opens[school]=0
                for school2 in range(len(SchoolDict)):
                    if(Connections[school][school2]<radi):
                        opens[school2]=0
        for school in range(len(SchoolDict)): #find next day
            Step(school,SchoolDict, Connections, opens[school])
        for school in range(len(SchoolDict)): #update all schools
            SchoolDict[school].ks = 1*SchoolDict[school].nks
            SchoolDict[school].ke = 1*SchoolDict[school].nke
            SchoolDict[school].ki = 1*SchoolDict[school].nki
            SchoolDict[school].kr = 1*SchoolDict[school].nkr
            SchoolDict[school].ads = 1*SchoolDict[school].nas
            SchoolDict[school].ae = 1*SchoolDict[school].nae
            SchoolDict[school].ai = 1*SchoolDict[school].nai
            SchoolDict[school].ar = 1*SchoolDict[school].nar
            aidays += SchoolDict[school].ai #adults that are sick
            aksick += SchoolDict[school].ki/SchoolDict[school].popa*(SchoolDict[school].popa-SchoolDict[school].ai) #healthy adults that have to stay home
            if not opens[school]:
                acdays += (SchoolDict[school].popa-SchoolDict[school].ai)*(SchoolDict[school].popk-SchoolDict[school].ki)/SchoolDict[school].popa

    print trig,
    print radi,
    kidssick = 0
    adultssick = 0
    for school in range(len(SchoolDict)):
        kidssick += SchoolDict[school].ke+SchoolDict[school].ki+SchoolDict[school].kr
        adultssick += SchoolDict[school].ae+SchoolDict[school].ai+SchoolDict[school].ar
    totalkids = sum(Pops)
    print aidays,
    print aksick,
    print acdays,
    print kidssick,
    print kidssick/totalkids,
    print adultssick,
    print adultssick/totalkids/atok
```

III) Table of Results: 2 infected in each school

a) δ = 3

Trigger	Radius	ad si days	ad kid miss	ad close miss	Kids Sick	Adults Sick
pure close		646414.9	155988	14668704	0.323033	0.491036
0.005	0	697434.1	175021.2	10882058	0.364175	0.527914
0.005	1	697127.4	174799.6	10926176	0.363709	0.527703

0.005	2	689872.1	171074.4	11548454	0.355778	0.522339
0.005	4	677152.8	165542	12545532	0.343658	0.512805
0.005	8	663574.9	160383.8	13679975	0.332206	0.503
0.008	0	729423.9	194732.9	9031878	0.407678	0.553034
0.008	1	728937.9	194265.6	9098609	0.406544	0.552667
0.008	2	719481.8	188433.6	9719317	0.394333	0.545539
0.008	4	700742.8	178551.6	10822754	0.372936	0.531222
0.008	8	677572	167717.3	12184943	0.349888	0.513732
0.011	0	760710.1	216592.5	7638497	0.454608	0.577442
0.011	1	759938.5	216017.2	7682264	0.453548	0.576883
0.011	2	748240.2	208032.7	8353892	0.436847	0.568111
0.011	4	726473.1	194899.7	9456949	0.408873	0.551571
0.011	8	698410.7	179816.8	10930877	0.37644	0.530338
0.014	0	789753.3	238582.8	6455417	0.501023	0.599694
0.014	1	788911.3	237872.3	6506932	0.499604	0.599078
0.014	2	775751.6	228706.6	7201506	0.480985	0.589547
0.014	4	748143.2	211754.5	8348956	0.445926	0.569014
0.014	8	719323.5	193623.5	9879755	0.406703	0.547117
pure open		936443.3	361115.1	0	0.764098	0.702681

b) δ = 3.5

Trigger	Radius	ad si days	ad kid miss	ad close miss	Kids Sick	Adults Sick
pure close		239339.3	36170.8	14942717	0.076756	0.189017
0.005	0	429569.9	83649.18	9417464	0.174529	0.331176
0.005	1	427365.3	82924.13	9504821	0.172906	0.329556
0.005	2	398670.4	73898.98	10352513	0.153961	0.308348
0.005	4	363134	63640.37	11488722	0.132693	0.281554
0.005	8	312847.6	50604.38	12788594	0.105857	0.243987
0.008	0	507159.5	115373.9	7621105	0.242388	0.390576
0.008	1	504406.6	114185.1	7715039	0.239857	0.388515
0.008	2	469387.9	99840.16	8741226	0.209513	0.362223
0.008	4	425679.6	84251.33	9896913	0.17696	0.329068
0.008	8	370211.9	65747.18	11425505	0.137803	0.286397
0.011	0	569432	146950	6215320	0.309982	0.438387
0.011	1	566177.7	145267.3	6323360	0.306439	0.435963
0.011	2	528807.5	127450.7	7337966	0.26942	0.408124
0.011	4	474901.7	105027.5	8658757	0.221881	0.367096
0.011	8	419078.2	83815.88	10087568	0.176688	0.324721
0.014	0	621194.6	177477.9	4996724	0.375081	0.47792
0.014	1	617961.7	175681.8	5102544	0.371373	0.47558
0.014	2	580712.1	155387.4	6157199	0.329269	0.448033
0.014	4	528018.6	130195.3	7410386	0.275922	0.408204

0.014	8	467706.7	104190.9	8846343	0.221215	0.362482
1	0	818106.3	313068.7	0	0.64998	0.616214

c) δ = 4

Trigger	Radius	ad si days	ad kid miss	ad close miss	Kids Sick	Adults Sick
pure close		75891.66	9488.16	15031311	0.019662	0.059843
0.005	0	328883.9	68978.01	6788576	0.144366	0.256119
0.005	1	325723.6	68066.63	6882272	0.142436	0.253726
0.005	2	287956.9	57262.13	7831274	0.119795	0.224878
0.005	4	243466.9	45490.51	8967595	0.095145	0.190555
0.005	8	196026.8	33781.92	10119638	0.070383	0.153676
0.008	0	421401	103197	5184204	0.217074	0.327339
0.008	1	417854.4	101867.6	5272276	0.214281	0.324663
0.008	2	374874.6	86631.54	6189623	0.182562	0.292168
0.008	4	310792.2	66159.98	7481985	0.139732	0.242995
0.008	8	269517.9	53778	8312134	0.113157	0.210927
0.011	0	490269.4	134630.7	3959199	0.284186	0.380342
0.011	1	486841.3	133089.4	4045488	0.28091	0.377768
0.011	2	441496.4	114432.7	4976716	0.242328	0.343915
0.011	4	384953.7	93358.92	5959391	0.198274	0.300912
0.011	8	321691.7	71393.07	7300319	0.151448	0.251491
0.014	0	544822.9	163456.8	2949126	0.345523	0.422096
0.014	1	541466.8	161782.3	3025100	0.342098	0.419628
0.014	2	502295.4	143488.4	3869561	0.304141	0.390797
0.014	4	447339.5	120449.2	4758295	0.256594	0.349796
0.014	8	384109.2	95217.85	5961306	0.201898	0.300688
pure open		720324.6	269799.9	0	0.557438	0.546543

IV) Table of Results: 2 Infected in Pease

a) δ = 3

Trigger	Radius	ad si days	ad kid miss	ad close miss	Kids Sick	Adults Sick
pure close		305253.2	65762.36	14778483	0.164121	0.270303
0.005	0	623008.7	151888.9	8623102	0.321807	0.481832
0.005	1	621817.6	151533.2	8630465	0.321214	0.481087
0.005	2	609130.7	147387.8	8875305	0.313764	0.472989
0.005	4	585388.3	140548.1	9331510	0.301457	0.457354
0.005	8	553039.6	131632	10036026	0.285465	0.436171
0.008	0	656788.2	163866.9	7953710	0.346673	0.505086
0.008	1	655721	163467.1	7984716	0.345833	0.504411

0.008	2	643542.8	158697.6	8395359	0.335705	0.496283
0.008	4	618772.8	150478.5	9006144	0.31932	0.479029
0.008	8	587405.1	141002.6	9697529	0.301655	0.458186
0.011	0	681800.3	176381.6	6972636	0.376038	0.523996
0.011	1	680765.2	175844.9	7009608	0.374873	0.523296
0.011	2	667152.2	168881.1	7528733	0.359867	0.513529
0.011	4	640317	158227.8	8376024	0.33648	0.494046
0.011	8	608449.9	147044.1	9404749	0.312603	0.471988
0.014	0	705386.2	190885.4	6131848	0.409321	0.542442
0.014	1	704355.4	190233.5	6172421	0.407861	0.54171
0.014	2	688468.7	180925.3	6768129	0.387656	0.530046
0.014	4	659072.8	167200.8	7598600	0.358246	0.508012
0.014	8	626221.8	153525	8733459	0.327816	0.484136
pure open		916440	354318.6	0	0.754839	0.693098

b) δ = 3.5

Trigger	Radius	ad si days	ad kid miss	ad close miss	Kids Sick	Adults Sick
pure close		6952.815	838.0464	14956400	0.001962	0.006178
0.005	0	238597.5	44951.5	4947209	0.099237	0.198639
0.005	1	235758.3	44352.2	4972572	0.097967	0.196502
0.005	2	208685.1	37757.05	5374305	0.083886	0.175186
0.005	4	172187.5	29602.35	6070420	0.066127	0.145875
0.005	8	131819.2	21425.81	7030391	0.048287	0.113018
0.008	0	303303.1	63269.91	4391742	0.139331	0.249497
0.008	1	300005.7	62356.27	4440725	0.13732	0.246998
0.008	2	267649.4	52780.34	4957135	0.116597	0.22173
0.008	4	225538.9	41640.89	5688363	0.092118	0.188042
0.008	8	186837.9	32522.87	6480438	0.07225	0.15688
0.011	0	347811.3	78959.58	3874820	0.174295	0.284849
0.011	1	343981.2	77678.8	3932174	0.171509	0.281923
0.011	2	309055	65651.36	4529639	0.144926	0.254589
0.011	4	268196.6	53311.17	5234713	0.117582	0.221761
0.011	8	219651.9	40271.18	6099591	0.088992	0.182633
0.014	0	383287.7	93616.29	3397440	0.207864	0.31324
0.014	1	379316.6	92116.73	3466000	0.204471	0.310199
0.014	2	343754.9	78216.45	4056986	0.173622	0.282248
0.014	4	303008.4	64683.33	4654635	0.143319	0.249764
0.014	8	250005.7	48054.4	5713191	0.105997	0.206313
pure open		623344.2	244893.7	0	0.538821	0.499536

c) δ 4

Trigger	Radius	ad si days	ad kid miss	ad close miss	Kids Sick	Adults Sick
pure close		932.3162	106.574	14959412	0.000224	0.000753
0.005	0	90068.04	21175.95	1878270	0.047853	0.079253
0.005	1	88583.63	20761.57	1907242	0.046996	0.077959
0.005	2	74109.52	16488.01	2355475	0.037184	0.065115
0.005	4	57339.11	12845.4	2581044	0.028996	0.051106
0.005	8	37161.68	7945.523	3566139	0.017932	0.03316
0.008	0	124046.8	31633.05	1568074	0.072211	0.109001
0.008	1	122106.5	31020.74	1620343	0.070636	0.10733
0.008	2	104372.5	25003.75	2025754	0.056856	0.09154
0.008	4	83722.66	19779.74	2269446	0.044889	0.074215
0.008	8	59300.3	13738.41	2875431	0.031682	0.052981
0.011	0	146421.7	40075.98	1307644	0.091996	0.12905
0.011	1	144229.3	39282.62	1328173	0.090469	0.127123
0.011	2	124906.3	31874.2	1743751	0.073107	0.109739
0.011	4	103123.9	25137.72	2174691	0.056765	0.090788
0.011	8	76884.75	18428.36	2586027	0.042251	0.068284
0.014	0	163029.4	47275.49	1082619	0.10946	0.144177
0.014	1	160768.2	46381.62	1124241	0.107253	0.142197
0.014	2	141453	38260.42	1504781	0.088194	0.124715
0.014	4	122169.4	31749.47	1839822	0.072373	0.107808
0.014	8	93812.4	23411.36	2271222	0.054309	0.083075
pure open		229720.8	91216.2	0	0.224829	0.209094

V) Table of Results: 2 infected in Menchaca

a) δ = 3

Trigger	Radius	ad si days	ad kid miss	ad close miss	Kids Sick	Adults Sick
pure close		12645.04	2301.01	14915851	0.006645	0.013679
0.005	0	497282.7	117338.2	6249481	0.267243	0.408922
0.005	1	495020.6	116674.5	6272927	0.265943	0.407428
0.005	2	476306.1	110740.1	6526197	0.25475	0.394881
0.005	4	453253.5	104100.9	6952636	0.241702	0.378543
0.005	8	422394.5	96097.44	7653442	0.225643	0.355957
0.008	0	542630.7	132227.5	5737248	0.296222	0.440431
0.008	1	540681.7	131598.9	5757163	0.295008	0.439148
0.008	2	522687.6	125390.7	5994253	0.283348	0.427217

0.008	4	497614	117342.1	6477044	0.267208	0.409251
0.008	8	463661.5	107783.2	7160751	0.248046	0.38453
0.011	0	575034.9	144138.1	5341469	0.320048	0.463167
0.011	1	573418.2	143582.4	5357103	0.318988	0.462149
0.011	2	554566.8	136598.5	5613356	0.305569	0.449643
0.011	4	527565.2	127340	6083177	0.286954	0.430195
0.011	8	491295.2	116210.9	6800801	0.264139	0.403585
0.014	0	600189.7	154495.1	4986043	0.341806	0.481251
0.014	1	598580.2	153890.5	4996902	0.340776	0.480242
0.014	2	579295.9	146176.5	5298103	0.325158	0.467253
0.014	4	550383.4	135292.9	5810079	0.302528	0.446086
0.014	8	513844.5	123395.6	6503580	0.278082	0.41928
pure open		844080	332119.1	0	0.727031	0.659943

b) $\delta = 3.5$

Trigger	Radius	ad si days	ad kid miss	ad close miss	Kids Sick	Adults Sick
pure close		268.1074	37.36332	14922803	7.72E-05	0.000212
0.005	0	80535.74	20925.24	1952784	0.049462	0.077594
0.005	1	79327.56	20561.74	1980231	0.048672	0.076432
0.005	2	73054.84	18061.37	2298642	0.042598	0.069707
0.005	4	65903.34	15429.2	2734873	0.036005	0.062392
0.005	8	50178.18	10512.63	3705795	0.024429	0.047003
0.008	0	97888.75	28156.72	1503928	0.067754	0.095957
0.008	1	96536.45	27666.71	1535184	0.066651	0.094621
0.008	2	89810.92	24435.82	1867133	0.058237	0.087025
0.008	4	82534.8	21296.47	2198133	0.050506	0.079247
0.008	8	65678.84	15077.69	3054955	0.035403	0.062082
0.011	0	108973.3	33728.81	1199171	0.082659	0.108323
0.011	1	107623.1	33167.19	1233942	0.081313	0.106955
0.011	2	101153.1	29533.06	1533888	0.071642	0.099261
0.011	4	94435.75	26109.54	1859578	0.062554	0.091677
0.011	8	77916.78	19265.34	2643693	0.045272	0.074299
0.014	0	117011.8	38423.9	991858.1	0.095281	0.117742
0.014	1	115679.6	37762.56	1030027	0.09362	0.11632
0.014	2	109651.8	33909.26	1309420	0.083052	0.108816
0.014	4	103506.2	30356.08	1611190	0.073503	0.101533
0.014	8	88470.56	23655.21	2235908	0.056341	0.08542
pure open		138250.3	61736.99	0	0.180991	0.150669

c) $\delta = 4$

Trigger	Radius	ad si days	ad kid miss	ad close miss	Kids Sick	Adults Sick
pure close	8	177.5198	27.22522	14922847	5.43E-05	0.000135
0.005	0	9847.608	3436.662	40841.65	0.009042	0.009592
0.005	1	9846.314	3426.634	51364.58	0.008974	0.009583
0.005	2	9845.659	3420.114	65862.21	0.008886	0.009578
0.005	4	8934.722	3113.721	107363.3	0.008126	0.008742
0.005	8	7058.38	2354.367	563889.4	0.00594	0.006818
0.008	0	11348.16	4021.228	23989.36	0.010474	0.010961
0.008	1	11348.16	4021.228	23989.36	0.010474	0.010961
0.008	2	11348.16	4021.228	23989.36	0.010474	0.010961
0.008	4	10465.99	3722.031	36919.21	0.009797	0.010162
0.008	8	8729.691	3031.288	261645.1	0.007966	0.008395
0.011	0	12285	4429.21	14534.08	0.011431	0.011803
0.011	1	12285	4429.21	14534.08	0.011431	0.011803
0.011	2	12285	4429.21	14534.08	0.011431	0.011803
0.011	4	11562.7	4170.614	21467.19	0.010869	0.011148
0.011	8	10160.21	3613.406	152550.4	0.009406	0.009726
0.014	0	12862.23	4693.832	7750.61	0.012072	0.012311
0.014	1	12862.23	4693.832	7750.61	0.012072	0.012311
0.014	2	12862.23	4693.832	7750.61	0.012072	0.012311
0.014	4	12335.45	4484.634	13754.74	0.011589	0.011819
0.014	8	11302.33	4060.805	98003.69	0.010473	0.010761
pure open		13641.29	5085.66	0	0.012965	0.012968