Design of Community Containment for Pandemic Influenza with Loki-Infect

Supplement to the National Population and Infrastructure Impacts of Pandemic Influenza Report

15 October 2007

Prepared by
National Infrastructure Simulation & Analysis Center
Infrastructure Analysis and Strategy Division
Office of Infrastructure Protection
Department of Homeland Security

This page intentionally left blank.

Acknowledgements

This research was supported by the National Infrastructure Simulation and Analysis Center (NISAC), a program of the U.S. Department of Homeland Security's Infrastructure Protection/Risk Management Division and composed of a core partnership of Sandia National Laboratories (SNL) and Los Alamos National Laboratory (LANL).

Robert Glass, Jason Min, and Walt Beyeler of NISAC's Advanced Methods and Techniques Investigations (AMTI) team and Laura Glass of the Albuquerque Public School System were the authors of this study report. An earlier version (25 January 2007), differing from this report by minor editorial revisions, was published as an unclassified-unrestricted Sandia report (SAND2007-1184P) and can be obtained at the AMTI web site: http://www.sandia.gov/nisac/amti.html.

Many colleagues have contributed to this work:

Richard Hatchett, of the National Institutes of Health's National Institute of Allergy and Infectious Diseases (NIH/NIAID), and Carter Mecher (U.S. Department of Veteran Affairs [VA]) worked with the senior author to define and frame the context for the studies contained within this report.

Victoria Davey (VA) helped to formulate regionally mitigated and unmitigated scenarios and design effective criteria for rescinding mitigation strategies that minimize illness, epidemic recurrence, and social disruption.

Hillery Harvey, Robert Taylor, and Lone Simonsen, of NIH/NIAID, invited the use of preliminary results as part of the 2006 Discovery Channel Young Scientist Challenge hosted by NIH/NIAID and helped to refine the results in a way that could be used by policy makers (the young scientist's role in the Challenge).

Louise Maffitt (NISAC) provided constructive review of the manuscript.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

This page intentionally left blank.

Table of Contents

List of Figures

List of Tables

This page intentionally left blank.

List of Acronyms and Abbreviations

3D	3-dimensional
AMTI	Advanced Modeling Techniques Investigation
CDC	Centers for Disease Control and Prevention
CIPDSS	Critical Infrastructure Protection Decision Support System
CMG	Community Management Guidance
CMG-SE	Community Management Guidance – Selected Elements
DHS	U.S. Department of Homeland Security
H5N1	Avian influenza A (bird flu)
HHS	U.S. Department of Health and Human Services
IOM	Institute of Medicine
MIDAS	Models of Infectious Disease Agent Study (funded by National Institute of General Medical Sciences of the National Institutes of Health)
NAS	National Academy of Sciences (National Academies)
NIAID	National Institute of Allergy and Infectious Diseases
NIH	National Institutes of Health
NISAC	National Infrastructure Simulation and Analysis Center
PIP	Pandemic Implementation Plan
TLC	targeted layered containment
VA	U.S. Department of Veterans Affairs
WHHSC	White House Homeland Security Council

List of Symbols

$<I_R>$	Weighted average of I_R for adults over symptomatic (reduced by diagnosis) and asymptomatic individuals for the mean contagious period
F	Weighted average of I_A for adults over symptomatic (reduced by diagnosis) and asymptomatic individuals for the mean contagious period
I_A	Relative infectivity of the person who is transmitting
I_D	Infectivity of the disease
$IDfactor$	Multiplier on I_D for systematic variation of disease infectivity relative to a base
I_R	Relative infectivity of the disease state
pH	Probability of staying at home if symptomatic
pM	Probability of death if symptoms occur
pS	Probability of staying at home if symptomatic
R_0	Basic reproductive number of a disease defined as the average number of people infected by a diseased individual in an entirely susceptible population
S_A	Relative susceptibility of the person who is receiving
SD	Standard deviation
S_P	Susceptibility of people to the disease

Executive Summary

The National Infrastructure Simulation and Analysis Center (NISAC) has applied a community-scale model that simulates the spread of influenza in an explicit, multiply-overlapping network of social contacts within a stylized community. The modeled community can be isolated or embedded within a regional epidemic where other communities are either imposing the same containment strategies or doing nothing to abate the epidemic. By focusing on a single community, analysts have been able to evaluate an extensive matrix of containment strategy combinations and disease infectivity levels. This exploration has enabled the analysis team to identify community containment strategies that minimize illness, death, and loss of workforce in the face of constrained antiviral or pre-pandemic vaccine supplies. Building on this foundation, the team assessed the robustness of containment designs to variations in disease manifestation, social network configuration, strategy implementation threshold, public compliance, and neighboring community behavior. Based on the findings of this study, the NISAC analysis team recommends policy in 3 areas: requirements of robust, effective community containment; necessity of uniform national policy; and administration of pre-pandemic vaccine. In addition, the study team recommends continued evaluation and reduction of uncertainty.

For a 1918-like pandemic infectivity level, strategies can be found that are effective at minimizing illness to below 5 percent of the population (with nearly no deaths), using only the levels of antiviral coverage currently within U.S. stockpiles and limiting cost in terms of adult days spent at home to less than 1 week. The best community containment strategy combines full social distancing with antiviral treatment and household antiviral prophylaxis. This strategy is robust to changes in the social contact network that remove enhanced transmission by children and teenagers and to changes in the disease manifestation within the range currently used in modeling studies found in the literature. However, strategy effectiveness depends on rapid implementation and a high degree of public compliance for both social distancing measures and antiviral application. The latter encompasses administration of antiviral drugs by the healthcare infrastructure and use by the affected persons within the population.

The first critical recommendation for policy is that prioritization should be given first to the planning, education, and training required for the effective triggering and implementation of high-compliance social-distancing measures and second to case-based strategies such as home quarantine or antiviral prophylaxis. The most important component of effective strategy combinations is the implementation of social distancing with high compliance. For infectivity similar to that of the 1918 pandemic, administration of antiviral prophylaxis at levels above 2-percent coverage adds no benefit and does not remove the necessity of implementing high compliance social distancing, which includes closing schools. Closing schools imposes the largest cost in days adults are at home. However, containment strategies that combine closing schools and implementing social distancing of children and teens are very effective when layered with home antiviral prophylaxis. By adding implementation of social distancing by adults and seniors (including a 50-percent reduction in contacts at work), adult days at home can be minimized to an average of 6 per adult.

Thus, high compliance social distancing forms the foundation for effective community containment. This conclusion contradicts the emphasis within the medical and public health community over the past years, where antiviral prophylaxis has been the primary consideration, and is given further emphasis from recent data that show avian influenza type A, or bird flu (H5N1), is developing resistance to the antiviral oseltamivir, our most potent antiviral. Societal support of families with

young children is an important component for high-compliance social distancing of children, as families will bear the vast majority of the costs of adult days at home. Mechanisms including private (company business plans, insurance policies), public (community organization, taxation), and not-for-profit resources could accomplish such a redistribution of burden.

The second critical recommendation for policy is that a uniform national policy should be imposed and supported for the benefit of all. Isolated communities implementing effective community containment strategies, and communities embedded within regions implementing effective community containment strategies, perform identically. However, the model simulations, in which communities implementing containment strategies are embedded in a region that is doing nothing to abate the epidemic ("regionally unmitigated" with full contact through the work place), show the importance of regional implementation of community containment strategies. Without such regional policy, the best community containment strategy (full social distancing layered with household antiviral prophylaxis and 90-percent compliance) still reduces infectious attack rates below 10 percent. However, the attack and death rates quadruple from their values for the regionally mitigated epidemic, as do antiviral requirements (to 9-percent coverage, well above the current stockpile of oseltamivir of 7.2 percent in January 2007), and the number of days adults are at home double. Leaving mitigation policy up to individual communities could cost the nation a great deal.

The third critical recommendation for policy is that if pre-pandemic vaccine is available at currently proposed stockpile levels (7-percent coverage and 50-percent efficacy), the best community containment strategy (full social distancing layered with household antiviral prophylaxis and 90-percent compliance) should still be implemented and the pre-pandemic vaccine should be used primarily to ensure that critical infrastructures continue to function during the period of the pandemic. Simulations show that the most optimal focus of pre-pandemic vaccination at proposed stockpile levels is on children and teens; however, such targeting influences the spread of disease only somewhat. If the best community containment strategy is implemented (full social distancing layered with household antiviral prophylaxis and 90-percent compliance), pre-pandemic vaccine affords no added benefit. For highest community benefit, people in positions that cannot be replaced in infrastructures that must remain operable, such as healthcare and first responders, should be given the pre-pandemic vaccine. The vaccine will decrease the probability of them falling ill and increase the probability of them continuing to work. In future studies, analysts should consider if a stockpile size above the current proposed 7-percent coverage with 50-percent effective pre-pandemic vaccine would yield enough benefit to change the choice of best community containment strategy.

As has been pointed out in a recent review by the National Academy of Sciences (NAS) Institute of Medicine (IOM), "Modeling Community Containment for Pandemic Influenza,"[1] much work remains to evaluate the uncertainty of community containment efficacy. Simulation studies such as this study can aid in evaluating uncertainty and in reducing this uncertainty over time. The current study has taken a step forward along this path and developed a foundational set of results for evaluation. Future studies should systematically consider parametric assumptions for the underlying disease manifestations, social contact network, action of antiviral drugs, and containment strategy implementation. Modification of community-scale models and subsequent analytic sweeps of parameter space are feasible to evaluate the uncertainty imposed by these assumptions. Additionally,

[1] IOM/NAS (Institute of Medicine of the National Academy of Sciences), 2006, "Modeling Community Containment for Pandemic Influenza: A Letter Report," The National Academies Press, Washington, D.C., 11 December (hereinafter referred to as IOM/NAS, 2006)

analysis can be refined in response to evolving constraints and changes in uncertainty from data collected as new influenza strains emerge and combined strategy implementations are undertaken. Ongoing work in this area should include and emphasize community-scale modeling in addition to modeling at the regional or national scales. Modeling activities at all scales and work to fully integrate with economic analysis and detection/monitoring systems for influenza should continue indefinitely.

This page intentionally left blank.

1. Introduction

1.1 Programmatic Context

Performed as part of the joint National Infrastructure Simulation and Analysis Center (NISAC)-Critical Infrastructure Protection Decision Support System (CIPDSS) pandemic influenza analysis task for the U.S. Department of Homeland Security (DHS), this work supports Task 1.1.2, "Evaluation of the Effects of Uncertainties on Response Effectiveness and Economic Impacts," described as follows:

> Initial evaluation of the effects of uncertainties about pandemic influenza disease characteristics on response effectiveness and costs, particularly those uncertainties that can not be resolved until the virus attains human to human transmission capability. This would include an evaluation of the effectiveness of different regional mitigation options as well as the impact differential of response timing and mitigation actions. This task is designed to characterize the effectiveness of selected response options in the context of behavioral responses and enhance the understanding of the economic impact of the pandemic.

Disease modeling and analysis personnel will work with Centers for Disease Control and Prevention (CDC) and U.S. Department of Health and Human Services (HHS) experts to refine disease parameter estimates, including uncertainties, and identify selected mitigation strategies for minimizing impacts in the U.S., assuming that initial efforts to contain the disease have failed.

More specifically, this study supports Subtask 2 "Response Effectiveness and targeted epidemiological uncertainty analysis. (Principal: NISAC)," defined as follows:

> This subtask will utilize the full suite of cross-calibrated epidemic modeling capabilities (including EpiSimS, EpiCast, EpiC, Loki-Infect, and several EpiScope tools), focusing on issues identified in subtask 1. The analysis will address uncertainties in characterization and parameterization of the disease manifestations, systematic variation of parametric assumptions underlying social networks, levels of sympathetic or fear-based isolation, and the ability of the health care system to cope with pandemic. Mitigation strategies will include various forms and timing of antiviral, vaccine, isolation, closure and other behavior modifications, individually and in composition, including levels of compliance and strategy implementation thresholds. This study should identify those strategies or combinations of strategies that are both effective and robust to uncertainties in the impending pandemic.

1.2 Accomplishments

In support of specified tasks, the NISAC Advanced Modeling Techniques Investigation (AMTI) team has

1. Continued interactions with the White House Homeland Security Council's Pandemic Implementation Plan (WHHSC PIP) writing team to support the design of combined mitigation strategy community containment for pandemic influenza, using results of the

NISAC-AMTI Loki-Infect model, a networked agent-based model developed to analyze complex adaptive systems[2]

2. Opened interactions with the National Institutes of Health (NIH)-funded Models of Infectious Disease Agent Study (MIDAS) consortium of epidemic modelers, including Neil Ferguson (Imperial College) and Ira Longini (University of Washington)
3. Refined Loki-Infect to represent the influenza manifestations of both Ferguson and Longini, as used in MIDAS/NIH models, because these are the most accepted manifestations of influenza in the literature
4. Compared Loki-Infect results, to the extent possible, to past epidemics of 1918, 1957, and 1968
5. Evaluated the robustness of social distancing strategies to increased disease infectivity and transmission networks that are less focused on the young (that is, removal of enhanced relative infectivity and susceptibility for children and teenagers and increase in number of contacts for adults within the workplace to put them on par with children and teenagers in schools)
6. Completed peer review of "Targeted Social Distancing Design for Pandemic Influenza"[3] for expedited publication in CDC's *Emerging Infectious Disease*. This paper, included in Appendix A, contains a description of Loki-Infect, a subset of the results from analysis in Glass et al, 2005c,[4] our comparison to past epidemics (Number 4, above), and our evaluation of robustness (Number 5, above).
7. Worked with medical and public health experts within the WHHSC PIP writing team (Richard Hatchett of NIH/National Institute of Allergy and Infectious Diseases [NIAID] and Carter Mecher of the U.S. Department of Veterans Affairs [VA]) to define an extended set of community containment strategies around the concept of targeted layered containment (TLC) that included both network-based strategies (social distancing) and case-based strategies (home quarantine and 3 levels of antiviral administration: treatment, home prophylaxis, and extended network prophylaxis)

Note: After this supplemental document was completed, the Centers for Disease Control and Prevention (CDC) changed the designations of the TLC and TLC Lite scenarios to Community Management Guidance (CMG) and Community Management Guidance – Selected Elements (CMS-SE), respectively.

8. Worked with public health expert, Vicky Davey of the VA, to define regionally mitigated and unmitigated implementations of external interaction within Loki-Infect and to formulate

[2] HSC (Homeland Security Council), 2006, *National Strategy for Pandemic Influenza Implementation Plan*, The White House, Washington, D.C., May

[3] Glass, R. J., L. M. Glass, W. E. Beyeler, and H. J. Min, 2006, "Targeted Social Distancing Design for Pandemic Influenza," *Emerging Infectious Diseases* **12**(11), Centers for Disease control and Prevention, U.S. Department of Health and Human Services, 11 November, http://www.cdc.gov/ncidod/eid/vol12no11/06-0255.htm (hereinafter referred to as Glass et al., 2006)

[4] Glass, R. J., L. M. Glass, and W. E. Beyeler, 2005c, "Local Mitigation Strategies for Pandemic Influenza," SAND2005-7955J, prepared for the U.S. Department of Homeland Security under the National Infrastructure Simulation and Analysis Center (hereinafter referred to as Glass et al., 2005c)

effective criteria for rescinding mitigation strategies that minimize illness, epidemic recurrence, and social disruption

9. Defined an extended simulation matrix required for evaluation of network-based and case-based community containment combination strategy efficacy in context of regionally mitigated and unmitigated scenarios as a function of critical system parameters and their uncertainties (several million simulations)
10. Refined the Loki-Infect simulation environment to accommodate the large number of simulations required and make use of Sandia National Laboratories' (SNL's) high-performance Thunderbird computing cluster (8,960 64-bit processors, each with 6 gigabytes of random access memory) databases for effective organization and query of output and archival systems for reproducibility and quality assurance
11. Worked with scientists at NIH/NIAID (Hillery Harvey, Rob Taylor, and Lone Simonsen) in the 2006 Discovery Channel Young Scientist Challenge on the Avian Influenza Challenge (a nationwide middle school science contest) that used preliminary Loki-Infect simulation results to weigh the impact of disease against social costs of mitigation strategies within communities
12. Presented initial results of an extended simulation matrix (defined in Number 9, above) at the National Academy of Sciences (NAS)/Institute of Medicine (IOM) review of community containment strategies for pandemic influenza held 25 and 26 October 2006. This presentation is included in Appendix F.
13. Completed the simulation matrix (defined in Number 9, above) and analyzed results as a base evaluation of community containment strategy efficacy and robustness to principle uncertainties

1.3 This Report

This report documents the design (Section 2), methods (Section 3), and results (Section 4) for the study team's base evaluation of community containment strategy efficacy and robustness (accomplishment 13, above). In Section 5, the team used the model results to demonstrate a design process for effective, robust community containment of pandemic influenza in light of current uncertainties. Section 6 contains a discussion of 3 areas in which recommendations for policy can be made: requirements for robust, effective community containment; necessity of uniform national policy; and administration of pre-pandemic vaccine. In addition, Section 6 contains the study team's summary recommendation for continued evaluation and reduction of uncertainty.

This page intentionally left blank.

2. Study Definition

In the fall of 2005, the NISAC team applied the Loki-Infect to evaluate the effectiveness of a range of social distancing and vaccination strategies to mitigate the spread of pandemic influenza.[5] Through interactions with the WHHSC PIP writing group over the winter and spring of 2006, Loki-Infect results aided in the design of a combined TLC mitigation strategy that forms the basis of a proposed response to pandemic influenza within the U.S.[6] The CDC has integrated TLC into their "Interim Pre-pandemic Planning Guidance" released on 1 February 2007.[7]

To evaluate the likely effectiveness of the TLC mitigation strategy, the WHHSC PIP group defined a series of large-scale epidemiological simulations, outlining the interventions/parameters, their compliance/efficacy, outcomes of interest, and a set of simulations to be conducted (Appendix B). Each set of simulations was to be conducted at a range of infectivity yielding overall values of the basic reproductive number (R_o) of 1.9, 2.4, and 3.0. The R_o value of 1.9–2.0 is the current accepted infectivity range for the 1918 Spanish flu pandemic, while a value of 1.6 would be representative of the 1958 Asian influenza pandemic. R_o values of 2.4 and 3.0 are far above these historic values and represent an extremely virulent influenza strain.

The NISAC study team used the interactions with the WHHSC PIP writing group and their simulation outline to define this study, focused on the evaluation of community containment strategy robustness in the context of uncertainty.

As a base simulation matrix, the team considered

1. Natural history disease manifestation: Ferguson-like reflective of that in Ferguson et al. (2006; 2005)[8]
2. Disease infectivity factors (0.75, 1.0, 1.25, 1.5, 2.0, 2.5, and 3.0) about a base level that yielded an infection attack rate of 50 percent
3. Boundary conditions for external contact (surrounding communities either implementing identical strategies or doing nothing to abate the epidemic)
4. Community containment strategies applied individually or in combination (64 combinations)
5. Diagnosis rate (80 percent of symptomatic)
6. Compliance rates (60 percent and 90 percent) applied to all social distancing, antiviral treatment, and antiviral prophylaxis

[5] Glass et al., 2006 (See Footnote 3); and Venkayya, R., 2006, "Targeted Layered Containment: Policy Perspective," presented at the Modeling Community Containment Workshop, Institute of Medicine of the National Academies, 26 October, retrieved 19 January 2007 from http://www.iom.edu/Object.File/Master/38/244/Rajeev%20Venkayya.pdf

[6] CDC (Centers for Disease Control and Prevention), 2007, "Interim Pre-pandemic Planning Guidance: Community Strategy for Pandemic Influenza Mitigation in the United States—Early, Targeted, Layered Use of Nonpharmaceutical Interventions," 1 February, http://www.pandemicflu.gov/plan/community/community_mitigation.pdf

[7] Ferguson N. M., D. A. T. Cummings, S. Cauchemez, C. Fraser, S. Riley, A. Meeyai, S. Iamsirithaworn, and D. S. Burke, 2005, "Strategies for containing an emerging influenza pandemic in Southeast Asia," *Nature* **437**(7056):209–14, 8 September (hereinafter referred to as Ferguson,et al., 2005); and Ferguson, N. M., D. A. T. Cummings, C. Fraser, J. C. Cajka, P. C. Cooley, and D. S. Burke, 2006, "Strategies for mitigating an influenza pandemic," *Nature* **442**:448–52, 27 July, http://www.nature.com/nature/journal/v442/n7101/abs/nature04795.html (hereinafter referred to as Ferguson, et al., 2006)

[8] Ibid.

7. Implementation threshold (day after 10 diagnosed within the community)
8. Pre-pandemic vaccination strategy (none)

This base simulation matrix contains 1,792 scenarios, defined by a set of parameters (disease model, infectivity, infectious contact network, and community containment strategy combination) that encompass and bound possible system behavior for a range of influenza infectivity from normal to twice that of the 1918 pandemic.

The team then extended the analysis to consider uncertainty in the disease manifestation through implementation of a substantially different, though accepted, manifestation with the full set of 2 through 8 above:

9. Natural history disease manifestation: Longini-like reflective of that in Longini et al (2005)[9]

After evaluation of the difference between disease manifestations with this set, the team worked with the Ferguson-like manifestation alone and extended the matrix in items 7 and 8, above, to consider additional uncertainties:

10. Relaxed implementation thresholds for mitigation activity (day after 30 or 100 diagnosed within the community)
11. 3 pre-pandemic vaccination strategies with 7-percent coverage of 50-percent efficacy vaccine administered, randomly targeted to children and teens or targeted to adults (constituting the proposed level for a pre-pandemic vaccine stockpile)

Finally, the team conducted a first-level evaluation of uncertainty in the social network using the Ferguson-like manifestation and the original set of values for items 2 through 8, above, consisting of

12. Uniform transmission within populations of children, teens, and adults (uniform relative infectivity and susceptibility, and identical number of contacts within workplaces and schools)

This final evaluation considered a network absent of enhanced transmission by the young, meaning that the enhanced relative infectivity and susceptibility for children and teenagers was removed and the number of contacts for adults within the workplace was increased to put them on par with children and teenagers in schools. While the NISAC team believes these 2 characteristics are unlikely (especially in combination), they represent an extreme that the team believes will bound the uncertainty in the resulting network of infectious contacts.

With this final series of perturbations, the number of scenarios considered was increased by a factor of 48 over the base simulation matrix, for a total of 86,016 scenarios. To capture the random variability that is inherent and expected from community to community due to the details of community structure and seeding, the team created 100 realizations of the community for each of these scenarios over which summary statistics were calculated, resulting in 8,601,600 simulations.

[9] Longini, Jr., I. M., A. Nizam, S. Xu, K. Ungchusak, W. Hanshaoworakul, D. A. Cummings, and M. E. Halloran, 2005, "Containing pandemic influenza at the source," *Science* **309**(5737):1083–7, 3 August (hereinafter referred to as Longini et al., 2005); and Germann, T. C., K. Kadau, I. M. Longini, Jr., and C. A. Macken, 2006, "Mitigation strategies for pandemic influenza in the United States," *Proceedings of the National Academy of Sciences of the United States of America*, **103**(15):5935–40, 11 April, http://www.washington.edu/home/international/pdfs/mitigationStrategiesPNAS.pdf (hereinafter referred to as Germann et al., 2006)

3. Methods

3.1 Loki-Infect Model

Loki is a generalized networked agent-based modeling tool kit that has been developed by NISAC-AMTI to model critical infrastructures and their interdependencies.[10] Agent-based models treat entities (individuals and groups) explicitly as agents. Individual agents are endowed with behavioral rules for internal states and interaction with other agents or the external environment. Such models have been developed and applied in a wide range of fields including economics,[11] sociology,[12] and more recently, epidemiology.[13] Within the epidemiological context, a number of theoretical studies show the critical importance of the underlying contact network along which an infectious disease spreads.[14] The Loki simulation approach combines both agents and explicit networks.[15]

Loki has been applied to generic congestive cascade,[16] power grids,[17] payment systems,[18] social simulation,[19] and infectious diseases.[20]

Loki-Infect is NISAC-AMTI's infectious disease application in which agents represent individual people and are linked to each other within and among groups to form a contact network reflective of a multiply overlapping, structured community. Loki-Infect specifies behavioral rules for agents, their

---

[10] Glass, R. J., W. Beyeler, K. Stamber, L. Glass, R. LaViolette, S. Conrad, N. Brodsky, T. Brown, A. Scholand, and M. Ehlen, 2005a, "Simulation and Analysis of Cascading Failure in Critical Infrastructure," Advanced Modeling and Techniques Investigations, National Infrastructure Simulation and Analysis Center (NISAC), Sandia National Laboratories (hereinafter referred to as Glass, et al., 2005a)

[11] Feigenbaum, J., 2003, "Financial physics," *Reports on Progress in Physics* **66**(10):1611-49, October, http://www.iop.org/EJ/abstract/0034-4885/66/10/R02/

[12] Goldstone, R. L., and M. A. Janssen, 2005, "Computational models of collective behavior," *TRENDS in Cognitive Sciences* **9**(9):425–30, September, http://cognitrn.psych.indiana.edu/rgoldsto/pdfs/AgentsTICS.pdf

[13] Eubank, S., H. Guclu, V. S. A. Kumar, M. V. Marathe, A. Srinivasan, Z. Toroczkai, and N. Wang, 2004, "Modelling disease outbreaks in realistic urban social networks," *Nature* **429**:180–4, 13 May, http://cnls.lanl.gov/~toro/nat02541.pdf

[14] Barthelemy, M., A. Barrat, R. Pastor-Satorras, and A. Vespignani, 2005, "Dynamical patterns of epidemic outbreaks in complex heterogeneous networks," *Journal of Theoretical Biology* **235**:275–288; and Newman, M. E. J., 2002, "Spread of epidemic disease on networks," *Physical Review Online Archive, American Physical Society* **66**:1, 26 July, http://prola.aps.org/pdf/PRE/v66/i1/e016128

[15] Glass et al., 2005a (See Footnote 10)

[16] Laviolette, R. A., W. E. Beyeler, R. J. Glass, K. L. Stamber, and H. Link, 2006, "Sensitivity of the resilience of congested random networks to rolloff and offset in truncated power-law degree distributions," *Physica A: Statistical Mechanics and its Applications* **368**(1):287–93, 1 August (see Laviolette, et al., 2006)

[17] Glass, R. J., W. E. Beyeler, and K. L. Stamber, 2005b, "Advanced Simulation for Analysis of Critical Infrastructure: Abstract Cascades, the Electric Power Grid, and Fedwire," SAND2004-4239, prepared for the U.S. Department of Homeland Security under the National Infrastructure Simulation and Analysis Center (hereinafter referred to as Glass et al., 2005b)

[18] Beyeler, W. E., R. J. Glass, M. Bech, and K. Soramaki, 2006, "Congestion and Cascades in Payment Systems," Federal Reserve Bank of New York, Staff Reports, No. 259, September, http://www.newyorkfed.org/research/staff_reports/sr259.html; Glass et al., 2005b (See Fotenote 17); Soramaki, K., M. L. Bech, J. Arnold, R. J. Glass, W. E. Beyeler, 2006, "The Topology of Interbank Payment Flows," Federal Reserve Bank of New York Staff Report No. 243, March, http://www.newyorkfed.org/research/staff_reports/sr243.pdf;

[19] Backus, G. A., and R. J. Glass, 2005, "An Agent-based Model Component to a Framework for the Analysis of Terrorist-group Dynamics," SAND2006-0860P, prepared for the U.S. Department of Homeland Security (hereinafter referred to as Backus and Glass, 2005)

[20] Glass et al., 2005c (See Footnote 4); Glass et al., 2006 (See Footnote 3)

interaction, and the performance of network links to model the spread of influenza. Community containment strategies are implemented through modifications of these behavioral rules. Appendix A includes a copy of NISAC's recent paper documenting Loki-Infect and its application to the design of targeted social distancing.[21]

3.1.1 Contact Network

The model creates a social contact network by first specifying groups of given sizes (or ranges of sizes) within which individuals of specified ages interact (for example, school classes, households, and bridge clubs). It also specifies the average number of individuals with which a person has contact within the group to reflect that cliques form or are imposed (for example, seating in a classroom) within any group. Loki-Infect uses this average number to construct a within-group network that can take a variety of forms. For the stylized community simulated here, the model uses either fully connected, random, or ring networks for each group. Random networks are formed by choosing two individuals, at random, within the group and linking them. This connection process is repeated until the number of links within the group yields the specified average (each individual will have a different number of links). The ring is formed by first placing each individual next to a neighbor and linking them to form a complete circle. Additional links are then made to next nearest neighbors and others symmetrically around the ring (see Figure 3-1). Finally, the model gives an average frequency of contact (contacts per day) to links within a group. With this approach, a contact network can be built straightforwardly, from the experience of community members, which exhibits the clustered yet "small-world" character[22] and the multiply-overlapping quality of a structured community.[23]

[21] Glass et al., 2006 (See Footnote 3)

[22] Watts, D. J., and S. H. Strogatz, 1998, "Collective dynamics of 'small-world' networks," *Nature* **393**:440–2, 4 June, http://www.tam.cornell.edu/tam/cms/manage/upload/SS_nature_smallworld.pdf

[23] Newman, M. E. J., and J. Park, 2003, "Why social networks are different from other types of networks," *Physical Review Online Archive, American Physical Society* **68**:036122, 22 September, http://prola.aps.org/pdf/PRE/v68/i3/e036122; and Palla, G., I. Derenyi, I. Farkas, and T. Vicsek, 2005, "Uncovering the overlapping community structure of complex net works in nature and society," *Nature* **435**(7043):814–8, 9 June, http://www.cfinder.org/papers/communitylettm.pdf

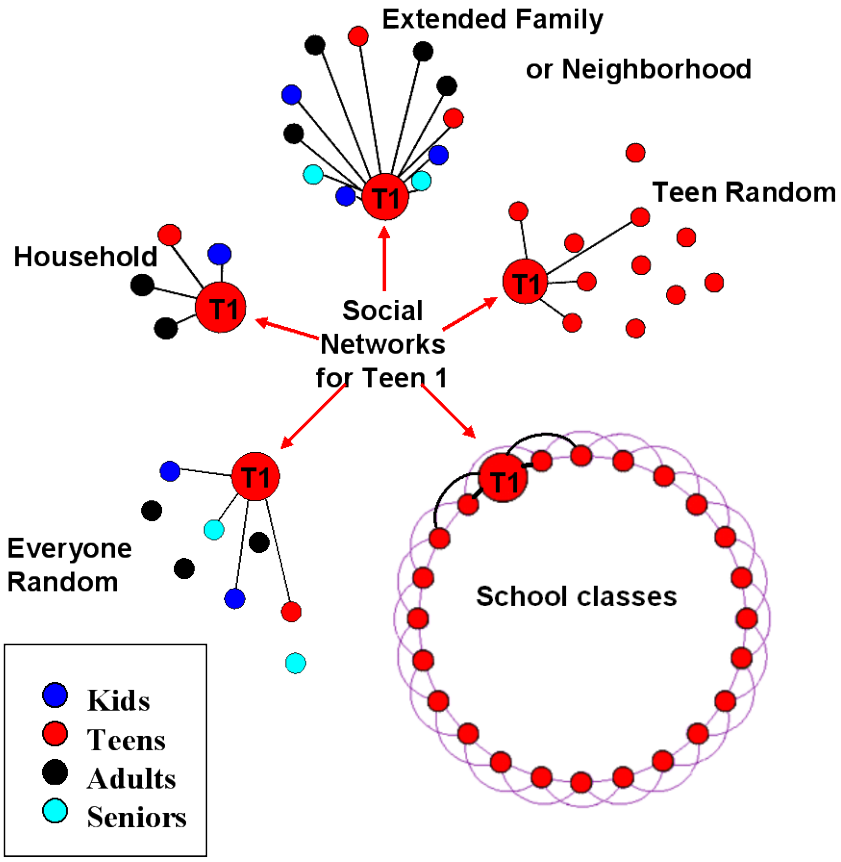


Figure 3-1: Example contact network[24]

The teenager (T1) belongs to a household (fully connected network, mean link contact frequency of 6 per day), an extended family or neighborhood (fully connected network, mean link contact frequency of 1 per day), and 6 school classes (ring network with connections to 2 other teenagers on each side, shown as black links; purple links denote connections of other teenagers within the class; mean link contact frequency of 1 per day). Two random networks are also imposed: 1 within the age group (teenager random, average of 3 links per teenager, mean link contact frequency of 1 per day) and 1 across all age groups (overall random, average of 25 links per person [not all links shown], mean link contact frequency of 0.04 per day).

For the current analysis, the team constructed the contact network to represent a stylized small town in the U.S. The population of 10,000 conforms to the 2000 Census and consists of children (0–11 years of age, 17.7 percent), teenagers (12–18 years of age, 11.3 percent), adults (19–64 years of age, 58.5 percent) and seniors (65+ years of age, 12.5 percent).[25] All individuals belong to multiple groups, each associated with a sub-network of links reflecting their lives within the community. Figure 3-1 shows a typical teenager's groups and contact network. Table 1 of Glass et al, 2006,[26] reports complete group specifications (Appendix A). Families (adults with children/teenagers) or adults and/or seniors without children/teenagers comprise households. The age class makeup and size of households conform to the statistics of the 2000 Census. All individuals within each household are linked to each other (fully connected sub-network topology) with mean link contact

[24] Glass et al., 2006 (See Footnote 3)
[25] Census, 2000, "United States Census 2000," U.S. Census Bureau
[26] Glass et al., 2006 (See Footnote 3)

frequencies of 6 contacts per day. Every individual also belongs to 1 multi-age extended family (or neighborhood) group that has a mean membership of 12.5 and is fully connected with mean link contact frequencies of 1 contact per day.

All children and teenagers go to a preschool or school; children attend a single class per day while teenagers attend 6 (all classes of size 20–35). All adults go to work daily where they interact with other adults (10–50 a day), and all seniors attend senior gatherings (5–20 a day). For contacts within school classes, work, and senior gatherings, the team assumed the simplest sub-network topology that imposes local clustering: a ring lattice in which an individual is linked to 2 (for children/teenager classes and senior gatherings) or 3 (adult work) neighboring individuals on each side along the ring (see Figure 3-1). Mean link contact frequencies for children in a single class are 6 contacts per day while teen classes, adult work, and senior gatherings have mean link contact frequencies of 1 contact per day.

To represent additional within-age-class interactions, such as extracurricular activities, playgrounds, bowling leagues, or friends, individuals are linked at random to an average of 3 other individuals of the same age class (mean link contact frequency of 1 contact per day). Finally, to emulate a somewhat patterned set of random contacts that come from commercial transactions and other ventures into public spaces, the team imposed a random overall network across all age classes with a mean of 25 links per person to yield 1 contact per person per day (mean link contact frequency of 0.04 per day).

3.1.2 Behavioral Rules

The spread of influenza within the contact network is modeled as a series of events. There are 2 classes of events: the transition of a person between disease states and person-to-person influenza transmissions. State transitions follow the natural history of influenza (see Figure 3-2).

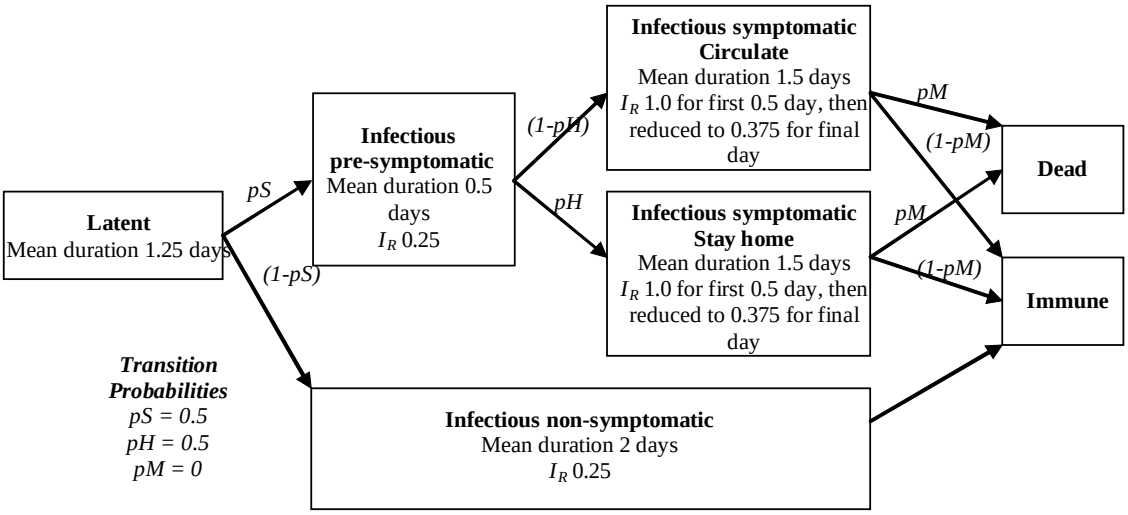


Figure 3-2: State transitions of natural history of influenza in the model[27]

The duration of each state for a given person is chosen from an exponential distribution. The team chose state relative infectivity (I_R) and mean state duration to reflect the infectivity variation of normal influenza (see Figure 3-3). The variations shown in the figure are for the Ferguson-like disease manifestation.

After the latent state, an infected person transitions to a pre-symptomatic infectious state or an infectious asymptomatic state with probability *pS* (probability of symptomatic) or 1–*pS*, respectively. Those in whom symptoms develop either stay home with probability *pH* (probability of staying at home if symptomatic), thus influencing their contacts, or continue to circulate with probability 1–*pH*. Infected persons who are asymptomatic continue interacting without behavioral changes. Persons who are symptomatic transition to dead or immune with probability *pM* (probability of death if symptoms occur) or 1–*pM*, respectively, and asymptomatic persons simply transition to immune. Finally, the model appends a recovery period for every individual who becomes symptomatic but does not die.

The model evaluates person-to-person transmission events at the beginning of each period during which a person is infectious. Assuming contact events are statistically independent, a transmission time for each of an infectious person's links within the contact network is chosen from an exponential distribution, with a mean given by the reciprocal of the link's contact frequency scaled by

$$I_D I_R I_A S_P S_A, \qquad \text{Equation 1}$$

Where

I_D = the infectivity of the disease

I_R = the relative infectivity of the disease state

S_P = the susceptibility of people to the disease (here taken as 1.0)

I_A = the relative infectivity of the person who is transmitting

S_A = is the relative susceptibility of the person receiving

[27] Glass et al., 2006 (See Footnote 3)

If the transmission time is less than the time that the person will be in a particular infectious state (also chosen from an exponential distribution with prescribed means), transmission is scheduled at the chosen time. Otherwise, transmission along that link does not occur during that particular period.

All transmission parameters and contact frequencies may be modified in each of the various states, as well as varied among age classes, by using relative scaling factors such as *IR*. In this way, specific disease manifestations and community containment strategies are implemented.

3.2 Specific Manifestations of Influenza

The study team considered 2 manifestations of influenza: 1 of which conformed closely to Ferguson et al. (2006; 2005) and the other to Longini and colleagues.[28]

Ferguson uses a functional form for infectivity that matches latent period data[29] and viral shedding data.[30] While Ferguson uses this for individuals, this model matches this functional form at the population scale (averaged across the population). Loki-Infect represents this with the following state periods and relative infectivities:

- Latent offset (constant 0.75 day)
- Latent (mean of 0.5 day)
- Infectious pre-symptomatic (mean of 0.5 day, relative infectivity 0.25)
- Infectious symptomatic1 (mean of 0.5 day, relative infectivity 1.0)
- Infectious symptomatic2 (mean of 1.0 day, relative infectivity 0.35)

Half of infected become symptomatic ($pS = 0.5$), infectious nonsymptomatic have half the infectivity of symptomatic. Loki-Infect represents nonsymptomatic infectivity with a constant relative infectivity of 0.25 for mean of 2 days, starting after the latent period.

Loki-Infect represents Longini's disease manifestation[31] with the following states and relative infectivities:

- Latent offset 0.75 day
- Latent (mean of 0.45 day)
- Pre-symptomatic (mean of 0.7 day, relative infectivity 1.0)
- Symptomatic1 (mean of 3.4 days, relative infectivity 1.0)

Two-thirds of infected develop symptoms (pS = 0.67), infectious non-symptomatics have half the infectivity of symptomatics (mean duration 4.1 days, relative infectivity 0.5).

---

[28] Germann et al., 2006 (See Footnote 9); Longini et al., 2005 (See Footnote 9)

[29] Moser, M. R., T. R. Bender, H. S. Margolis, G. R. Noble, A. P. Kendal, and D. G. Ritter, 1979, "An outbreak of influenza aboard a commercial airliner," *American Journal of Epidemiology*, **110**(1): 1–6, July

[30] Hayden, F. G., R. Fritz, M. C. Lobo, W. Alvord, W. Strober, and S. E. Straus, 1998, "Local and systemic cytokine responses during experimental human influenza A virus infection: Relation to symptom formation and host defense," *The Journal of Clinical Investigation* **101**(3):643–9, 1 February, http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=508608 (hereinafter referred to as Hayden et al., 1998)

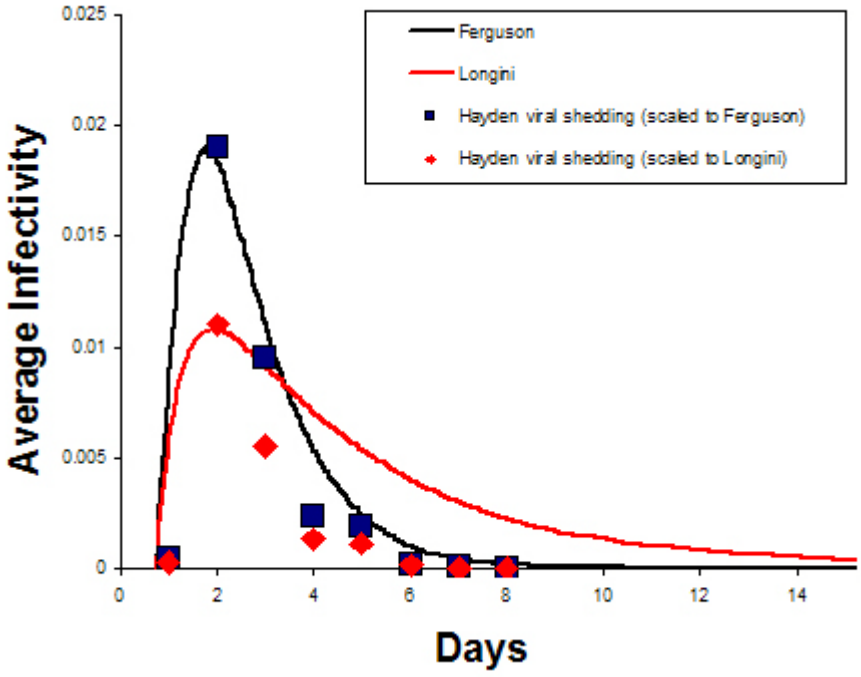
[31] Germann et al., 2006 (See Footnote 9); Longini et al., 2005 (See Footnote 9)

Common to both manifestations and in conformance with the WHHSC PIP group simulation outline (see Appendix B), the study team used

- Diagnosis: infectious symptomatic at 0.8 and all diagnosed go home where they remain while sick (pH = 0.8; this is age class independent); all nonhousehold contacts reduced by a compliance factor (60 percent, 90 percent); household contacts remain the same; those that are not diagnosed continue to circulate with no distinction by age class
- Babysitting: 1 household adult stays home with a diagnosed child (11 or younger) while they are sick at home or with the child when schools are closed. In this state, all non-household contacts for the babysitter are reduced by a compliance factor (60 percent, 90 percent), household contacts for the babysitter are doubled when tending well children (just as for the rest of the household members when schools are closed), but not doubled for tending sick children.
- Mortality: pM = 0.02, no distinction by age class
- Recovery: a final recovery period with mean of 7 days

Figure 3-3 shows the infectivity averaged over the population of those who are infected within a typical simulation for both disease manifestations at an infection attack rate of approximately 50 percent. In addition, Hayden, et al.'s viral shedding data[32] are plotted for comparison. These data are scaled to fit the maximum value of each disease manifestation, and comparison shows reasonable functional correspondence with average population-scale results for Ferguson-like, but not Longini-like, disease manifestations. Thus, the Longini-like manifestation represents a virus with a lower but longer acting infectivity.

[32] Hayden et al., 1998 (See Footnote 30)



Note: Viral shedding data from Hayden et al. (1998),[33] scaled to the peak for each disease manifestation, is shown for comparison.

Figure 3-3: Average infectivity in time; average population scale I_R in time for Ferguson-like and Longini-like disease manifestations

3.3 Network of Infectious Contacts

For a given disease manifestation (Ferguson-like or Longini-like) and disease infectivity (I_D), the network of infectious contacts is dependent on both the contact network and the choice of age class-specific infectivity and susceptibility (I_A and S_A). As a baseline, the team considered I_A and S_A to have equal values within each age class with children, 1.5; teenagers, 1.25; and adults and seniors, 1.0. This assumes that children and teenagers individually are more infective and susceptible, as they have closer contact with others (hugging, wrestling, holding hands, and so forth) and are less likely to wash hands or control coughing.[34] As shown in "Targeted Social Distancing Design for Pandemic Influenza,"[35] this baseline emphasizes transmission among the young and yields age class-specific attack rates within the community reflective of past epidemics (see Figure 6 in Appendix A).

The strain of influenza that emerges in the next pandemic may not hit children and teenagers harder than adults and seniors. Additionally, the social contact network may have more emphasis on adults within the working environment than currently considered. Both possibilities reduce the transmission within children and teenagers relative to transmission within the adult population and change the resulting network of infectious contacts. To address this potential, the team developed an extension

[33] Hayden et al., 1998 (See Footnote 30)
[34] Cauchemez, S., F. Carrat, C. Viboud, A. J. Valleron, and P. Y. Boelle, 2004, "A Bayesian MCMC approach to study transmission of influenza: application to household longitudinal data," *Statistics in Medicine* **23(22)**:3469–87, 30 November
[35] Glass et al., 2006 (See Footnote 3)

to the model's base simulation matrix in which the enhanced relative infectivity and susceptibility for children and teenagers were removed entirely and the number of contacts for adults within the workplace was increased by a factor of 4 to put the adults on par with children and teenagers in schools. While the team believes these 2 characteristics to be unlikely, especially in combinations, they represent an extreme that likely bounds the uncertainty in the resulting network of infectious contacts.

3.4 Choosing Disease Infectivity (I_D)

Following the selection of values for contact network parameters, disease manifestation, and relative infectivity for various age classes, the overall infectivity of the disease (I_D) is the final parameter used to tune the simulations to yield attack rates with different basic reproductive numbers (R_o) for an epidemic. For the systematic variation of disease infectivity, the team first found a reference I_D that yields approximately a 50-percent infection attack rate (25-percent illness attack rate for Ferguson-like, 33-percent illness attack rate for Longini-like disease manifestations) reflective of the 1958 pandemic (where the best data for age class attack rates exits). I_D was then scaled by factors of 0.75, 1.0, 1.25, 1.5, 2.0, 2.5, and 3.0 to yield both lower and higher attack rates. This scaling factor is referred to as the *IDfactor* in the remainder of this report. An *IDfactor* of 1.5 is reflective of the 1918 pandemic. The *IDfactor* for the reference 50-percent infection attack rate is chosen independently for each set of contact network parameters, disease manifestation, and compliance level (compliance influences sick at home and babysitting behavior and, thus, the attack rate) so that comparisons of strategy efficacy may be made evenly across the full set of combinations.

3.5 Instigation and Boundary Conditions

For the base matrix of community containment strategy combinations, each simulation is instigated with 10 adults chosen at random (the business traveler assumption). Alone, this models a closed community with no further interaction outside. It also models a fully open community in interaction with like communities implementing identical mitigation strategies and similarly seeded.

As a possible worst case and along the lines of recent work by Davey and Glass (2007),[36] the model also considers the community as surrounded by a regional population within which no mitigation strategies are implemented. The modelers conceive of this contact with this regional population as exclusively through the work environment, where the model assumes that contacts along all work links are replaced with random contacts with a fully mixed reservoir of external adults. The fraction of those adults that is contagious as a function of time is modeled by the unmitigated epidemic for the given *IDfactor* and compliance. Thus, the regional population is assumed to be uninfluenced by the course of the disease within the local community. Preserving the number of contacts within the work environment, the fraction that contacts a contagious external adult (given by their fully mixed contagious fraction) is infectious with probability

$$I_D<I_R>I_A S_A F, \qquad \text{Equation 2}$$

[36] Davey, V. J., and R. J. Glass, 2007, "Rescinding community mitigation strategies in an influenza pandemic: a modeling study," in review (hereinafter referred to as Davey and Glass, 2007)

Where

$<I_R>$ = the weighted average over symptomatic (reduced by diagnosis) and asymptomatic individuals for the mean contagious period, and

F = the current work frequency scaling for the particular adult agent chosen at random from the community's population.

F reflects the current situation of the adult, such as sick at home or babysitting, and the particular strategy implemented, quarantine or social distancing, all modified by compliance. The relative susceptibility for the person (S_A) is adjusted if the adult is receiving antiviral prophylaxis. The restriction of external contact to within the normal work environment seems reasonable during a period of pandemic. This approach also simulates an embedded geographically contiguous local sub-community within a larger city where contacts outside the household are assumed to be all within the local community except at work, where all work contacts are assumed to be external to the local community.

3.6 Community Containment Strategies

The team distilled 8 independent containment strategies (S, CTsd, ASsd, Q, T, P, and PEx) from the WHHSC PIP writing group simulation outline (see Appendix B), as defined in Table 3-1.

Table 3-1: Containment strategies

Strategy	Definition
S	Schools closed, all school contacts reduced by 90%, household contacts doubled
CTsd	Children and teenagers social distancing, all nonschool and nonhousehold contacts with or between children and teenagers reduced by 60% and 90%, household contacts doubled
ASsd	Adults and senior social distancing, all nonhousehold, nonwork contacts within and between adults and seniors reduced by 60% and 90%, work contacts reduced by 50%, household contacts doubled
Q	Household quarantine for 10 days once an individual is diagnosed, all nonhousehold contacts reduced by 60% and 90%, household contacts doubled
T	Antiviral treatment, individual given antiviral course with probability (60% and 90%) for 5 days immediately after diagnosed, reduces infectivity by 60% from that point forward[37]
P	Antiviral prophylaxis, household members given antiviral with probability (60% and 90%) for 10 days starting immediately after reference case diagnosed, reduces susceptibility by 30%, reduces probability of symptomatic by 65%, reduces infectivity by 60%[38]
PEx	Extended antiviral prophylaxis; household members, workplace contacts, school contacts, work contacts, and neighborhood/extended family contacts given antiviral with probability (60% and 90%) for 10 days starting immediately after reference case diagnosed; reduces susceptibility by 30%; reduces probability of symptomatic by 65%; reduces infectivity by 60%. (Note that school and workplace contact rates used here are much less than the entire school or work groups. Ferguson's implementation: children groups, 90%; teenager groups, 90%; and adult groups, 90%. Longini implementation: children groups, 100%; teenager groups, 60/80%; and adult groups, 60/80%)

Each strategy can have varying compliances and thresholds for implementation, yielding an infinite set of combinations. In conformance with the WHHSC outline, the team applied 2 levels of implementation (compliance) as good (60 percent) and very good (90 percent) and 1 threshold for strategy implementation (following the diagnosis of 10 symptomatic individuals within the community). The team analyzed relaxations of the implementation threshold (following either 30 or 100 diagnosed individuals) as an extension to the base simulation matrix.

For a given compliance level, each strategy is implemented separately or in combination to yield a full matrix of combinations for evaluation. Antiviral strategies T, P, and PEx are nested, with P necessarily incorporating T and PEx necessarily incorporating both T and P. Thus, a matrix of 64 combinations of containment strategies is constructed and used as a base simulation matrix as other parameters (disease manifestation, implementation threshold, boundary condition, compliance, and infectivity) are varied.

[37] Ferguson et al., 2005 (See Footnote 8); Ferguson et al., 2006 (See Footnote 8)
[38] Ibid.

A recent condition study by Davey and Glass[39] revealed that ceasing mitigation strategies following 7 days with no newly diagnosed individuals (corresponding to 2 to 3 generation periods depending on the disease manifestation; see Appendix C) was sufficiently effective to contain an epidemic. Subsequently, if the number of newly diagnosed individuals was to rise above the implementation threshold (10, 30, or 100), containment strategies would be reapplied and a second containment cycle would begin. If required, additional cycles based on these beginning and ending conditions could be implemented until no infected individuals remain within the community. The team used these specifications for the rescinding of all mitigation strategies in this study.

As extensions to the base containment strategy combination matrix, the team also analyzed 3 pre-pandemic vaccination strategies based on 7-percent coverage of a 50-percent effective vaccine administered randomly, targeted to children and teens, or targeted to adults. For each of these target groups, the vaccine was administered before the initial seeding of infected adults. The team then conducted the full simulation matrix (64 containment strategy combinations, 7 *IDfactors*, 2 compliances, and 2 boundary conditions).

[39] Davey and Glass, 2007 (See Footnote 35)

4. Results

Each simulation yields overall and daily output for a variety of measures in addition to documenting the complete sequence of infectious contacts that takes place. All output is automatically written into databases that can be queried by input or output to yield statistics of interest. The team has focused on 15 measures across all analyses:

- Number of simulations that yield epidemics (defined as greater than 1 percent of population infected)
- Infection attack rate
- Illness attack rate
- Deaths
- Peak infected
- Time to peak infected
- Peak symptomatic
- Time to peak symptomatic
- Epidemic duration (from first 10 diagnosed to last diagnosed)
- Total time of effects (from initial seeding to last person recovered)
- Number of days strategies imposed
- Number of containment cycles
- Number of external infections
- Number of antiviral courses given
- Number of days adults are at home (either sick, quarantined, or tending sick or children sent home from school)

For these measures, the team calculated means and standard deviations across each set of 100 runs for a given containment strategy combination, infectivity, compliance, and boundary condition. The team grouped these analyses by disease manifestation, vaccination strategy, implementation threshold, and infectious contact network. Only those simulations that created epidemics (defined as greater than 1 percent of the population infected) were used in calculating statistics.

The appendices contain the full results, compiled in Excel work sheets. Appendix C contains analyses of unmitigated simulations for both Ferguson-like and Longini-like disease manifestations. Appendix D contains the base containment combination matrix results for the Ferguson-like disease manifestation. Appendix E contains additional Excel worksheets where the matrix extensions for the Longini-like disease manifestation, relaxed implementation thresholds, vaccination strategies, and infectious contact network variations are compiled.

4.1 Base Containment Strategy Combination Matrix for Ferguson-like Disease Manifestation

For each of the 15 summary measures, the team created a set of 4 tables and accompanying 3-dimensional (3D) bar graphs (in the Excel worksheets of Appendix D). Each of the 4 tables and sets of graphs present results for 90-percent compliance, 60-percent compliance, 90-percent compliance where adults are in contact with an external unmitigated epidemic, and 60-percent compliance where adults are in contact with an external unmitigated epidemic.

Strategies are organized in each table and graph, with network focused strategy combinations of S, CTsd, and ASsd in columns (x-axis), and case-based strategy combinations of Q, T, P, and PEx in rows (y- axis), yielding the 64 possible strategy combinations at each of 7 *IDfactors*. To aid in viewing this data, those combinations that yield an infection attack rate that is 10 percent or less are shaded green, and those between 10 percent and 25 percent are shaded pink (see example in Figure 4-1).

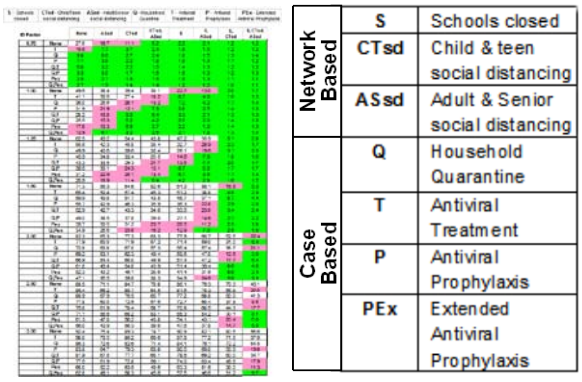


Figure 4-1: Example Table and Strategy Legend

Time series plots for daily measures averaged over the set of 100 simulations may be made for any of the combinations. An example set for an *IDfactor* of 1.5 and Ferguson-like disease manifestation that considers the measures of people infected, treated with antivirals, adults at home, and symptomatic are attached as PDF files in Appendix D.

4.1.1 90-Percent Compliance

Table 4-1 shows the infection attack rate resulting from 90-percent compliance where the community is embedded within a region implementing identical containment strategies. At the lowest *IDfactor* (0.75), the efficacy of network-focused strategies applied alone increases from ASsd, CTsd, CTsd+ASsd, S, S+ASsd, A+CTsd, to S+CTsd+ASsd. As the *IDfactor* increases, case-based measures that include ASsd increase in efficacy relative to those with CTsd. This is because the branching factor for adults is pushed above 1 (see Appendix C), there are more adults in the community, and ASsd includes the work environment while CTsd does not include schools. Applied alone, the efficacy of case-based strategies increases from T through Q, P, Q+T, Q+P, and PEx, to Q+PEx. This order does not change as the *IDfactor* increases.

Network-based strategies can more effectively drop the infection attack rate than case-based strategies. For influenza virulence above an *IDfactor* of 1, case-based strategies alone cannot drop the infection attack rate below 10 percent, while network-based strategies can accomplish this up to an *IDfactor* of 1.5 where all conditions (S+CTsd+ASsd) are required.

Table 4-1: Base containment strategy combination matrix infection attack rates, regionally mitigated, 90-percent compliance

S - Schools closed	**CTsd** - Child/Teen social distancing	**ASsd** - Adult/Senior social distancing	**Q** - Household Quantine	**T** - Antiviral Treatment	**P** - Antiviral Prophylaxis	**PEx** - Extended Antiviral Prophylaxis

ID Factor		None	ASsd	CTsd	CTsd, ASsd	S	S, ASsd	S, CTsd	S, CTsd, ASsd
0.75	None	27.8	18.7	11.1	6.2	2.2	2.1	1.2	1.2
	T	15.6	7.7	3.7	2.4	1.6	1.5	1.2	1.2
	Q	9.8	5.6	2.7	2.4	1.8	1.5	1.3	1.4
	P	7.1	3.8	2.2	1.8	1.6	1.4	1.1	1.2
	Q,T	6.0	3.2	2.2	1.6	1.4	1.3	1.2	1.2
	Q,P	3.3	3.0	1.7	1.6	1.5	1.3	1.2	1.3
	Pex	2.5	2.1	1.5	1.5	1.5	1.3	1.1	1.1
	Q,Pex	2.7	1.9	1.4	1.4	1.2	1.2	1.0	1.1
1.00	None	49.6	38.4	39.4	30.1	22.7	13.0	2.0	1.7
	T	41.1	30.6	27.4	18.2	6.7	4.0	1.6	1.3
	Q	36.0	26.6	20.1	13.2	7.2	4.2	1.7	1.4
	P	31.9	21.9	12.1	7.3	2.8	2.5	1.4	1.3
	Q,T	28.2	18.8	9.2	6.4	3.3	2.1	1.3	1.3
	Q,P	25.5	15.3	6.2	4.2	2.5	2.0	1.4	1.3
	Pex	17.8	10.3	6.0	3.7	2.2	1.9	1.4	1.3
	Q,Pex	12.9	6.1	3.2	2.6	2.1	1.8	1.3	1.4
1.25	None	62.5	49.2	54.4	43.8	47.2	35.9	5.1	2.8
	T	55.5	42.3	45.8	35.4	32.7	20.9	2.3	1.7
	Q	49.9	40.6	39.6	32.4	28.1	19.6	3.1	2.3
	P	45.9	34.8	33.4	25.5	14.6	7.9	1.8	1.6
	Q,T	43.3	33.5	29.3	21.7	13.5	7.7	2.0	1.7
	Q,P	39.5	30.1	24.3	15.1	6.7	5.0	1.7	1.7
	Pex	31.2	22.9	20.1	13.4	6.7	3.5	1.7	1.4
	Q,Pex	26.9	18.9	11.4	6.4	4.2	2.8	1.6	1.5
1.50	None	71.3	56.3	64.6	52.6	61.0	50.1	16.6	5.3
	T	65.4	50.4	57.4	45.3	51.2	38.8	4.8	2.4
	Q	59.9	49.8	51.7	43.5	45.7	37.1	8.7	4.4
	P	55.7	42.9	46.3	35.9	36.3	22.8	2.9	2.0
	Q,T	52.9	42.7	43.3	34.6	33.6	23.0	3.4	2.4
	Q,P	49.0	38.5	37.8	29.0	27.1	14.6	2.7	2.2
	Pex	39.7	30.5	31.2	23.7	20.5	11.2	2.5	1.8
	Q,Pex	34.9	26.6	23.8	16.2	12.9	7.0	2.5	1.9
2.00	None	82.3	65.3	77.3	63.3	77.9	66.7	52.6	22.4
	T	77.9	60.0	71.9	57.2	71.4	59.0	31.0	6.4
	Q	72.8	60.8	67.0	57.3	66.4	57.4	38.7	21.1
	P	69.2	53.1	62.3	49.4	59.6	47.0	12.5	3.9
	Q,T	66.9	54.4	60.0	49.9	57.4	47.2	17.7	6.4
	Q,P	61.8	49.4	54.8	43.9	51.4	39.4	8.6	4.0
	Pex	52.3	40.2	46.1	35.6	41.4	31.6	6.6	3.4
	Q,Pex	47.1	36.5	39.8	30.3	34.9	24.6	5.6	3.3
2.50	None	88.5	71.1	84.7	70.0	86.1	76.3	70.3	43.1
	T	85.4	66.2	80.7	64.5	81.6	70.3	56.8	20.0
	Q	80.9	67.9	76.5	65.7	77.2	68.8	60.0	41.3
	P	77.8	60.0	72.5	57.6	72.7	60.4	37.9	8.6
	Q,T	75.8	61.9	70.4	58.7	70.8	60.5	44.3	17.7
	Q,P	71.1	56.6	65.2	53.1	65.3	54.2	30.1	8.1
	Pex	61.3	47.0	56.2	43.8	54.1	43.1	20.4	6.0
	Q,Pex	56.0	43.9	50.3	39.0	47.6	37.8	14.7	5.8
3.00	None	92.4	75.4	89.3	74.7	90.9	82.1	80.6	56.6
	T	90.0	70.5	86.2	69.6	87.8	77.2	71.6	37.6
	Q	86.3	72.6	82.6	71.4	84.1	76.1	72.2	54.5
	P	83.8	64.7	79.3	63.0	80.5	69.0	56.9	19.0
	Q,T	81.9	67.0	77.7	65.1	78.6	69.2	60.0	34.7
	Q,P	77.5	61.9	72.8	59.1	74.0	63.4	49.8	17.9
	Pex	68.0	52.2	63.5	49.6	63.3	51.6	38.0	11.3
	Q,Pex	62.8	49.1	58.3	45.6	57.6	46.6	31.2	9.7

Note: For Ferguson-like disease manifestation and implementation threshold 10 diagnosed. Case-based strategy combinations downward, network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent.

Combining network-based and case-based strategies across the 64 combinations yields banded green zones (where infection attack rates are 10 percent or less) and pink zones (where infection attack rates are 10 to 25 percent) within each *IDfactor* region in the tables. The less-than-10-percent green zone is concentrated in each lower right corner where all strategies are imposed. As can be seen in the tables and the 3D bar graphs, there is a sharp falloff in attack rate within the pink 10- to 25-percent region. All time scales (epidemic duration, total time, times to peak) increase above the unmitigated epidemic within the pink region; however, once within the green region, they quickly fall below and continue to decrease as one moves to the lower right corner of each *IDfactor* region.

Strategy combinations that are as far as possible into the less-than-10-percent attack rate (green) zone are most effective. Not only are fewer local epidemics triggered with fewer people infected, symptomatic, or dead, epidemics last much less time with greatly suppressed peaks and, ultimately, a much reduced total cost. This is borne out in the number of days that adults are at home; implementing S+CTsd+ASsd always decreases this number over S+CTsd alone. Of course, implementing S is the major component of this measure because closing the schools requires approximately 1,300 adults to be sequestered at home to mind children. This is a worst-case assessment because the model assumes that all adults go to work, and it is likely that many of the child-minding adults could maintain reasonable work productivity (telecommuting, time shifting, job sharing). Additionally, teenagers present within the household could provide the oversight of children and thus release the adult babysitter to go to work.

The measure of days adults are at home needs more discussion. The model assumes that all adults participate in a work group. This is not a large problem as the model could easily interpret some of these work groups as nonwork activity groups composed of nonworking adults. To adjust for these unemployed in the calculation of workforce reduction, the number of adult days at home should be reduced by the fraction of unemployed. Every day is a work day. To adjust for weekends, 2 days out of 7 should also be removed from the measure to apply to the number of days adults are absent from work. ASsd includes a reduction in contact frequency at work of 50 percent. This is assumed to be accomplished within the workplace without adults staying at home. If this is not true, the number of days adults would be absent from work should be increased by the fraction of the time not present (50 percent) times the average duration of the ASsd strategy.

The application of a strategy-ending threshold of 7 days with no new diagnosed people works well. The generation period for the Ferguson-like manifestation is 2.6 days (see Appendix C), so this period is just short of 3 generation periods. On average and across all the *IDfactors*, additional cycles are needed only 10 percent of the time and it is rare that more than 1 additional cycle must be imposed.

For strategies resulting in attack rates of 10 percent or less (the green zone), required antiviral courses are below 40-percent coverage. Excluding PEx, a maximum of only 8-percent coverage is required within this zone, and for most of the combinations, it is far less. Applying PEx alone is only effective (green) at an *IDfactor* of 0.75. At higher *IDfactors*, applying PEx can lead to coverage of almost 150 percent, where each individual receives an antiviral course an average of 1.5 times over the course of the epidemic. These greater-than-100-percent coverages are also very ineffective (outside the green or pink regions). If an antiviral had simply been given to everyone in the community early enough, 100-percent coverage would likely have been more effective than the tracing approach of PEx implemented in the model. The combination of reduced infectivity and reduced susceptibility assumed for antiviral prophylaxis together yields a factor of a 0.28 reduction

in infectious contacts and, with full compliance, could theoretically stop an epidemic with an *IDfactor* of 3.0.

4.1.2 60-Percent Compliance

Reducing compliance to 60 percent reduces the efficacy of case-based and network-based strategies (Table 4-2). Infection attack rates increased, thus pushing green zones (less than 10 percent) and pink zones (10 to 25 percent) further to the lower right of each *IDfactor* region where more strategies must be implemented. Regions with attack rates less than 10 percent (green) were entirely lost for *IDfactors* above 1.5; regions with attack rates between 10 percent and 25 percent (pink) were lost for *IDfactors* above 2.0.

Relative rankings within networked strategies have been maintained; however, for case-based strategies, Q has fallen below T and Q+T has fallen below P. Additionally, antiviral strategies increase their relative efficacy to be nearer to network-based strategies. Some of this increase in relative efficacy of antivirals is because when Q or any of the network-based strategies are implemented, the contact frequency within the household is doubled and this doubling is maintained for both 90-percent and 60-percent compliances.

Reducing compliance also increases epidemic time scales, but within most of the green zone (less than 10-percent attack rate), the time scales remain at or below the unmitigated epidemic. Days adults are home also increase (because time scales increase) and remain within a factor of 3 of the 90-percent compliance values within most of the green zone. While the number of containment cycles is not significantly influenced, the number of antiviral courses increases up to nearly a factor of 4 within the green zone. At lower compliance, PEx becomes more effective at reducing adult days at home.

Table 4-2: Base containment strategy combination matrix infection attack rates, regionally mitigated, 60-percent compliance

S - Schools closed	**CTsd** - Child/Teen social distancing	**ASsd** - Adult/Senior social distancing	**Q** - Household Quantine	**T** - Antiviral Treatment	**P** - Antiviral Prophylaxis	**PEx** - Extended Antiviral Prophylaxis

ID Factor		None	ASsd	CTsd	CTsd, ASsd	S	S, ASsd	S, CTsd	S, CTsd, ASsd
0.75	None	28.0	27.3	26.6	24.5	2.8	2.4	1.6	1.4
	T	14.1	14.7	13.2	9.7	1.8	1.5	1.1	1.2
	Q	21.8	21.3	20.6	17.4	2.1	1.9	1.6	1.5
	P	8.6	7.2	6.9	4.7	1.5	1.3	1.1	1.2
	Q,T	7.9	7.9	6.4	5.9	1.7	1.5	1.2	1.2
	Q,P	6.2	4.7	4.0	3.5	1.4	1.3	1.1	1.1
	Pex	3.3	3.1	2.5	2.3	1.3	1.3	1.2	1.1
	Q,Pex	2.6	2.4	2.4	1.9	1.4	1.2	1.1	1.2
1.00	None	50.0	46.7	48.8	44.8	25.1	20.6	6.0	3.8
	T	41.1	38.1	39.5	35.4	9.5	5.9	2.3	1.8
	Q	44.2	43.2	44.0	41.6	16.3	13.7	5.3	3.9
	P	34.1	30.7	30.6	27.1	4.2	3.2	1.6	1.6
	Q,T	35.2	33.7	33.9	31.7	5.0	3.8	2.0	1.9
	Q,P	29.8	27.0	25.7	23.4	2.9	2.4	1.9	1.6
	Pex	20.1	17.4	16.9	13.9	2.5	2.2	1.5	1.5
	Q,Pex	16.3	13.9	13.2	9.8	1.9	1.9	1.5	1.5
1.25	None	62.9	58.4	61.6	57.3	49.8	44.4	31.2	23.4
	T	55.6	51.1	54.4	49.4	37.0	31.1	10.1	5.9
	Q	57.6	55.9	57.6	55.1	42.4	38.9	28.3	21.8
	P	47.9	44.1	46.4	42.0	23.2	17.4	3.9	3.0
	Q,T	49.4	47.6	49.3	46.1	28.4	23.3	8.3	5.6
	Q,P	43.7	41.5	42.1	39.3	17.4	10.9	3.7	3.1
	Pex	32.8	30.2	30.9	27.9	11.2	7.0	2.6	2.3
	Q,Pex	29.8	27.8	27.9	25.6	6.4	4.9	2.7	2.2
1.50	None	71.4	66.1	70.6	65.8	64.3	58.9	51.9	43.3
	T	65.4	59.9	64.2	58.9	54.7	48.5	34.4	23.7
	Q	66.9	64.5	66.6	64.1	57.9	54.3	48.0	42.9
	P	58.1	53.0	56.7	51.7	43.3	36.8	18.4	9.9
	Q,T	59.7	57.4	59.4	56.3	47.0	42.2	30.4	22.8
	Q,P	53.7	50.7	53.1	49.5	37.7	32.0	16.7	10.9
	Pex	41.6	38.2	40.3	36.4	26.9	21.9	7.5	4.7
	Q,Pex	38.3	35.9	37.7	34.3	21.3	16.6	6.4	4.6
2.00	None	82.6	76.6	81.5	76.5	80.0	75.4	73.0	66.0
	T	78.2	71.2	76.8	70.8	73.7	68.2	62.6	53.4
	Q	78.8	76.0	78.4	75.6	75.3	72.5	70.1	66.1
	P	71.5	64.9	70.2	64.2	65.2	58.9	51.2	40.6
	Q,T	73.2	69.8	72.7	69.5	67.8	63.8	59.2	53.1
	Q,P	67.5	63.6	66.8	62.8	60.6	55.4	48.7	40.0
	Pex	54.1	48.9	53.4	48.1	46.8	41.4	33.1	23.5
	Q,Pex	51.1	47.5	50.6	46.6	42.6	37.9	29.9	23.2
2.50	None	89.0	83.4	88.0	83.1	87.9	84.1	83.6	77.9
	T	85.6	78.5	84.3	78.3	83.5	78.8	76.9	69.0
	Q	85.8	82.9	85.4	82.7	84.2	81.9	81.2	77.9
	P	80.1	73.0	78.7	72.6	77.0	71.7	68.3	59.1
	Q,T	81.5	77.8	81.0	77.4	78.9	75.7	73.6	68.9
	Q,P	76.4	72.2	75.9	71.6	73.0	69.0	65.6	58.8
	Pex	62.9	56.9	62.2	56.3	58.9	53.1	48.1	39.7
	Q,Pex	60.1	55.8	59.4	55.0	55.1	50.6	46.5	39.3
3.00	None	92.8	87.8	91.8	87.6	92.2	89.2	89.4	85.0
	T	90.2	83.7	89.1	83.6	89.3	85.1	84.9	78.4
	Q	90.3	87.4	89.8	87.4	89.6	87.6	87.5	84.9
	P	85.7	78.7	84.7	78.6	84.2	79.3	78.2	70.4
	Q,T	86.9	83.1	86.3	83.0	85.4	82.7	82.1	78.1
	Q,P	82.6	78.1	82.0	77.9	80.6	77.0	75.5	70.0
	Pex	69.7	62.8	68.8	62.6	67.2	61.7	58.8	50.6
	Q,Pex	66.6	61.9	66.4	61.6	64.0	59.3	56.9	50.7

Note: For Ferguson-like disease manifestation and implementation threshold 10 diagnosed. Case-based strategy combinations downward; network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent.

4.1.3 External Contacts

When communities within the surrounding regions are implementing no or ineffective containment strategies, full contact of adults across communities within the work environment leads to degradation in the effectiveness of the local community strategy (Tables 4-3 and 4-4). In general, attack rates rise above 10 percent (green regions in the tables shrink). At 90-percent compliance, the efficacy of local containment strategies shrinks to near that of 60-percent compliance with a uniform regional policy.

At 60-percent compliance, continued interaction with contagious adults from outside reduces local strategy efficacy enough that attack rates of less than 10 percent (a green zone) cannot be found at an *IDfactor* of 1.5, and at an *IDfactor* of 1.25, green strategies require PEx with nearly 40-percent antiviral coverage. Within the green zones of Tables 4-3 and 4-4, time scales all approach the unmitigated epidemic, but days adults are at home increase by a factor of 2 or 3 from the regionally mitigated simulations (Tables 4-1 and 4-2).

Table 4-3: Base containment strategy combination matrix infection attack rates, regionally unmitigated, 90-percent compliance

S - Schools closed	**CTsd** - Child/Teen social distancing	**ASsd** - Adult/Senior social distancing	**Q** - Household Quantine	**T** - Antiviral Treatment	**P** - Antiviral Prophylaxis	**PEx** - Extended Antiviral Prophylaxis

ID Factor		None	ASsd	CTsd	CTsd, ASsd	S	S, ASsd	S, CTsd	S, CTsd, ASsd
0.75	None	27.9	20.0	15.3	9.4	6.6	3.8	3.1	2.2
	T	18.0	10.6	8.6	4.2	4.2	2.7	2.6	1.9
	Q	15.2	8.1	7.6	4.6	4.5	3.1	3.1	2.3
	P	11.0	5.8	5.2	3.1	3.3	2.4	2.4	1.9
	Q,T	9.6	4.2	5.2	3.2	3.5	2.4	2.6	1.8
	Q,P	7.9	4.2	4.5	2.8	3.1	2.3	2.4	1.9
	Pex	6.6	3.5	4.4	2.8	3.0	2.2	2.4	1.9
	Q,Pex	5.1	3.1	3.9	2.6	2.9	2.1	2.3	1.9
1.00	None	49.5	38.7	40.0	31.4	27.8	18.6	9.5	4.9
	T	41.9	31.8	31.1	22.4	18.5	10.4	7.4	3.8
	Q	37.8	29.3	27.4	19.7	18.3	10.4	9.0	4.8
	P	33.8	24.6	22.2	13.7	12.4	6.3	6.3	3.4
	Q,T	31.6	22.6	20.5	12.9	12.6	6.9	7.2	3.7
	Q,P	28.6	19.5	17.6	9.9	10.7	5.8	6.2	3.5
	Pex	22.7	14.7	15.0	9.0	9.5	5.6	5.9	3.3
	Q,Pex	18.9	11.9	12.5	6.7	8.6	5.0	5.8	3.4
1.25	None	62.4	49.6	54.9	44.8	48.7	37.3	19.9	9.8
	T	56.2	43.7	47.6	37.3	37.9	26.5	14.4	6.9
	Q	52.1	42.5	43.9	35.6	36.1	26.6	18.5	9.5
	P	47.7	36.7	38.1	29.0	27.9	17.4	11.9	5.9
	Q,T	45.8	35.8	36.8	27.5	27.5	17.3	13.4	6.8
	Q,P	41.8	32.1	32.2	22.8	23.3	14.4	11.6	5.9
	Pex	33.4	25.4	26.2	18.6	18.6	11.6	10.2	5.3
	Q,Pex	29.8	21.3	22.1	14.1	16.0	10.0	9.9	5.4
1.50	None	71.1	56.8	65.0	53.4	62.4	51.1	33.8	16.7
	T	66.0	51.6	58.9	47.2	54.0	41.6	24.6	11.4
	Q	61.9	51.4	55.6	46.2	50.8	41.1	30.7	17.4
	P	57.7	44.9	50.1	39.0	42.8	30.9	19.7	9.3
	Q,T	55.7	45.3	48.4	38.4	42.0	30.9	22.4	11.4
	Q,P	51.6	40.8	43.7	33.6	37.4	25.4	19.0	9.4
	Pex	42.8	32.7	35.8	27.3	28.8	19.8	15.4	8.1
	Q,Pex	38.5	29.4	31.2	22.4	25.0	16.4	15.1	8.1
2.00	None	82.2	65.6	77.4	64.0	78.1	67.1	57.3	34.6
	T	78.3	61.3	72.7	58.8	72.5	60.3	46.2	23.5
	Q	74.6	62.7	70.0	59.7	69.0	59.5	52.4	34.3
	P	70.9	55.7	65.0	52.3	62.8	50.3	36.4	17.9
	Q,T	69.0	56.8	64.1	52.9	61.9	51.0	41.6	23.1
	Q,P	64.5	52.0	59.0	47.8	56.4	44.9	34.9	18.3
	Pex	55.5	43.3	50.0	39.2	45.1	34.9	26.1	14.5
	Q,Pex	50.7	40.0	45.1	34.9	40.0	30.7	25.2	14.3
2.50	None	88.4	71.5	84.6	70.5	86.3	76.5	72.4	49.9
	T	85.6	67.4	81.2	66.0	82.4	71.2	63.1	36.9
	Q	82.3	69.6	78.8	67.7	79.2	70.5	67.4	49.6
	P	79.3	62.6	74.6	60.5	74.5	62.8	52.6	28.6
	Q,T	77.7	64.4	73.8	62.0	73.9	63.3	57.6	36.8
	Q,P	73.1	59.7	69.1	56.7	68.5	57.5	49.6	28.4
	Pex	64.4	50.5	59.6	47.7	57.0	46.2	36.9	21.1
	Q,Pex	59.6	47.5	54.7	43.6	51.5	41.5	35.5	20.9
3.00	None	92.2	75.5	89.3	75.0	91.0	82.1	81.4	60.2
	T	90.1	71.7	86.6	70.7	88.2	78.0	74.3	48.1
	Q	87.2	74.2	84.3	73.2	85.5	77.3	76.9	60.2
	P	84.9	67.2	81.2	66.0	82.0	70.9	64.3	38.5
	Q,T	83.3	69.5	80.2	67.8	80.9	71.5	68.8	48.4
	Q,P	79.2	65.2	76.0	62.8	76.2	66.2	61.2	38.6
	Pex	71.1	55.8	67.1	53.8	65.5	54.3	46.2	28.1
	Q,Pex	66.3	53.4	62.2	50.3	60.5	50.2	44.0	27.4

Note: For Ferguson-like disease manifestation and implementation threshold 10 diagnosed. Case-based strategy combinations downward, network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent.

Table 4-4: Base containment strategy combination matrix infection attack rates, regionally unmitigated, 60-percent compliance

S - Schools closed	**CTsd** - Child/Teen social distancing	**ASsd** - Adult/Senior social distancing	**Q** - Household Quantine	**T** - Antiviral Treatment	**P** - Antiviral Prophylaxis	**PEx** - Extended Antiviral Prophylaxis

ID Factor		None	ASsd	CTsd	CTsd, ASsd	S	S, ASsd	S, CTsd	S, CTsd, ASsd
0.75	None	27.8	26.5	26.6	23.8	6.4	4.5	4.3	3.0
	T	18.5	16.1	15.9	12.1	4.3	3.0	3.2	2.3
	Q	23.5	21.9	22.4	19.4	5.6	3.9	4.3	2.9
	P	12.9	9.2	10.2	7.1	3.6	2.7	3.1	2.2
	Q,T	13.8	10.6	12.2	9.3	3.9	2.7	3.2	2.3
	Q,P	10.1	7.1	8.7	5.3	3.6	2.5	2.8	2.2
	Pex	7.2	4.8	6.6	4.2	3.3	2.5	2.8	2.1
	Q,Pex	5.9	4.4	5.4	3.4	3.3	2.4	2.8	2.1
1.00	None	49.4	45.9	48.3	44.2	29.9	23.5	16.7	11.1
	T	41.8	38.5	40.3	35.7	19.8	13.6	11.4	7.1
	Q	44.9	42.6	44.3	41.3	23.9	18.5	16.4	11.2
	P	35.2	31.7	33.7	28.7	14.9	9.4	9.1	5.5
	Q,T	37.0	34.3	36.1	31.9	16.3	11.0	11.2	6.9
	Q,P	31.9	28.8	30.6	25.9	12.8	8.6	9.0	5.6
	Pex	23.7	20.5	22.0	17.4	10.9	7.2	8.0	5.0
	Q,Pex	21.3	17.9	20.0	15.6	10.4	6.7	7.7	5.1
1.25	None	62.1	57.5	61.2	56.4	50.3	44.1	36.5	27.2
	T	56.0	51.0	54.8	49.7	40.6	33.6	25.9	16.9
	Q	57.8	55.1	57.9	54.3	44.6	38.9	34.9	27.4
	P	49.5	44.8	47.9	43.1	32.0	24.5	20.2	12.4
	Q,T	51.2	47.9	50.7	46.3	34.9	28.3	24.5	16.9
	Q,P	45.8	42.3	45.3	40.6	28.3	21.3	19.3	12.2
	Pex	35.3	31.5	34.3	29.5	21.5	15.9	14.7	9.5
	Q,Pex	32.8	29.3	31.7	27.4	20.0	14.3	14.8	9.8
1.50	None	71.1	65.5	70.0	64.8	64.1	58.0	52.9	44.0
	T	65.9	60.0	64.6	58.7	56.1	48.9	42.1	31.4
	Q	67.1	63.8	67.0	63.3	58.9	54.0	51.0	43.8
	P	59.4	53.9	58.3	52.7	47.9	39.9	33.7	23.5
	Q,T	61.1	57.4	61.0	56.5	50.1	44.1	40.4	31.0
	Q,P	56.0	51.9	55.3	50.5	43.7	36.6	32.7	23.3
	Pex	44.2	39.4	43.4	38.1	32.8	26.1	23.3	16.5
	Q,Pex	42.0	37.7	41.0	36.3	29.7	24.2	22.9	16.2
2.00	None	82.2	75.8	81.1	75.5	79.7	74.4	72.7	64.8
	T	78.3	71.1	77.0	70.5	74.2	67.9	64.8	55.1
	Q	78.8	75.1	78.6	74.9	75.6	71.3	70.8	65.1
	P	72.8	65.8	71.7	65.1	66.9	60.6	56.3	45.3
	Q,T	74.2	69.8	73.9	69.4	69.1	63.7	62.7	54.8
	Q,P	69.3	64.4	68.9	63.7	63.1	57.0	55.0	45.3
	Pex	57.1	51.0	56.4	50.3	49.5	43.0	39.5	30.4
	Q,Pex	54.5	49.3	54.1	48.8	46.4	40.5	38.6	30.3
2.50	None	88.5	82.4	87.6	82.2	87.5	83.2	83.4	76.8
	T	85.8	78.2	84.5	78.0	83.8	78.3	77.7	69.2
	Q	86.0	82.0	85.5	81.9	84.4	81.1	81.5	76.7
	P	81.1	73.6	80.0	73.2	78.3	72.1	70.8	61.0
	Q,T	82.2	77.6	81.8	77.4	79.9	75.3	75.6	69.1
	Q,P	77.9	72.6	77.5	72.4	74.7	69.5	69.1	61.2
	Pex	66.1	59.0	65.2	58.4	60.8	54.4	52.0	43.1
	Q,Pex	63.3	57.8	63.0	57.3	58.1	51.9	51.0	42.7
3.00	None	92.4	86.8	91.6	86.8	91.9	88.4	89.1	83.8
	T	90.2	83.2	89.1	83.1	89.3	84.8	85.2	78.0
	Q	90.3	86.7	89.8	86.7	89.6	86.9	87.6	83.8
	P	86.6	79.1	85.4	78.9	84.9	79.6	79.5	71.1
	Q,T	87.4	82.9	86.8	82.7	86.1	82.5	83.1	77.7
	Q,P	83.8	78.6	83.2	78.4	81.9	77.3	77.9	71.0
	Pex	72.9	64.8	71.7	64.5	69.1	62.8	61.7	52.6
	Q,Pex	70.1	63.9	69.6	63.5	66.3	60.4	60.2	52.5

Note: For Ferguson-like disease manifestation and implementation threshold 10 diagnosed. Case- based strategy combinations downward, network focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent.

4.2 Base Matrix Extensions

The analysis team first extended simulations from the base containment strategy combination matrix to analyze the influence of disease manifestation by running the full matrix for the Longini-like version (see section 3.2 for a comparison of Ferguson-like and Longini-like disease manifestations). Then, returning to the Ferguson-like manifestation, the team extended the matrix to include relaxation of the implementation threshold to the day after 30 and 100 are diagnosed within the community, and 3 vaccination strategies with 7-percent coverage and 50-percent efficacy administered randomly, targeted to children and teens, or targeted to adults. Finally, the team conducted a first-level evaluation of the influence of the social network using the Ferguson-like manifestation, implementation threshold of 10 symptomatics diagnosed in the community, and no pre-pandemic vaccination. This social network evaluation implemented a network absent enhanced transmission by the young; that is, the enhanced relative infectivity and susceptibility for children and teenagers were removed, and the number of contacts for adults within the workplace was increased by a factor of 4 to put them on par with children and teenagers in schools (considered as bounding in Glass et al., 2006[40]). For each of the matrix extensions, the team created a set of Excel worksheets similar to those for the base containment strategy combination matrix and included them in Appendix E.

4.2.1 Longini-like Disease Manifestation

Once the disease infectivity (I_D) is tuned to yield an infection attack rate of approximately 50 percent for the unmitigated epidemic, total and age class-specific infection attack rates for the Ferguson-like and Longini-like disease manifestations are indistinguishable across the full range of *IDfactors* and for both compliances (well within 1 standard deviation [*SD*] of each other). Maximum branching factors by age class and overall (an estimate of R_o, see Appendix C) are indistinguishable up to an *IDfactor* of 3.0 (a highly infectious and unlikely case), at which point the maximum branching factor for the Longini manifestation falls below that of Ferguson by approximately 10 percent. Infectious contact fractions by age class and by transmission context also show no significant difference (nearly all within 1 *SD* of each other).

However, because the time scale of the Longini-like manifestation is longer, all measures influenced by time scale are stretched. For the unmitigated epidemic, generation time increases by approximately 40 percent (from 2.37 to 3.35 days), epidemic duration increases by 55 percent, total time increases by 20 percent, time to peak infected increases by 36 percent, and time to peak symptomatic increases by 31 percent. Peak infected also increases slightly by 10 percent. Because of the 33-percent increase in the probability of becoming symptomatic when infected (*pS*) within the Longini-like disease manifestation, the total number of symptomatics is increased (34 percent) as well as their peak value (28 percent). These values for symptomatics translate directly into a 34-percent increase in deaths. The combination of the increase in *pS* and the longer time scales translates into a 61-percent greater number of days that adults are at home sick or tending sick children for the unmitigated epidemic.

Tables 4-5 through 4-8 show the infection attack rates for the full set of containment strategy combinations, *IDfactor*, compliance, and connection with external epidemic (full set of tables for this extension are in Appendix E). In these tables, strategy combinations that meet the infection

[40] Glass et al., 2006 (See Footnote 3)

attack rates of less than or equal to 10 percent and between 10 and 25 percent have been colored green and pink, respectively.

For social distancing strategy combinations, the infection attack rates for the Longini-like disease manifestation are nearly identical to the Ferguson-like and those strategies within either green or pink zones do not change. However, for antiviral strategies, the Longini-like manifestation proves more effective (green and pink zones increase). This happens because the increased time scale of the epidemic allows prophylaxis to better capture the spreading disease (see Appendix G). Over all containment strategy combinations, the infection attack rate for the Ferguson-like manifestation is slightly higher; the average difference at 90-percent compliance is 1.5 percent (maximum, 11.6; minimum -6.9; *SD*, 2.2 percent). With decreasing compliance and contact with an external unmitigated epidemic, this difference decreases somewhat, and the range and *SD* decrease by almost half.

While the illness attack rate for the unmitigated epidemic is 33 percent greater for the Longini-like manifestation, the average difference between Ferguson-like and Longini-like across the 4 containment strategy combination tables is insignificant (between -3.9 and -6.3 with *SD* of 4.6 across both compliance and connection with the external unmitigated epidemic). Most of these differences occur for strategy combinations that are ineffective. When effective containment strategy combinations are implemented, the 2 manifestations produce nearly identical outcomes (the differences in illness attack rate are almost all below 1 percent).

Over all containment strategy combinations, the Longini-like manifestation requires more anitiviral courses, with an average difference at 90-percent compliance of -4.9 percent (maximum, 28.6; minimum, -52.1; *SD*, 12.6). These average differences do not change significantly with decreasing compliance and contact with the external unmitigated epidemic. Once again, differences reduce significantly as strategy combinations achieve an infection attack rate of 10 percent or less (green zone).

The average difference between adult days at home at 90-percent compliance for Ferguson-like and Longini-like manifestations is -3.6 (maximum, 4.6; minimum, -16.6; *SD*, 3.8). This increase in days adults are home for the Longini-like manifestation does not change significantly with decreasing compliance and contact with the external unmitigated epidemic. Unlike for illness attack rate and antiviral courses, these average differences also do not change significantly moving into the green zone.

Table 4-5: Longini-like infection attack rates, regionally mitigated, 90-percent compliance

S - Schools closed	CTsd - Child/Teen social distancing	ASsd - Adult/Senior social distancing	Q - Household Quantine	T - Antiviral Treatment	P - Antiviral Prophylaxis	PEx - Extended Antiviral Prophylaxis

ID Factor		None	ASsd	CTsd	CTsd, ASsd	S	S, ASsd	S, CTsd	S, CTsd, ASsd
0.75	None	28.1	19.1	11.1	6.8	2.5	2.0	1.3	1.3
	T	13.7	7.3	3.0	2.4	1.5	1.6	1.1	1.2
	Q	8.9	4.3	2.4	1.9	1.7	1.5	1.4	1.4
	P	4.3	2.4	1.7	1.5	1.2	1.2	0.0	1.1
	Q,T	3.5	2.7	1.8	1.5	1.3	1.3	1.1	1.0
	Q,P	2.4	2.3	1.4	1.6	1.4	1.2	1.1	0.0
	Pex	2.5	1.8	1.3	1.6	1.3	1.2	1.1	1.1
	Q,Pex	1.6	1.4	1.5	1.3	1.3	1.2	1.2	1.1
1.00	None	50.4	39.1	39.9	31.0	23.3	13.6	1.9	1.5
	T	40.1	29.3	25.6	16.2	6.4	3.4	1.5	1.4
	Q	34.2	25.7	16.8	11.2	5.1	3.7	1.5	1.6
	P	28.8	18.0	7.9	4.6	2.4	2.1	1.3	1.3
	Q,T	24.7	13.8	5.3	4.6	1.9	2.0	1.5	1.3
	Q,P	19.8	10.3	3.9	2.8	2.0	1.7	1.3	1.2
	Pex	13.1	6.8	3.3	2.9	1.9	1.5	1.4	1.2
	Q,Pex	6.1	3.9	2.2	2.0	1.6	1.5	1.5	1.4
1.25	None	63.2	50.2	55.0	44.4	47.7	37.3	5.5	2.6
	T	54.7	42.0	44.2	34.3	31.1	18.8	2.2	1.9
	Q	49.2	39.9	37.4	31.4	26.5	18.8	3.6	2.5
	P	43.3	32.3	28.9	20.4	10.1	5.4	1.7	1.5
	Q,T	40.4	30.8	23.6	15.7	6.9	5.3	1.7	1.7
	Q,P	36.3	25.8	14.9	9.9	4.4	2.7	1.7	1.5
	Pex	28.8	20.6	15.9	7.9	4.5	2.8	1.7	1.5
	Q,Pex	20.9	13.0	5.6	4.4	2.4	2.2	1.5	1.6
1.50	None	71.8	57.1	65.3	53.3	62.0	51.0	20.9	5.7
	T	64.6	49.8	56.1	44.4	49.4	37.4	4.1	2.2
	Q	58.7	49.2	49.7	43.4	43.8	36.4	9.7	5.2
	P	53.8	41.0	43.0	33.2	30.6	17.8	2.2	1.9
	Q,T	51.0	40.2	38.1	31.3	26.3	16.6	2.9	2.1
	Q,P	45.9	35.2	31.4	23.2	15.5	8.5	2.1	1.9
	Pex	38.2	29.1	28.4	19.9	13.5	7.3	2.0	1.6
	Q,Pex	32.2	23.5	16.5	10.3	5.8	4.3	2.0	1.7
2.00	None	82.5	66.1	77.6	64.2	78.1	67.7	55.5	29.3
	T	77.4	59.8	71.0	56.9	69.8	58.0	30.5	6.3
	Q	71.8	60.8	65.6	57.4	64.6	56.6	40.9	25.7
	P	67.3	51.7	59.5	47.2	55.7	43.2	8.6	3.5
	Q,T	64.8	53.0	56.7	47.2	53.0	43.2	13.1	5.3
	Q,P	59.5	47.0	49.4	39.8	44.8	33.2	5.4	3.2
	Pex	51.9	39.5	44.4	34.3	38.7	28.3	4.5	2.7
	Q,Pex	45.5	35.1	35.4	26.7	27.2	17.6	3.5	2.6
2.50	None	88.6	71.8	84.9	70.9	86.3	76.8	72.3	48.7
	T	84.8	66.0	79.9	64.3	81.0	69.6	56.1	21.1
	Q	79.9	68.1	75.1	65.8	75.8	68.3	60.6	45.9
	P	76.1	58.5	70.1	55.8	69.6	57.3	32.3	7.4
	Q,T	73.7	60.7	67.4	56.8	67.4	57.5	39.7	17.7
	Q,P	68.5	54.6	61.1	49.8	60.5	49.0	19.3	6.8
	Pex	61.0	46.8	55.1	42.9	52.3	41.0	16.1	4.8
	Q,Pex	54.9	42.6	47.6	36.9	43.9	33.0	9.0	4.6
3.00	None	92.4	76.1	89.4	75.5	90.9	82.5	81.7	60.6
	T	89.5	70.3	85.6	69.4	87.1	76.7	70.5	38.5
	Q	85.1	73.1	81.4	71.7	82.9	75.6	72.5	58.1
	P	82.2	63.5	77.4	61.7	78.1	66.5	52.5	15.7
	Q,T	79.9	66.3	75.2	63.7	75.9	66.8	57.4	35.2
	Q,P	74.9	60.0	69.4	56.3	70.0	59.1	41.9	13.9
	Pex	68.2	52.0	63.0	49.4	62.2	50.9	32.8	8.2
	Q,Pex	62.3	48.3	56.2	44.1	54.4	43.3	23.6	8.2

Note: For Longini-like disease manifestation and implementation threshold 10 diagnosed. Case-based strategy combinations downward, network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent.

Table 4-6: Longini-like infection attack rates, regionally mitigated, 60-percent compliance

S - Schools closed	**CTsd** - Child/Teen social distancing	**ASsd** - Adult/Senior social distancing	**Q** - Household Quantine	**T** - Antiviral Treatment	**P** - Antiviral Prophylaxis	**PEx** - Extended Antiviral Prophylaxis

ID Factor		None	ASsd	CTsd	CTsd, ASsd	S	S, ASsd	S, CTsd	S, CTsd, ASsd
0.75	None	28.8	26.9	26.7	23.8	2.6	2.4	1.4	1.4
	T	13.2	11.5	8.9	7.6	1.6	1.7	1.2	1.5
	Q	22.7	21.1	20.5	17.5	2.0	1.8	1.5	1.4
	P	6.0	5.5	3.3	3.4	1.4	1.3	1.2	1.2
	Q,T	7.4	6.7	5.2	4.8	1.3	1.3	1.3	1.1
	Q,P	4.2	3.1	2.6	2.2	1.2	1.6	1.2	1.0
	Pex	2.1	2.2	1.8	2.1	1.6	1.2	1.2	0.0
	Q,Pex	1.9	1.6	1.5	1.6	1.3	1.1	1.1	1.3
1.00	None	50.1	47.2	49.0	45.2	26.2	20.7	6.4	4.4
	T	39.7	36.7	37.8	34.2	8.0	4.0	2.1	1.9
	Q	44.5	43.4	44.2	42.1	16.3	12.6	5.1	4.7
	P	30.8	28.0	27.1	23.6	2.4	2.2	1.5	1.5
	Q,T	33.4	31.5	31.8	29.3	3.7	2.8	2.0	2.0
	Q,P	26.6	22.8	21.4	18.1	2.4	2.1	1.5	1.6
	Pex	14.6	12.7	11.6	8.3	2.0	1.8	1.5	1.5
	Q,Pex	10.7	8.7	7.0	6.1	1.7	1.7	1.3	1.3
1.25	None	63.0	58.8	61.9	57.9	50.1	45.2	33.4	25.5
	T	54.1	50.1	52.7	48.6	34.5	28.4	8.6	5.3
	Q	57.9	56.3	57.6	55.8	42.0	38.4	30.1	25.5
	P	45.8	41.4	43.2	39.4	16.3	10.3	3.5	2.6
	Q,T	48.4	46.4	47.4	45.2	23.0	18.7	6.8	5.5
	Q,P	41.2	38.7	39.1	36.1	10.1	6.7	3.0	2.6
	Pex	30.0	27.5	28.3	24.9	5.4	4.2	2.3	2.0
	Q,Pex	26.8	24.6	23.8	21.3	3.7	3.2	2.4	1.8
1.50	None	71.8	66.9	70.7	66.3	64.4	59.5	53.3	45.9
	T	64.3	59.1	63.2	58.0	52.2	46.3	32.7	23.1
	Q	67.0	64.9	66.7	64.6	57.5	54.6	49.1	45.4
	P	55.9	51.1	53.9	49.6	38.0	31.7	13.7	7.1
	Q,T	58.5	56.5	58.0	55.3	43.5	39.2	29.1	22.8
	Q,P	51.4	48.3	50.0	46.9	30.1	24.8	10.4	7.3
	Pex	39.7	36.4	38.4	34.4	20.8	14.6	4.6	3.1
	Q,Pex	36.5	34.0	34.6	32.1	13.4	10.4	3.7	3.2
2.00	None	82.8	77.5	81.7	77.1	79.9	76.0	73.7	67.8
	T	77.4	70.9	75.8	70.3	72.3	67.2	61.7	52.9
	Q	78.7	76.5	78.5	76.3	75.1	72.6	70.6	67.5
	P	69.6	63.4	67.9	62.5	61.6	55.8	47.2	36.5
	Q,T	72.2	69.3	71.6	68.9	65.6	62.2	58.2	53.2
	Q,P	65.3	61.5	64.4	61.0	56.1	51.5	43.9	36.3
	Pex	53.1	48.1	51.8	47.1	43.5	38.0	27.9	18.3
	Q,Pex	49.8	46.4	48.9	45.3	38.3	34.7	24.8	18.2
2.50	None	89.1	83.9	88.0	83.8	87.8	84.5	83.9	79.2
	T	84.9	78.3	83.5	78.0	82.6	78.1	76.1	69.0
	Q	85.8	83.6	85.3	83.4	84.1	82.3	81.6	79.0
	P	78.2	71.5	76.9	71.1	74.7	69.0	65.2	56.2
	Q,T	80.5	77.4	79.9	77.3	77.3	74.5	73.1	68.6
	Q,P	74.4	70.4	73.7	70.0	69.6	65.4	62.2	56.0
	Pex	62.4	56.1	61.2	55.7	57.0	51.3	45.8	37.3
	Q,Pex	59.0	54.9	58.4	54.2	52.7	47.7	43.5	37.7
3.00	None	92.8	88.3	92.0	88.2	92.1	89.5	89.7	85.7
	T	89.7	83.5	88.5	83.4	88.5	84.7	84.3	78.3
	Q	90.2	88.0	89.8	88.0	89.3	87.9	87.7	85.7
	P	84.1	77.4	82.8	77.2	82.1	77.4	75.9	68.3
	Q,T	86.0	82.9	85.5	82.8	84.3	82.0	81.4	78.0
	Q,P	80.5	76.6	80.0	76.4	78.1	74.9	73.4	67.9
	Pex	69.3	62.5	68.4	62.1	66.0	60.6	57.8	49.3
	Q,Pex	66.2	61.5	65.7	61.0	62.2	57.8	55.2	49.5

Note: For Longini-like disease manifestation and implementation threshold 10 diagnosed. Case-based strategy combinations downward, network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent.

Table 4-7: Longini-like infection attack rates, regionally unmitigated, 90-percent compliance

S - Schools closed	**CTsd** - Child/Teen social distancing	**ASsd** - Adult/Senior social distancing	**Q** - Household Quantine	**T** - Antiviral Treatment	**P** - Antiviral Prophylaxis	**PEx** - Extended Antiviral Prophylaxis

ID Factor		None	ASsd	CTsd	CTsd, ASsd	S	S, ASsd	S, CTsd	S, CTsd, ASsd
0.75	None	28.7	20.4	15.6	9.9	6.3	4.2	3.4	2.5
	T	17.3	9.4	7.8	4.5	3.9	2.6	2.5	2.0
	Q	13.5	7.6	6.9	4.3	4.7	3.2	3.3	2.6
	P	8.8	4.2	4.8	3.0	3.2	2.4	2.4	2.0
	Q,T	7.9	4.2	4.7	3.1	3.4	2.5	2.5	2.1
	Q,P	6.3	3.6	3.6	2.6	3.0	2.2	2.4	1.9
	Pex	5.4	3.3	4.1	2.6	3.0	2.2	2.4	2.0
	Q,Pex	4.3	2.7	3.4	2.5	2.7	2.2	2.4	1.9
1.00	None	49.9	39.2	40.2	31.6	28.4	18.8	9.5	4.7
	T	41.1	30.8	29.7	21.2	16.9	9.4	6.7	3.5
	Q	36.7	27.4	25.6	17.7	16.8	10.0	8.7	4.8
	P	31.0	21.8	18.8	11.2	10.7	5.7	5.6	3.2
	Q,T	28.8	18.0	16.9	9.8	10.4	5.7	6.3	3.5
	Q,P	24.9	15.4	13.4	7.2	8.6	4.7	5.5	3.1
	Pex	19.5	12.2	12.6	7.3	8.0	4.6	5.2	3.0
	Q,Pex	15.2	8.2	9.9	5.2	7.2	4.1	5.2	3.0
1.25	None	62.6	50.2	55.1	45.2	49.0	38.5	20.3	9.8
	T	55.3	42.9	46.0	36.1	36.4	25.2	13.3	6.2
	Q	51.0	41.5	42.1	33.7	34.6	25.3	18.2	9.5
	P	45.5	34.4	34.9	25.6	23.8	13.7	10.5	5.1
	Q,T	43.1	33.4	32.3	23.9	24.0	14.4	12.3	6.4
	Q,P	39.0	28.5	26.9	18.1	18.8	10.3	10.2	5.2
	Pex	31.5	23.2	23.7	15.8	16.0	9.4	9.2	4.8
	Q,Pex	26.6	17.9	18.6	11.3	13.7	7.8	8.9	4.6
1.50	None	71.4	57.1	65.0	53.7	62.6	51.7	34.3	17.6
	T	64.9	50.7	57.5	46.1	52.2	40.2	22.7	10.4
	Q	60.8	50.6	53.5	45.2	49.5	40.0	30.4	17.3
	P	55.4	43.1	46.7	36.3	38.5	26.5	17.0	8.2
	Q,T	53.5	42.6	44.7	35.5	38.2	26.6	20.2	10.3
	Q,P	48.9	37.7	38.8	28.4	31.1	19.7	16.3	8.1
	Pex	41.3	31.5	33.6	24.7	25.8	17.0	13.7	7.2
	Q,Pex	36.1	26.1	27.7	18.5	21.5	13.5	13.4	7.2
2.00	None	82.3	66.2	77.3	64.3	77.9	67.8	58.5	36.8
	T	77.4	60.7	71.5	58.0	71.2	59.1	44.2	22.5
	Q	73.5	62.3	68.7	59.1	67.6	58.6	52.4	36.9
	P	68.9	54.0	62.5	50.2	59.5	47.1	32.8	15.9
	Q,T	67.1	55.3	61.4	50.6	58.4	47.5	39.2	22.1
	Q,P	62.1	49.7	55.1	43.9	51.5	39.9	30.7	15.9
	Pex	54.8	42.4	48.7	37.8	42.9	32.7	24.3	12.7
	Q,Pex	49.4	38.2	42.5	32.0	37.1	26.5	23.2	12.7
2.50	None	88.3	71.8	84.4	70.8	86.0	76.5	72.8	51.8
	T	84.8	66.7	79.9	65.2	81.2	70.1	61.2	35.9
	Q	81.2	69.4	77.4	67.5	78.0	69.4	66.9	51.8
	P	77.4	60.8	72.1	58.6	71.5	59.7	48.2	25.1
	Q,T	75.6	62.9	71.2	60.0	70.6	60.3	54.9	35.6
	Q,P	70.7	57.4	65.5	53.5	64.4	53.0	45.0	25.2
	Pex	64.0	49.6	58.6	46.6	55.2	44.5	34.4	18.8
	Q,Pex	58.5	46.3	53.0	41.3	48.9	38.3	32.7	19.2
3.00	None	92.1	75.9	89.1	75.2	90.9	82.2	81.7	62.2
	T	89.4	71.1	85.5	70.2	87.3	77.2	72.8	47.6
	Q	86.4	74.4	83.3	73.2	84.2	76.5	76.5	61.9
	P	83.1	65.8	79.0	64.3	79.5	68.4	60.9	35.1
	Q,T	81.5	68.5	77.9	66.5	78.2	68.9	66.6	47.6
	Q,P	77.0	63.2	72.9	60.3	73.1	62.1	56.6	35.3
	Pex	70.8	55.4	66.1	52.9	64.2	52.8	44.4	25.6
	Q,Pex	65.4	52.1	60.8	48.5	58.1	47.5	41.7	26.0

Note: For Longini-like disease manifestation and implementation threshold 10 diagnosed. Case-based strategy combinations downward, network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent.

Table 4-8: Longini-like infection attack rates, regionally unmitigated, 90-percent compliance

S - Schools closed	**CTsd** - Child/Teen social distancing	**ASsd** - Adult/Senior social distancing	**Q** - Household Quantine	**T** - Antiviral Treatment	**P** - Antiviral Prophylaxis	**PEx** - Extended Antiviral Prophylaxis

ID Factor		None	ASsd	CTsd	CTsd, ASsd	S	S, ASsd	S, CTsd	S, CTsd, ASsd
0.75	None	28.9	26.5	26.8	23.5	6.9	4.6	4.5	3.3
	T	16.8	13.5	14.8	10.6	4.2	2.9	3.3	2.4
	Q	23.5	22.1	22.2	19.3	5.7	3.8	4.4	3.2
	P	10.1	7.5	8.9	5.6	3.5	2.6	3.0	2.2
	Q,T	11.8	8.9	10.7	7.5	3.9	2.8	3.2	2.4
	Q,P	8.1	5.7	6.5	4.4	3.4	2.5	2.8	2.2
	Pex	5.6	4.0	5.4	3.6	3.1	2.5	2.8	2.1
	Q,Pex	4.9	3.5	4.8	3.1	3.1	2.4	2.8	2.2
1.00	None	49.5	45.8	48.4	44.7	29.4	23.4	17.2	11.3
	T	40.5	36.8	38.8	34.6	17.6	12.4	10.5	6.5
	Q	44.9	43.0	44.6	41.6	23.4	18.5	16.4	10.9
	P	32.8	29.3	30.3	25.5	12.5	8.0	8.3	5.0
	Q,T	35.3	32.3	34.1	30.5	14.6	9.4	10.2	6.3
	Q,P	29.4	25.4	26.9	22.1	10.9	7.0	8.4	5.1
	Pex	20.9	17.1	18.7	14.8	9.5	6.1	7.0	4.5
	Q,Pex	18.1	14.4	16.5	12.2	8.5	5.7	7.0	4.3
1.25	None	62.6	57.7	61.1	57.0	49.8	44.2	37.1	28.8
	T	54.8	50.2	53.5	48.3	38.3	31.4	24.4	16.3
	Q	58.1	55.3	57.8	54.8	44.1	38.4	35.6	28.6
	P	47.4	42.6	45.5	40.5	28.1	20.6	17.7	11.0
	Q,T	49.9	46.5	49.3	45.6	31.9	25.3	23.5	15.9
	Q,P	43.7	39.9	42.2	37.7	24.7	17.5	17.0	10.8
	Pex	33.6	29.4	31.9	27.1	19.0	13.3	13.5	8.4
	Q,Pex	30.7	26.5	29.2	24.6	17.0	11.9	13.2	8.7
1.50	None	71.1	65.8	70.0	65.2	63.7	58.2	53.5	45.4
	T	64.7	58.9	63.3	57.7	54.1	47.0	40.4	30.6
	Q	67.0	64.1	66.9	63.6	58.1	53.4	51.5	45.4
	P	57.5	51.9	55.9	50.2	43.4	36.0	30.2	21.0
	Q,T	59.9	56.2	59.6	55.5	47.3	41.2	38.8	30.5
	Q,P	53.9	49.4	52.9	48.1	38.9	31.2	29.5	20.4
	Pex	43.0	38.1	41.8	36.2	29.8	23.1	21.3	14.4
	Q,Pex	40.0	35.9	39.2	33.9	27.1	20.4	21.2	14.4
2.00	None	82.2	76.2	81.0	75.9	79.4	74.6	73.2	66.2
	T	77.4	70.5	76.0	69.8	72.7	66.7	63.8	54.3
	Q	78.7	75.4	78.4	75.2	75.1	71.1	71.1	66.2
	P	70.8	64.0	69.6	63.4	64.1	57.0	53.3	42.4
	Q,T	73.1	69.0	72.7	68.6	67.2	62.2	61.5	54.3
	Q,P	67.3	62.5	66.7	61.7	59.7	52.9	51.7	42.1
	Pex	56.4	50.0	55.2	48.9	47.6	40.9	37.4	28.6
	Q,Pex	53.4	48.5	52.8	47.2	43.8	37.4	36.9	28.5
2.50	None	88.4	82.8	87.4	82.6	87.3	83.3	83.4	77.6
	T	84.8	77.7	83.6	77.4	82.8	77.5	76.6	68.8
	Q	85.7	82.4	85.3	82.2	83.9	80.9	81.6	77.6
	P	79.2	71.9	78.1	71.6	75.6	69.4	67.7	58.2
	Q,T	81.1	77.0	80.7	76.8	78.2	74.0	74.2	68.5
	Q,P	75.9	71.0	75.4	70.7	71.6	66.1	66.2	58.1
	Pex	65.2	58.2	64.3	57.4	59.3	52.7	50.4	41.2
	Q,Pex	62.3	56.8	61.9	55.9	55.9	49.8	49.0	41.2
3.00	None	92.3	87.3	91.5	87.3	91.8	88.4	89.3	84.5
	T	89.6	82.9	88.4	82.8	88.5	84.0	84.4	77.5
	Q	90.1	87.1	89.6	87.1	89.3	86.9	87.7	84.4
	P	84.8	77.7	83.7	77.5	82.8	77.5	77.3	68.9
	Q,T	86.4	82.5	85.9	82.3	84.8	81.2	82.2	77.6
	Q,P	81.9	77.1	81.5	76.8	79.4	74.8	75.6	68.9
	Pex	71.9	64.2	70.9	63.8	67.9	61.5	60.0	51.1
	Q,Pex	69.0	63.1	68.8	62.9	64.5	58.9	58.9	51.2

Note: For Longini-like disease manifestation and implementation threshold 10 diagnosed. Case-based strategy combinations downward, network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent.

4.2.2 Relaxing Implementation Threshold

In Glass et al. (2006),[41] the model showed that relaxation of the implementation threshold with S+CTsd rapidly eroded effectiveness. This was also the case for the full containment strategy combination matrix in which the higher the *IDfactor*, the greater the erosion. For an implementation threshold of 100 diagnosed individuals, the Ferguson-like disease manifestation infection attack rates (shown in Tables 4-9 through 4-12) reflect significantly fewer mitigation strategies available to keep infection attack rates below 25 percent (green and pink zones). Appendix E contains a full set of tables for this extension. Because treatment with antivirals is not controlled by an implementation threshold, those strategy combinations that include treatment (T, P, and PEx) erode less than those that do not.

The average time for strategy implementation is delayed by 6 days (30 diagnosed) to 14 days (100 diagnosed) at an *IDfactor* of 1 in the less-than-10-percent infection attack rate zone (green). For an *IDfactor* of 1.5, strategies are able to achieve only an infection attack rate of between 10 and 25 percent (pink zone), and implementation is delayed by 4 days (30 diagnosed) to 7 days (100 diagnosed). These delays translate into similar delay periods for peak infected and symptomatic. Adult days at home generally decrease slightly (by about a day) within the green zones as fewer days are spent minding children sent home from school. However, required antiviral courses significantly increase for both of the lower infection attack rate zones (green and pink) and even more so as the *IDfactor* increases.

[41] Glass et al., 2006 (See Footnote 3)

Table 4-9: Implementation threshold 100 diagnosed infection attack rates, regionally mitigated, 90-percent compliance

S - Schools closed	CTsd - Child/Teen social distancing	ASsd - Adult/Senior social distancing	Q - Household Quantine	T - Antiviral Treatment	P - Antiviral Prophylaxis	PEx - Extended Antiviral Prophylaxis

ID Factor		None	ASsd	CTsd	CTsd, ASsd	S	S, ASsd	S, CTsd	S, CTsd, ASsd
0.75	None	27.5	19.8	15.9	11.9	7.8	6.8	5.1	4.4
	T	15.7	10.8	6.3	5.8	4.5	4.5	3.6	3.6
	Q	14.1	10.9	8.2	7.4	6.1	5.6	4.7	4.8
	P	8.8	6.8	5.2	4.9	4.2	3.9	3.5	3.5
	Q,T	7.6	6.6	5.1	4.5	4.2	4.2	3.6	3.5
	Q,P	7.6	5.9	5.1	4.3	4.0	4.1	3.3	3.5
	Pex	6.2	5.3	4.4	4.3	4.2	3.8	3.6	3.3
	Q,Pex	4.6	4.5	4.4	4.0	3.9	3.9	3.5	3.7
1.00	None	49.5	38.9	40.2	32.3	28.8	22.1	10.8	8.8
	T	41.0	31.5	29.9	23.1	17.2	12.8	7.2	6.3
	Q	36.9	30.2	26.3	22.0	17.8	15.8	9.9	8.8
	P	32.4	24.4	20.1	16.1	11.9	9.7	6.6	5.8
	Q,T	29.5	22.8	18.3	14.5	11.7	10.0	6.7	6.5
	Q,P	27.0	20.4	15.3	12.3	9.9	8.5	6.1	5.9
	Pex	20.3	15.2	13.1	10.2	9.1	8.0	5.9	5.6
	Q,Pex	16.5	12.7	10.4	9.3	8.2	7.5	6.1	5.8
1.25	None	62.6	50.0	55.2	45.3	49.2	40.2	20.6	15.0
	T	55.8	43.5	46.8	37.3	37.0	28.8	12.6	10.0
	Q	50.9	42.8	42.6	36.4	35.3	30.1	17.3	14.6
	P	46.5	36.2	36.3	28.9	25.8	19.9	10.8	9.6
	Q,T	43.8	35.6	33.9	28.0	24.9	20.2	11.3	9.7
	Q,P	40.6	31.8	29.7	24.2	21.4	17.0	10.5	9.0
	Pex	31.3	25.0	23.6	18.3	16.4	14.0	9.5	8.1
	Q,Pex	27.5	21.5	19.6	16.0	14.6	12.8	9.2	8.4
1.50	None	71.3	57.1	65.0	54.2	62.4	52.4	34.1	23.3
	T	65.4	51.3	58.0	46.8	53.4	42.9	22.7	15.1
	Q	60.5	51.2	53.8	46.7	49.6	43.1	28.6	22.4
	P	56.3	44.4	47.9	39.1	41.1	32.5	16.8	13.0
	Q,T	53.8	44.6	45.7	38.4	40.0	32.8	19.0	15.2
	Q,P	49.7	39.9	40.8	33.7	34.0	27.6	16.4	13.1
	Pex	40.4	32.0	33.1	26.8	26.9	21.0	13.4	11.9
	Q,Pex	36.0	28.6	27.8	23.0	23.0	19.0	12.7	11.4
2.00	None	82.3	66.3	77.7	64.7	78.2	68.3	59.1	40.5
	T	78.1	60.9	72.3	58.8	72.1	60.8	45.6	28.4
	Q	73.6	62.5	68.4	60.0	68.2	60.4	50.6	39.5
	P	69.7	54.8	63.4	51.4	61.5	51.0	33.7	23.0
	Q,T	67.6	55.9	61.6	52.6	60.2	51.6	36.9	27.3
	Q,P	63.0	51.4	56.7	47.4	54.6	45.7	30.4	22.1
	Pex	52.8	41.8	47.4	38.1	43.1	35.6	24.3	17.8
	Q,Pex	47.9	39.0	41.6	34.5	38.3	31.9	22.1	17.9
2.50	None	88.6	72.3	85.1	71.3	86.3	77.2	74.2	54.6
	T	85.4	67.3	81.0	66.0	82.2	71.5	64.0	42.3
	Q	81.5	69.4	77.5	67.7	78.6	71.0	65.7	53.2
	P	78.3	61.8	73.5	59.8	73.7	62.8	51.4	33.7
	Q,T	76.5	63.6	71.9	61.3	72.1	63.6	54.9	39.7
	Q,P	72.0	58.8	66.9	55.9	67.1	57.9	46.7	32.7
	Pex	61.7	49.0	56.9	46.5	55.1	45.6	35.7	25.8
	Q,Pex	56.9	46.3	51.8	43.1	49.9	42.1	32.5	24.8
3.00	None	92.3	76.6	89.7	76.0	91.0	82.8	82.9	64.2
	T	90.0	71.9	86.6	71.1	88.1	78.3	75.4	52.8
	Q	86.7	74.2	83.5	73.2	84.8	77.8	75.8	62.6
	P	84.2	66.7	80.3	65.4	81.1	70.9	65.2	43.0
	Q,T	82.5	69.0	78.8	67.4	80.0	71.7	66.9	50.4
	Q,P	78.4	64.2	74.4	62.2	75.4	66.4	59.9	42.5
	Pex	68.6	54.6	64.4	52.6	64.0	54.1	46.3	32.8
	Q,Pex	63.7	52.1	59.4	49.3	58.9	50.4	42.8	32.0

Note: For Longini-like disease manifestation and implementation threshold 10 diagnosed. Case-based strategy combinations downward, network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent.

Table 4-10: Implementation threshold 100 diagnosed infection attack rates, regionally mitigated, 60-percent compliance

S - Schools closed	**CTsd** - Child/Teen social distancing	**ASsd** - Adult/Senior social distancing	**Q** - Household Quantine	**T** - Antiviral Treatment	**P** - Antiviral Prophylaxis	**PEx** - Extended Antiviral Prophylaxis

ID Factor		None	ASsd	CTsd	CTsd, ASsd	S	S, ASsd	S, CTsd	S, CTsd, ASsd
0.75	None	28.7	26.9	26.5	24.8	8.3	7.6	6.1	5.5
	T	16.1	14.1	13.3	11.1	4.9	4.2	4.0	3.9
	Q	23.6	22.3	21.8	20.7	7.3	7.3	5.8	5.6
	P	10.1	9.8	8.6	7.7	4.4	4.2	3.9	3.8
	Q,T	10.7	10.5	9.6	9.0	4.2	4.5	4.2	4.2
	Q,P	8.2	7.6	7.3	7.5	3.9	4.3	3.6	3.6
	Pex	5.9	5.9	5.7	5.6	3.9	4.1	3.7	3.6
	Q,Pex	5.9	6.0	5.6	5.0	4.0	4.0	3.6	3.4
1.00	None	50.0	46.6	48.9	45.2	30.8	27.3	18.3	15.3
	T	41.0	38.3	39.7	35.7	18.5	16.2	10.6	9.0
	Q	44.4	43.4	44.7	42.3	25.2	23.3	17.8	15.2
	P	34.0	31.4	31.8	28.6	14.0	11.9	8.3	7.7
	Q,T	35.5	34.4	34.8	32.5	14.5	13.6	9.6	8.9
	Q,P	30.2	28.5	28.2	26.1	11.8	10.6	8.6	7.8
	Pex	21.6	20.1	19.7	18.2	9.9	9.3	7.3	6.9
	Q,Pex	18.9	17.7	17.5	16.0	8.8	8.9	7.2	7.0
1.25	None	62.9	58.4	61.9	57.7	51.6	47.1	38.3	32.9
	T	55.6	51.3	54.3	50.0	40.0	35.0	24.0	20.0
	Q	57.9	56.1	57.9	55.5	45.5	42.1	35.4	32.4
	P	48.3	44.9	47.0	42.8	31.3	27.4	17.9	15.4
	Q,T	49.8	48.0	49.5	46.9	33.6	30.2	22.1	19.9
	Q,P	44.6	42.1	43.4	40.4	26.6	23.9	17.2	15.9
	Pex	33.3	31.3	31.7	29.0	19.1	17.5	13.1	11.6
	Q,Pex	30.9	29.1	29.6	26.8	16.9	15.9	12.7	11.6
1.50	None	71.7	66.5	70.7	65.9	65.3	60.5	54.6	48.0
	T	65.5	60.0	64.4	59.1	55.8	50.2	41.6	34.1
	Q	67.0	64.8	67.0	64.5	59.4	56.7	51.7	47.9
	P	58.4	53.9	57.0	52.6	46.4	41.3	31.8	26.0
	Q,T	60.0	57.6	59.8	56.8	49.3	46.3	38.7	33.9
	Q,P	54.3	51.7	53.6	50.5	42.2	37.7	29.9	25.7
	Pex	42.2	39.0	41.2	37.6	30.5	26.9	20.1	17.6
	Q,Pex	39.2	37.3	38.4	35.7	27.6	24.8	20.0	18.5
2.00	None	82.6	77.0	81.7	76.7	80.3	76.0	74.2	68.0
	T	78.0	71.5	76.9	71.1	74.2	69.1	65.1	57.3
	Q	78.9	76.2	78.7	76.1	76.1	73.3	71.8	68.2
	P	71.7	65.9	70.7	65.3	66.7	61.1	56.0	47.9
	Q,T	73.5	70.3	73.0	69.8	68.7	65.4	62.0	57.4
	Q,P	68.0	64.5	67.7	63.7	62.3	58.4	53.0	47.7
	Pex	54.5	50.2	53.9	49.1	47.4	43.3	37.5	32.1
	Q,Pex	51.6	48.7	51.2	47.8	44.7	40.5	35.9	31.8
2.50	None	88.9	83.5	88.1	83.5	88.1	84.4	84.3	79.1
	T	85.6	78.9	84.5	78.6	83.8	79.2	78.4	71.0
	Q	86.0	83.1	85.6	83.1	84.7	82.9	82.0	79.1
	P	80.4	73.8	79.2	73.4	78.0	72.7	70.7	63.1
	Q,T	81.7	78.2	81.2	78.0	79.6	76.6	75.0	71.2
	Q,P	76.9	72.7	76.5	72.7	74.1	70.5	68.1	63.2
	Pex	63.5	57.9	62.9	57.4	59.3	54.5	50.8	44.4
	Q,Pex	60.6	56.8	60.3	56.3	56.1	52.3	49.3	44.5
3.00	None	92.8	88.0	91.9	87.9	92.3	89.3	89.9	85.8
	T	90.3	84.0	89.1	84.0	89.4	85.4	85.5	79.8
	Q	90.5	87.8	89.9	87.7	89.8	88.1	87.9	85.6
	P	86.0	79.5	84.9	79.3	84.6	80.3	79.7	73.0
	Q,T	87.1	83.5	86.5	83.3	85.9	83.3	83.0	79.8
	Q,P	83.1	79.0	82.5	78.7	81.4	78.3	77.4	72.9
	Pex	70.3	64.0	69.5	63.7	67.6	62.4	60.9	53.5
	Q,Pex	67.7	63.4	67.1	63.0	64.4	60.9	58.5	53.8

Note: For Ferguson-like disease manifestation. Case-based strategy combinations downward, network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent.

Table 4-11: Implementation threshold 100 diagnosed infection attack rates, regionally unmitigated, 90-percent compliance

S - Schools closed	CTsd - Child/Teen social distancing	ASsd - Adult/Senior social distancing	Q - Household Quantine	T - Antiviral Treatment	P - Antiviral Prophylaxis	PEx - Extended Antiviral Prophylaxis

ID Factor		None	ASsd	CTsd	CTsd, ASsd	S	S, ASsd	S, CTsd	S, CTsd, ASsd
0.75	None	28.2	20.8	17.6	13.9	10.3	8.7	7.2	6.9
	T	19.0	12.7	10.5	8.0	6.9	5.8	5.6	5.4
	Q	17.2	12.2	11.4	9.5	9.1	8.2	7.0	7.0
	P	12.7	8.9	8.1	6.4	6.3	5.7	5.1	5.3
	Q,T	11.3	8.8	8.0	6.7	6.4	5.8	5.4	5.3
	Q,P	10.4	7.3	6.8	6.2	5.8	5.5	5.1	5.3
	Pex	9.3	7.2	6.8	5.9	5.7	5.5	5.2	5.3
	Q,Pex	8.1	6.4	6.7	5.8	5.6	5.8	5.4	5.4
1.00	None	49.4	39.5	41.0	33.1	31.3	24.1	15.6	11.8
	T	42.0	32.8	32.6	25.4	22.1	16.0	12.2	8.7
	Q	39.3	31.5	30.6	24.6	23.7	18.3	15.3	11.9
	P	34.2	26.2	25.2	18.8	17.4	12.4	11.0	8.5
	Q,T	32.6	24.7	23.9	18.2	17.8	13.1	11.6	9.3
	Q,P	29.8	22.1	20.9	15.5	15.8	11.7	10.7	8.2
	Pex	23.5	17.4	18.2	13.8	14.2	11.2	10.4	8.2
	Q,Pex	20.8	15.7	16.0	12.7	13.2	10.3	10.3	8.1
1.25	None	62.2	50.4	55.6	46.1	50.3	40.9	27.8	18.7
	T	56.2	44.6	48.7	39.1	41.2	31.6	21.2	14.2
	Q	52.7	44.4	46.2	38.7	40.5	32.6	26.2	19.3
	P	48.1	38.1	40.1	31.7	31.9	24.3	18.2	12.9
	Q,T	46.5	37.6	38.7	31.1	31.9	24.8	20.0	14.0
	Q,P	42.8	34.1	35.0	27.3	28.7	21.3	17.7	13.0
	Pex	34.6	27.2	29.1	22.6	22.9	18.1	15.7	11.9
	Q,Pex	31.2	24.1	25.6	19.8	21.4	16.6	15.8	11.9
1.50	None	71.1	57.4	65.5	54.6	63.5	53.3	41.3	28.0
	T	66.0	52.3	59.6	48.6	55.5	45.1	32.0	21.0
	Q	62.8	52.7	57.2	48.9	53.7	45.1	38.0	28.2
	P	57.8	46.3	51.6	41.6	45.8	36.0	27.1	18.6
	Q,T	56.6	46.5	50.1	41.6	45.3	36.8	30.0	20.7
	Q,P	52.4	42.5	46.2	37.3	40.8	32.4	26.2	18.2
	Pex	43.4	34.7	38.1	30.3	32.8	25.7	22.2	16.2
	Q,Pex	39.6	31.7	34.1	27.1	30.2	23.9	21.6	16.4
2.00	None	82.1	66.5	77.7	65.1	78.6	68.5	62.3	44.6
	T	78.4	62.2	73.2	60.1	73.2	62.3	52.7	35.1
	Q	75.1	63.8	71.1	61.7	70.6	62.3	57.4	44.7
	P	71.1	56.9	66.2	54.5	64.4	53.4	44.4	29.6
	Q,T	69.8	58.4	65.3	55.3	64.0	54.4	48.5	35.0
	Q,P	65.4	53.9	60.7	50.7	59.0	49.0	42.5	29.6
	Pex	56.2	45.1	51.7	42.2	48.2	39.4	33.8	25.0
	Q,Pex	51.7	42.0	47.7	38.8	44.3	36.4	33.1	24.3
2.50	None	88.5	72.5	85.0	71.7	86.6	77.4	75.7	57.6
	T	85.6	68.4	81.6	67.3	82.8	72.4	67.6	47.8
	Q	82.6	70.9	79.4	69.6	80.3	72.4	70.7	57.2
	P	79.6	63.9	75.5	62.4	75.6	64.8	58.9	41.0
	Q,T	78.1	65.9	74.7	64.1	74.9	65.9	62.9	47.3
	Q,P	74.1	61.6	70.2	59.2	70.4	60.8	56.2	40.6
	Pex	65.2	52.4	61.1	50.2	58.9	49.7	44.9	32.4
	Q,Pex	60.7	49.9	57.1	47.3	54.9	46.3	42.8	32.7
3.00	None	92.2	76.7	89.5	76.2	91.1	82.8	83.6	66.3
	T	90.1	72.9	86.8	72.1	88.4	78.7	77.5	57.1
	Q	87.6	75.6	85.0	74.8	86.1	78.7	79.1	66.2
	P	85.2	68.9	81.6	67.9	82.8	72.7	70.0	50.5
	Q,T	83.9	71.0	80.8	69.8	81.8	73.3	72.6	57.0
	Q,P	80.1	67.2	77.0	65.5	77.9	68.7	66.7	50.5
	Pex	71.6	57.9	68.2	56.2	67.2	57.3	53.7	39.7
	Q,Pex	67.5	55.7	64.2	53.8	63.2	54.2	51.6	39.5

Note: For Ferguson-like disease manifestation. Case-based strategy combinations downward, network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent.

Table 4-12: Implementation threshold 100 diagnosed infection attack rates, regionally unmitigated, 60-percent compliance

S - Schools closed	**CTsd** - Child/Teen social distancing	**ASsd** - Adult/Senior social distancing	**Q** - Household Quantine	**T** - Antiviral Treatment	**P** - Antiviral Prophylaxis	**PEx** - Extended Antiviral Prophylaxis

ID Factor		None	ASsd	CTsd	CTsd, ASsd	S	S, ASsd	S, CTsd	S, CTsd, ASsd
0.75	None	28.1	26.8	26.6	24.6	10.9	9.4	8.5	8.0
	T	18.2	16.5	16.6	13.6	7.4	6.5	5.9	5.4
	Q	23.6	22.7	22.6	20.2	10.4	8.7	8.4	7.4
	P	14.2	11.9	12.3	10.2	6.4	5.9	5.5	5.3
	Q,T	14.6	13.4	13.6	10.8	6.8	6.1	6.0	5.5
	Q,P	11.9	10.6	10.7	8.7	6.4	5.6	5.7	5.2
	Pex	9.0	8.1	8.8	7.2	6.1	5.7	5.8	5.1
	Q,Pex	8.2	7.5	8.0	6.9	6.0	5.5	5.5	5.2
1.00	None	49.5	46.2	48.3	44.8	33.2	28.0	22.6	17.9
	T	42.0	38.7	40.5	36.5	23.5	19.2	16.4	12.4
	Q	45.2	43.1	45.2	41.8	28.8	24.5	22.0	18.2
	P	36.1	32.8	34.3	30.3	19.2	15.4	13.8	10.9
	Q,T	37.5	34.9	36.7	33.1	20.6	16.7	15.8	12.5
	Q,P	32.8	29.8	31.3	27.8	17.8	14.4	13.9	10.8
	Pex	25.1	22.0	24.2	20.8	15.4	12.2	12.5	10.2
	Q,Pex	23.3	20.6	22.1	18.5	14.7	11.9	12.3	9.8
1.25	None	62.1	57.8	61.3	56.9	51.7	46.3	40.8	33.3
	T	56.0	51.2	55.1	50.0	42.9	36.7	30.8	24.1
	Q	58.1	55.4	58.1	54.9	47.0	42.3	39.2	33.6
	P	49.9	45.4	48.7	43.9	35.7	29.9	25.8	19.9
	Q,T	51.5	48.5	51.2	47.0	37.7	33.0	29.3	24.3
	Q,P	46.4	43.3	45.8	41.8	33.0	26.9	25.2	19.9
	Pex	36.7	32.7	35.4	31.1	26.0	21.6	20.7	16.3
	Q,Pex	34.3	30.5	33.5	29.7	24.7	20.3	20.2	16.4
1.50	None	71.2	65.6	70.1	65.1	64.9	59.4	55.7	48.1
	T	66.1	60.2	64.8	59.2	57.2	51.1	45.8	37.4
	Q	67.4	64.2	67.4	63.8	60.2	56.1	54.0	48.1
	P	59.9	54.7	58.8	53.4	49.8	43.5	38.8	31.6
	Q,T	61.6	58.0	61.2	57.2	52.1	47.0	44.2	37.6
	Q,P	56.6	52.6	56.2	51.7	46.5	40.6	38.1	31.1
	Pex	45.5	40.9	44.7	39.5	36.3	31.2	29.5	23.9
	Q,Pex	43.0	39.1	42.7	38.5	34.3	29.5	28.3	23.9
2.00	None	82.3	76.1	81.2	75.7	80.0	75.0	74.3	67.1
	T	78.3	71.3	77.0	70.9	74.7	68.8	66.7	58.4
	Q	79.0	75.5	78.9	75.2	76.1	72.4	72.2	67.3
	P	73.0	66.3	72.0	65.8	68.4	62.0	59.7	50.6
	Q,T	74.5	70.1	74.0	69.9	70.3	65.5	64.8	58.1
	Q,P	69.9	65.2	69.5	64.8	64.8	59.6	58.1	50.5
	Pex	58.0	52.2	57.3	51.4	51.9	46.0	44.2	37.3
	Q,Pex	55.4	50.8	55.3	50.2	49.3	43.8	43.4	36.8
2.50	None	88.6	82.8	87.7	82.6	87.7	83.6	84.0	78.1
	T	85.7	78.7	84.5	78.4	84.1	79.0	78.8	71.3
	Q	86.1	82.3	85.7	82.2	84.9	81.8	82.2	78.2
	P	81.3	74.1	80.2	74.0	79.1	73.4	72.9	64.6
	Q,T	82.4	77.9	82.0	77.8	80.5	76.3	76.7	71.0
	Q,P	78.4	73.4	78.0	73.3	75.8	71.1	71.0	64.5
	Pex	66.8	60.2	66.0	59.6	62.7	56.5	55.6	48.1
	Q,Pex	64.2	59.1	63.9	58.5	59.9	55.0	54.7	47.9
3.00	None	92.5	87.1	91.7	87.1	92.0	88.7	89.6	84.8
	T	90.3	83.6	89.2	83.5	89.4	85.1	85.9	79.3
	Q	90.4	87.0	89.9	86.9	89.8	87.4	88.2	84.8
	P	86.7	79.8	85.7	79.5	85.4	80.5	81.0	73.6
	Q,T	87.6	83.2	87.0	83.1	86.5	83.1	83.9	79.3
	Q,P	84.2	79.2	83.7	79.1	82.7	78.7	79.3	73.6
	Pex	73.4	66.3	72.5	65.8	70.7	64.6	64.7	56.7
	Q,Pex	71.0	65.6	70.6	65.0	68.0	62.6	63.3	56.7

Note: For Ferguson-like disease manifestation. Case-based strategy combinations downward, network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent.

4.2.3 Administering Pre-pandemic Vaccine

Glass et al. (2005b)[42] found vaccination focused on children and teens to be the most effective strategy in this social contact network. Targeting these groups with the full proposed stockpile (7 percent of the population or 700 doses in our community of 10,000) of partially effective vaccine (50-percent efficacy) yields much greater benefit than administering it either uniformly throughout age classes or focused entirely on adults (full set of tables for this extension in Appendix E).

In Tables 4-13 through 4-16, the expanding zones of green and pink show that vaccination targeting children and teens enlarges the pool of effective (less than 10-percent and less than 25-percent infection attack rate) strategies available for influenza strains at each *IDfactor*.

An example of this impact can be seen by comparing the vaccine/no vaccine infection rates in Figure 4-2. All 4 simulations are set to 90-percent compliance with an implementation threshold of 10. Those on the left reflect results in communities with regional mitigation conditions; those on the right are regionally unmitigated.

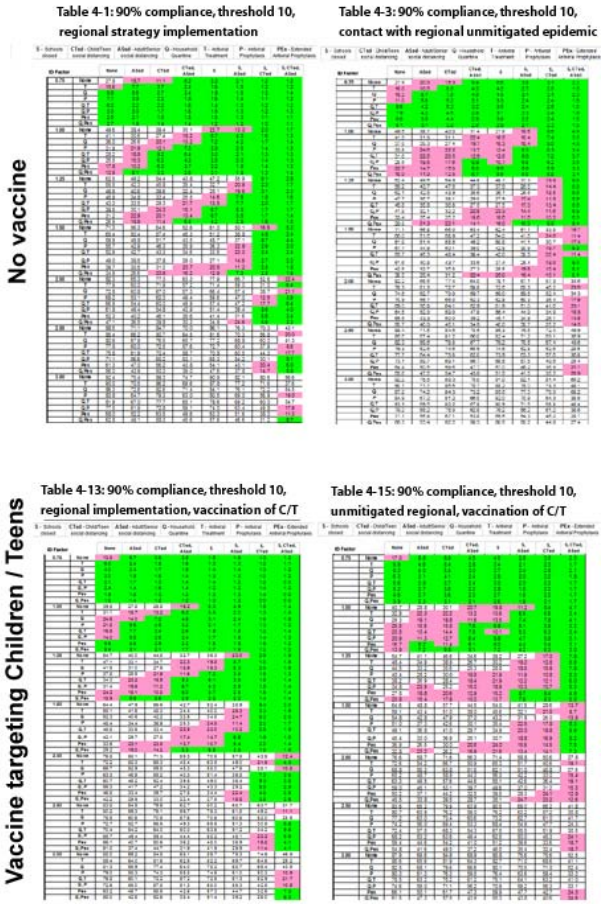


Figure 4-2: Comparison of infection attack rate tables for combined containment strategies without (top) and with (bottom) targeted vaccination of children and teens

[42] Glass et al., 2005b (See Footnote 17)

The greatest relative benefit is found in the 10- to 25-percent infection attack rate zone for no vaccination (pink zone, top of Figure 4-2) where vaccination has reduced attack rates by as much as 14 percent, moving many of the combined strategies into the green zone (10-percent or less attack rate). There, required antiviral courses decreased (up to 47-percent coverage) as did days adults are at home (up to 7 days). In the zone where the infection attack rate was 10 percent or less for no vaccination (green zone, top of Figure 4-2), added benefit from targeted vaccination with pre-pandemic vaccine is, in general, much less with only small decreases in antiviral courses given or days adults are at home. However, as discussed in Section 5, the increased benefit afforded by pre-pandemic vaccination may not influence the design of best community containment strategy combination.

Table 4-13: Children and teenager targeted pre-pandemic vaccination infection attack rates, regionally mitigated, 90-percent compliance

S - Schools closed	CTsd - Child/Teen social distancing	ASsd - Adult/Senior social distancing	Q - Household Quantine	T - Antiviral Treatment	P - Antiviral Prophylaxis	PEx - Extended Antiviral Prophylaxis

ID Factor		None	ASsd	CTsd	CTsd, ASsd	S	S, ASsd	S, CTsd	S, CTsd, ASsd
0.75	None	13.8	6.7	3.6	2.5	1.6	1.6	1.3	1.2
	T	6.0	2.4	1.8	1.6	1.3	1.3	1.2	1.1
	Q	4.0	2.4	1.7	1.6	1.4	1.4	1.3	1.2
	P	3.0	1.9	1.5	1.4	1.3	1.3	1.0	1.2
	Q,T	2.1	1.7	1.3	1.4	1.4	1.2	1.2	0.0
	Q,P	2.4	1.4	1.6	1.4	1.2	1.2	1.4	1.2
	Pex	1.9	1.5	1.3	1.3	1.3	1.3	1.4	0.0
	Q,Pex	1.8	1.4	1.2	1.2	1.3	1.2	0.0	0.0
1.00	None	39.8	27.8	26.8	16.2	8.3	4.9	1.6	1.4
	T	31.1	18.7	13.2	6.2	3.5	2.0	1.3	1.3
	Q	24.6	14.0	7.2	4.6	3.1	2.4	1.6	1.5
	P	21.8	9.6	4.5	3.2	2.1	1.7	1.3	1.2
	Q,T	16.5	7.7	3.4	2.6	1.9	1.8	1.2	1.4
	Q,P	14.0	5.5	2.5	2.4	1.7	1.5	1.4	1.3
	Pex	9.6	4.6	2.9	2.2	1.6	1.5	1.6	1.2
	Q,Pex	5.4	3.1	2.1	1.7	1.7	1.5	1.2	1.2
1.25	None	54.7	40.0	44.8	32.7	36.3	23.0	2.9	1.9
	T	47.1	33.1	34.7	22.3	19.8	8.7	1.8	1.6
	Q	41.5	31.0	27.9	18.9	15.3	8.3	2.5	1.9
	P	37.8	25.5	21.6	11.6	7.2	3.8	1.5	1.3
	Q,T	34.3	23.2	16.9	9.3	6.1	3.5	1.6	1.4
	Q,P	31.4	19.6	11.2	6.7	4.3	2.9	1.5	1.4
	Pex	24.2	15.1	10.8	5.0	3.7	2.5	1.6	1.4
	Q,Pex	18.9	9.9	5.6	2.9	2.8	2.2	1.4	1.4
1.50	None	64.4	47.9	56.6	42.7	52.4	38.9	9.4	3.0
	T	58.1	41.6	48.3	34.4	40.0	26.3	3.3	1.9
	Q	52.3	40.6	42.2	32.6	34.8	24.7	5.2	2.8
	P	48.4	34.4	36.9	25.3	24.8	11.4	2.2	1.7
	Q,T	45.8	33.6	33.4	22.5	22.0	10.2	2.5	1.9
	Q,P	42.1	29.7	27.8	17.4	14.7	6.6	1.9	1.8
	Pex	33.6	23.1	23.8	13.7	10.7	5.4	2.0	1.4
	Q,Pex	29.2	19.0	14.2	8.3	6.5	3.8	1.8	1.6
2.00	None	76.8	58.1	71.3	55.3	70.5	57.8	43.5	12.4
	T	72.2	52.3	65.3	48.4	63.5	49.0	21.5	4.3
	Q	66.7	52.9	59.8	48.3	58.0	47.6	28.1	10.8
	P	63.3	45.5	55.2	40.3	51.4	36.8	7.3	2.8
	Q,T	60.7	46.2	52.4	39.5	49.0	36.4	9.3	3.8
	Q,P	56.3	41.7	47.2	34.2	43.3	29.2	5.5	2.9
	Pex	46.8	33.4	39.7	27.8	34.4	22.4	4.8	2.5
	Q,Pex	42.2	29.9	33.0	22.4	27.5	15.8	3.8	2.6
2.50	None	83.8	64.5	79.6	62.7	80.2	68.7	63.7	31.7
	T	80.2	59.3	75.1	56.7	75.3	61.8	49.2	11.1
	Q	75.5	60.6	70.5	57.6	70.6	60.6	52.0	28.6
	P	72.7	52.7	66.5	49.3	65.6	51.3	30.5	5.6
	Q,T	70.4	54.2	64.0	50.0	63.6	51.2	34.2	9.6
	Q,P	65.7	49.4	59.4	44.4	58.2	45.1	22.2	5.6
	Pex	56.1	40.7	50.6	36.2	48.0	35.9	15.8	4.1
	Q,Pex	51.0	37.4	44.7	31.9	41.9	29.9	11.4	4.1
3.00	None	88.0	69.2	84.8	68.1	85.7	75.3	74.6	46.5
	T	85.4	64.0	81.6	62.5	82.2	69.7	64.6	25.2
	Q	81.3	65.9	77.4	64.0	78.2	68.7	65.4	43.5
	P	79.0	58.3	74.3	55.8	74.6	61.0	50.3	10.9
	Q,T	76.8	60.1	72.2	57.2	72.5	61.3	52.9	21.7
	Q,P	72.6	55.0	67.8	51.3	68.0	55.3	42.5	10.6
	Pex	63.2	45.7	58.5	42.6	57.3	44.7	32.6	7.3
	Q,Pex	58.0	42.8	52.6	38.4	51.4	39.2	26.0	6.3

Note: For Ferguson-like disease manifestation, implementation threshold 10 diagnosed, and 700 doses of 50-percent efficacy pre-pandemic vaccine given to children and teens. Case-based strategy combinations downward, network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent.

Table 4-14: Children and teenager targeted pre-pandemic vaccination infection attack rates, regionally mitigated, 60-percent compliance

S - Schools closed	**CTsd** - Child/Teen social distancing	**ASsd** - Adult/Senior social distancing	**Q** - Household Quantine	**T** - Antiviral Treatment	**P** - Antiviral Prophylaxis	**PEx** - Extended Antiviral Prophylaxis

ID Factor		None	ASsd	CTsd	CTsd, ASsd	S	S, ASsd	S, CTsd	S, CTsd, ASsd
0.75	None	15.9	13.6	12.4	9.6	1.7	1.6	1.3	1.5
	T	5.5	4.6	4.3	2.8	1.2	1.4	1.2	1.1
	Q	9.2	8.4	5.8	6.6	1.5	1.4	1.3	1.3
	P	3.0	2.6	2.7	2.2	1.2	1.2	1.2	1.2
	Q,T	3.7	2.6	2.9	2.5	1.3	1.4	1.2	1.4
	Q,P	2.5	2.1	1.9	1.9	1.3	1.2	1.1	1.2
	Pex	1.9	1.8	1.7	1.8	1.1	1.3	1.1	1.3
	Q,Pex	1.4	1.6	1.6	1.6	1.0	1.5	1.2	0.0
1.00	None	40.5	36.6	39.1	34.6	12.5	8.4	2.9	2.1
	T	30.8	27.6	27.5	23.5	3.7	2.9	1.7	1.6
	Q	34.8	33.4	33.7	31.1	6.8	4.5	2.6	2.4
	P	21.9	19.4	18.2	13.6	2.2	2.1	1.4	1.4
	Q,T	23.0	22.6	22.1	18.7	2.4	2.0	1.6	1.6
	Q,P	18.3	16.0	15.1	11.3	2.2	2.0	1.4	1.3
	Pex	10.1	8.0	6.9	5.6	1.9	1.6	1.4	1.4
	Q,Pex	7.3	5.8	5.5	4.2	1.5	1.6	1.5	1.4
1.25	None	54.7	49.7	53.8	48.4	40.1	33.8	19.6	11.3
	T	47.1	41.9	45.0	39.8	24.9	16.3	4.6	3.6
	Q	49.5	47.1	48.8	46.0	30.9	27.7	15.8	11.4
	P	39.5	35.0	36.8	32.1	12.3	7.5	2.8	2.1
	Q,T	41.2	38.0	39.8	35.7	14.8	10.8	4.0	2.9
	Q,P	34.8	32.4	33.1	29.3	7.6	5.2	2.6	2.1
	Pex	25.7	22.2	23.5	19.3	4.6	3.6	2.0	1.8
	Q,Pex	22.8	20.5	20.5	16.0	3.5	3.1	1.8	1.8
1.50	None	65.1	58.9	63.6	58.0	55.8	49.8	42.2	32.6
	T	58.1	51.6	56.6	50.2	44.8	37.8	23.2	11.9
	Q	59.8	56.9	59.4	55.8	49.6	44.9	38.1	32.1
	P	50.9	44.9	48.8	43.1	33.3	26.2	9.7	4.5
	Q,T	52.3	48.8	51.3	47.7	36.4	30.8	19.2	11.2
	Q,P	46.6	42.8	45.1	40.9	26.8	19.9	7.9	4.6
	Pex	35.4	31.1	33.8	29.4	18.8	11.8	5.2	3.0
	Q,Pex	32.5	29.2	30.7	27.0	13.4	9.1	3.6	3.0
2.00	None	77.1	70.3	76.1	70.0	73.4	68.5	65.9	58.1
	T	72.2	64.4	70.6	63.7	66.9	60.3	54.7	43.7
	Q	72.9	69.5	72.4	69.0	68.6	65.3	62.9	57.9
	P	65.5	58.1	63.8	57.0	57.8	50.9	43.2	30.3
	Q,T	66.9	62.8	66.3	62.0	60.3	55.9	50.7	43.7
	Q,P	61.2	56.5	60.5	55.6	53.0	47.3	39.3	30.0
	Pex	48.6	42.8	47.6	41.5	39.9	34.3	25.0	14.9
	Q,Pex	45.5	41.4	44.8	40.0	36.2	31.0	23.0	15.0
2.50	None	84.2	77.8	83.0	77.6	82.5	78.2	77.8	71.6
	T	80.4	72.6	79.1	72.2	77.8	72.1	70.5	61.5
	Q	80.7	77.3	80.4	77.0	78.9	76.1	75.2	71.2
	P	74.7	66.9	73.4	66.3	71.0	64.7	61.5	50.9
	Q,T	76.1	71.6	75.3	71.2	73.0	68.7	67.1	61.1
	Q,P	71.0	65.8	70.1	65.2	66.8	61.7	58.9	50.7
	Pex	57.8	50.9	56.8	50.3	53.3	46.8	42.8	32.9
	Q,Pex	54.7	49.8	54.1	48.9	49.5	44.2	40.5	32.7
3.00	None	88.4	82.9	87.6	82.6	87.5	84.0	84.6	79.3
	T	85.6	78.3	84.3	78.0	84.1	79.4	79.5	72.0
	Q	85.8	82.5	85.2	82.3	84.7	82.3	82.4	79.4
	P	81.0	73.1	79.8	72.8	78.8	73.3	72.6	63.6
	Q,T	81.8	77.6	81.3	77.5	80.2	76.9	76.4	71.6
	Q,P	77.7	72.4	76.9	72.3	75.3	71.1	70.0	63.1
	Pex	64.8	57.1	63.8	56.9	61.9	55.7	53.9	44.5
	Q,Pex	62.0	56.2	61.3	55.8	58.5	53.5	51.7	44.0

Note: For Ferguson-like disease manifestation, implementation threshold 10 diagnosed, and 700 doses of 50-percent efficacy pre-pandemic vaccine given to children and teens. Case-based strategy combinations downward, network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent.

Table 4-15: Children and teenager targeted pre-pandemic vaccination infection attack rates, regionally unmitigated, 90-percent compliance

S - Schools closed	CTsd - Child/Teen social distancing	ASsd - Adult/Senior social distancing	Q - Household Quantine	T - Antiviral Treatment	P - Antiviral Prophylaxis	PEx - Extended Antiviral Prophylaxis

ID Factor		None	ASsd	CTsd	CTsd, ASsd	S	S, ASsd	S, CTsd	S, CTsd, ASsd
0.75	None	17.0	8.8	8.9	4.5	4.5	2.8	2.8	2.0
	T	9.8	4.6	5.4	2.8	3.4	2.1	2.3	1.7
	Q	8.3	4.0	5.4	3.0	3.7	2.4	2.8	2.1
	P	6.3	3.1	4.1	2.4	2.8	2.0	2.2	1.8
	Q,T	5.6	2.8	3.7	2.4	3.0	2.0	2.3	1.7
	Q,P	5.2	2.7	3.6	2.2	2.8	1.9	2.2	1.7
	Pex	4.6	2.7	3.6	2.3	2.7	1.9	2.2	1.7
	Q,Pex	3.9	2.3	3.1	2.1	2.6	1.9	2.1	1.7
1.00	None	40.7	28.8	30.1	20.7	19.8	11.2	8.4	4.1
	T	32.9	22.3	22.2	13.2	13.6	6.9	6.6	3.4
	Q	29.3	19.1	19.8	11.6	13.5	7.4	7.8	4.1
	P	25.5	15.6	15.8	7.8	9.8	5.1	5.9	3.2
	Q,T	23.5	13.4	14.4	7.5	10.1	5.3	6.3	3.4
	Q,P	20.9	11.3	12.7	6.4	8.8	4.7	5.8	3.1
	Pex	16.7	9.2	11.4	6.1	8.0	4.4	5.4	3.1
	Q,Pex	13.9	7.2	9.8	5.1	7.2	4.2	5.3	3.0
1.25	None	54.7	41.1	46.6	34.6	39.2	27.2	17.0	7.8
	T	48.4	34.9	38.9	26.7	30.2	18.2	12.8	5.9
	Q	44.5	33.2	35.6	25.3	28.8	18.5	15.8	7.8
	P	40.4	28.2	30.8	19.5	21.9	11.9	10.8	5.3
	Q,T	38.2	26.9	28.4	18.4	21.9	12.2	12.1	6.0
	Q,P	34.8	23.5	25.2	15.0	18.9	10.3	10.7	5.3
	Pex	27.8	18.8	20.6	12.9	15.2	8.7	9.4	4.9
	Q,Pex	23.8	15.4	17.9	10.2	13.7	7.9	9.3	5.0
1.50	None	64.6	48.8	57.7	44.5	54.0	41.5	28.6	13.7
	T	59.1	43.4	51.0	38.0	45.6	32.1	21.5	9.7
	Q	54.8	42.8	47.9	37.0	43.2	31.8	26.0	13.5
	P	51.0	37.3	42.6	30.1	35.4	22.5	17.8	8.3
	Q,T	49.1	36.8	41.0	29.7	34.9	23.0	19.8	9.9
	Q,P	45.4	33.0	36.9	25.1	30.7	18.8	16.9	8.2
	Pex	36.9	26.5	30.0	20.5	24.0	15.6	14.5	7.5
	Q,Pex	32.8	23.2	26.2	16.9	21.6	13.4	14.1	7.3
2.00	None	76.6	58.7	71.6	56.3	71.4	58.8	50.6	27.8
	T	72.6	54.2	66.7	50.9	65.3	51.7	40.6	19.1
	Q	68.8	55.3	63.8	51.5	62.1	51.0	45.8	27.5
	P	65.2	48.7	58.9	44.3	56.0	42.2	33.0	15.4
	Q,T	63.3	49.5	57.6	44.6	55.1	42.6	36.4	19.1
	Q,P	59.0	45.1	53.1	39.7	49.6	37.0	31.2	15.3
	Pex	50.2	37.1	44.2	32.5	39.5	28.3	24.1	12.8
	Q,Pex	45.5	33.8	39.5	28.7	35.1	24.7	23.2	12.6
2.50	None	83.6	65.2	79.9	63.9	80.5	69.0	66.2	41.8
	T	80.7	60.9	76.2	59.0	76.2	63.2	57.2	30.8
	Q	77.2	63.0	73.4	60.6	73.2	62.7	61.0	41.7
	P	74.2	56.0	69.4	53.3	68.4	54.9	47.7	24.3
	Q,T	72.4	57.5	68.3	54.3	67.5	55.5	51.9	30.5
	Q,P	68.2	53.2	63.6	49.4	62.5	50.0	45.3	24.1
	Pex	59.4	44.6	54.2	41.0	51.2	39.6	33.6	18.7
	Q,Pex	54.8	41.6	49.5	37.2	46.5	35.4	32.4	18.7
3.00	None	87.9	69.6	84.9	68.9	85.8	75.6	75.6	52.5
	T	85.6	65.6	81.9	64.3	82.7	71.0	68.6	41.1
	Q	82.5	68.1	79.6	66.6	80.1	70.5	71.0	52.4
	P	80.3	61.3	76.3	59.5	76.4	63.6	59.4	33.3
	Q,T	78.5	63.2	75.2	61.2	75.1	64.1	63.2	41.0
	Q,P	74.6	59.0	71.1	56.2	70.9	59.2	56.3	33.1
	Pex	66.1	50.1	61.7	47.3	59.9	47.7	42.7	24.3
	Q,Pex	61.5	47.3	57.5	43.9	55.3	43.8	40.6	24.6

Note: For Ferguson-like disease manifestation, implementation threshold 10 diagnosed, and 700 doses of 50-percent efficacy pre-pandemic vaccine given to children and teens. Case-based strategy combinations downward, network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent.

Table 4-16: Children and teenager targeted pre-pandemic vaccination infection attack rates, regionally unmitigated, 60-percent compliance

S - Schools closed	**CTsd** - Child/Teen social distancing	**ASsd** - Adult/Senior social distancing	**Q** - Household Quantine	**T** - Antiviral Treatment	**P** - Antiviral Prophylaxis	**PEx** - Extended Antiviral Prophylaxis

ID Factor		None	ASsd	CTsd	CTsd, ASsd	S	S, ASsd	S, CTsd	S, CTsd, ASsd
0.75	None	18.1	15.7	16.1	12.0	4.7	3.2	3.5	2.6
	T	9.7	7.3	8.4	5.5	3.6	2.4	2.9	2.0
	Q	13.2	10.6	12.3	8.7	4.4	3.0	3.5	2.4
	P	6.7	4.6	6.0	3.6	3.1	2.2	2.6	2.0
	Q,T	7.2	4.5	6.7	4.4	3.2	2.3	2.8	2.0
	Q,P	5.6	3.4	5.1	3.3	3.0	2.2	2.6	1.9
	Pex	4.5	2.9	4.4	2.9	3.0	2.2	2.5	1.9
	Q,Pex	4.1	2.9	3.9	2.7	2.8	2.1	2.5	1.9
1.00	None	40.8	36.5	39.5	34.7	21.7	15.1	13.3	7.8
	T	33.0	28.7	31.1	25.7	15.1	9.6	9.5	5.6
	Q	36.2	33.3	35.5	31.7	17.8	12.4	12.9	8.0
	P	27.6	22.5	25.0	19.0	11.5	7.1	8.0	4.7
	Q,T	27.8	24.7	26.9	21.6	12.4	8.0	9.2	5.6
	Q,P	23.9	19.5	21.7	16.4	10.6	6.5	8.0	4.8
	Pex	17.6	13.7	16.2	11.6	9.2	5.8	7.1	4.4
	Q,Pex	15.7	11.3	14.7	9.6	8.6	5.4	7.0	4.3
1.25	None	54.7	49.3	53.5	48.0	41.9	34.4	28.9	20.0
	T	48.2	42.4	46.4	40.3	32.8	24.6	20.8	13.2
	Q	50.6	46.9	50.0	45.6	36.7	30.3	28.0	20.6
	P	42.5	36.4	40.5	34.4	25.5	17.7	17.0	10.3
	Q,T	43.4	39.2	42.9	37.6	27.7	20.3	20.2	12.6
	Q,P	38.9	33.9	37.2	31.7	23.1	15.6	16.6	10.0
	Pex	29.3	25.1	28.1	22.4	17.9	12.1	13.2	8.4
	Q,Pex	26.9	22.5	25.8	20.8	16.6	11.1	13.0	8.5
1.50	None	64.6	58.2	63.4	57.0	56.5	49.5	45.3	35.2
	T	58.9	52.1	57.5	50.8	48.4	39.8	35.4	24.8
	Q	60.4	56.2	60.0	55.6	51.3	45.0	43.9	35.6
	P	52.9	46.3	51.1	44.3	40.6	31.8	28.8	19.0
	Q,T	54.2	49.4	53.7	48.2	42.8	35.3	33.8	24.4
	Q,P	49.5	44.0	48.3	42.5	36.9	28.4	27.7	19.0
	Pex	38.9	33.2	37.6	31.4	28.0	20.9	20.9	13.6
	Q,Pex	36.4	31.4	35.5	29.9	25.8	19.4	20.4	13.6
2.00	None	76.8	69.4	75.7	69.0	73.3	67.2	66.3	57.4
	T	72.6	64.4	71.3	63.6	67.7	60.1	58.1	46.9
	Q	73.3	68.6	72.8	68.4	69.2	64.3	64.2	57.3
	P	67.1	58.9	65.8	58.1	60.7	52.9	50.3	37.8
	Q,T	68.4	62.9	67.9	62.5	62.5	56.5	56.1	46.8
	Q,P	63.8	57.7	63.0	56.8	56.8	49.5	48.9	38.3
	Pex	52.1	45.0	50.6	43.9	44.0	36.9	35.3	26.1
	Q,Pex	49.1	43.5	48.6	42.7	41.1	34.8	34.3	26.0
2.50	None	83.8	76.9	82.9	76.7	82.2	77.2	77.7	70.2
	T	80.7	72.4	79.3	72.0	78.1	71.9	71.8	62.2
	Q	80.9	76.5	80.6	76.2	79.1	74.9	76.1	70.4
	P	76.0	67.7	74.7	67.0	72.4	65.4	65.0	53.9
	Q,T	77.1	71.5	76.5	71.2	74.0	68.7	69.6	62.2
	Q,P	72.8	66.6	72.3	66.3	69.0	62.8	63.2	54.3
	Pex	61.2	53.1	59.9	52.5	55.6	48.6	47.4	37.7
	Q,Pex	58.5	51.9	57.9	51.2	52.8	46.2	46.4	37.4
3.00	None	88.0	81.7	87.2	81.8	87.2	83.0	84.2	78.2
	T	85.6	77.8	84.5	77.5	84.2	79.0	80.0	71.7
	Q	85.8	81.6	85.2	81.5	84.7	81.5	82.7	78.2
	P	81.9	73.6	80.7	73.4	79.8	73.7	74.2	64.8
	Q,T	82.6	77.5	82.1	77.2	80.9	76.6	77.8	71.6
	Q,P	79.0	73.0	78.4	72.7	76.8	71.6	72.6	64.8
	Pex	67.8	59.5	66.9	58.9	63.8	56.9	56.7	47.2
	Q,Pex	65.4	58.4	64.8	58.1	61.2	54.8	55.5	47.2

Note: For Ferguson-like disease manifestation, implementation threshold 10 diagnosed, and 700 doses of 50-percent efficacy pre-pandemic vaccine given to children and teens. Case-based strategy combinations downward, network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent.

4.2.4 Age Class Balanced Transmission

Glass et al. (2006)[43] found that removal of enhanced transmission for the young reduced the efficacy of targeted social distancing of children and teenagers and, in order to contain infection, required the implementation of social distancing within adult groups as well. The earlier analysis evaluated containment strategy robustness in light of the removal of enhanced relative infectivity and susceptibility (both set to 1.0), the increase of contacts within the work environment (by a factor of 4.0) to put adults on par with children and teens at school, and the combination of both. Only the age class balanced uniform transmission combination, given by applying both, is analyzed here. While the team believes these 2 characteristics are unlikely to occur even separately, their combination forms a bounding scenario. For this situation, the team ran the full containment strategy combination matrix with the Ferguson-like disease manifestation.

Tables 4-17 through 4-20 show the infection attack rate zones with less than 10 percent and with 10 to 25 percent colored green and pink, respectively. Those strategy combinations that rely on the social distancing of children and teenagers decrease in efficacy while those that rely on social distancing of adults increase. While the model showed roughly the same number of strategy combinations in the pink and green zones in each *IDfactor* region of the 90- and 60-percent compliance levels for the regionally uniform policy (Tables 4-17 and 4-18), degradation of efficacy is significant when the community is in contact with an unmitigated regional epidemic within surrounding communities (Tables 4-19 and 4-20). This degradation results from the increase (by the factor of 4) in the number of contacts within the work environment, all of which were assumed to take place with adults from surrounding communities where the epidemic remains unchecked.

The increased sensitivity of the unmitigated epidemic attack rate to *IDfactor* is also of interest. At *IDfactor* 0.75, the unmitigated epidemic only attacks 7 percent of the population (rather than 28 percent as seen for the transmission network emphasizing children and teenagers), and at *IDfactor* 1.5, 78 percent are infected (rather than 71 percent as seen for the transmission network emphasizing children and teenagers).

[43] Glass et al., 2006 (See Footnote 3)

Table 4-17: Uniform transmission infection attack rates, regionally mitigated, 90-percent compliance

S - Schools closed	**CTsd** - Child/Teen social distancing	**ASsd** - Adult/Senior social distancing	**Q** - Household Quantine	**T** - Antiviral Treatment	**P** - Antiviral Prophylaxis	**PEx** - Extended Antiviral Prophylaxis

ID Factor		None	ASsd	CTsd	CTsd, ASsd	S	S, ASsd	S, CTsd	S, CTsd, ASsd
0.75	None	7.6	2.3	4.2	1.5	2.0	1.4	1.3	1.2
	T	2.3	1.4	1.7	1.2	1.5	1.2	1.2	1.2
	Q	2.2	1.4	1.6	1.3	1.5	1.2	1.4	1.2
	P	1.8	1.4	1.4	1.5	1.3	1.1	1.2	1.1
	Q,T	1.5	1.3	1.5	1.2	1.3	1.4	1.2	1.0
	Q,P	1.6	1.2	1.3	1.2	1.3	1.1	1.2	1.2
	Pex	1.3	1.3	1.4	1.3	1.3	1.2	1.0	0.0
	Q,Pex	1.4	1.2	1.4	1.2	1.2	1.1	1.0	1.1
1.00	None	48.8	17.1	41.8	9.1	21.9	3.2	3.5	1.4
	T	34.0	4.8	24.3	2.9	5.3	1.9	2.0	1.3
	Q	25.5	3.6	13.3	2.8	4.5	2.1	2.3	1.4
	P	19.7	2.6	8.7	1.9	2.9	1.5	1.6	1.3
	Q,T	14.5	2.4	5.6	1.8	2.5	1.6	1.7	1.3
	Q,P	10.1	2.0	4.4	1.6	2.3	1.5	1.6	1.2
	Pex	6.8	1.9	3.3	1.5	1.8	1.4	1.3	1.2
	Q,Pex	3.8	1.6	2.4	1.4	1.9	1.4	1.4	1.2
1.25	None	67.9	41.6	63.2	34.1	51.2	21.5	25.6	2.7
	T	58.8	28.3	52.3	17.7	36.5	5.5	7.8	1.8
	Q	49.4	21.1	44.0	12.9	29.7	6.1	9.2	2.5
	P	46.3	12.1	38.5	6.5	18.1	2.7	3.7	1.4
	Q,T	41.4	9.3	32.5	4.6	14.3	2.9	3.5	1.6
	Q,P	38.1	6.8	26.6	3.5	9.2	2.5	2.9	1.5
	Pex	28.7	5.2	20.7	3.3	6.1	2.1	2.5	1.4
	Q,Pex	20.9	3.5	11.9	2.4	4.1	1.9	2.2	1.5
1.50	None	78.1	55.9	74.6	51.7	66.8	44.9	48.6	6.8
	T	71.9	44.8	67.6	38.4	56.6	25.6	31.4	2.7
	Q	63.2	40.9	59.3	34.2	50.0	24.9	31.4	4.8
	P	60.8	30.5	55.2	21.1	42.3	8.4	16.3	2.1
	Q,T	55.8	28.3	51.0	17.3	38.4	8.5	15.1	2.4
	Q,P	52.2	21.9	46.3	11.3	31.9	5.5	9.5	1.9
	Pex	42.4	16.4	37.1	9.8	23.3	4.7	6.4	1.9
	Q,Pex	36.5	9.6	28.8	5.1	14.9	3.4	4.9	1.9
2.00	None	88.6	71.5	86.2	69.7	82.5	68.3	71.0	38.2
	T	85.1	63.7	82.1	61.0	76.4	57.5	60.2	11.8
	Q	77.9	61.1	75.9	57.9	71.5	55.2	60.2	28.2
	P	76.1	52.6	72.9	47.2	65.2	40.4	48.0	5.3
	Q,T	71.9	51.5	69.3	46.4	62.9	40.8	47.7	8.9
	Q,P	67.2	44.6	64.3	37.8	57.5	30.5	40.8	4.4
	Pex	58.8	36.2	54.9	0.0	46.2	23.9	29.3	4.0
	Q,Pex	52.9	29.8	48.6	22.9	39.8	15.1	24.2	3.7
2.50	None	93.3	79.3	91.6	78.4	89.7	79.3	81.9	59.6
	T	91.2	73.8	89.0	72.4	85.9	72.0	74.4	40.0
	Q	85.8	72.4	84.4	70.5	81.6	70.1	74.5	52.2
	P	84.4	64.5	82.0	61.5	77.4	59.5	63.9	19.3
	Q,T	80.8	64.2	79.0	61.1	75.2	59.5	65.2	29.1
	Q,P	76.0	57.3	74.2	54.0	69.8	51.3	57.8	14.6
	Pex	68.9	47.9	66.0	0.0	59.2	41.0	45.4	9.5
	Q,Pex	62.9	41.7	60.0	37.2	53.9	33.4	40.2	7.7
3.00	None	95.8	83.8	94.5	83.3	93.4	85.4	87.7	71.5
	T	94.5	79.6	92.7	78.7	90.8	80.1	82.4	57.2
	Q	90.4	78.8	89.3	77.9	87.7	78.6	82.5	66.1
	P	89.5	71.8	87.6	70.3	84.3	70.2	73.7	39.1
	Q,T	86.4	72.1	85.0	70.3	82.6	70.5	75.0	48.4
	Q,P	81.8	65.5	80.5	63.4	77.5	63.1	68.4	32.5
	Pex	75.8	55.9	73.3	0.0	68.0	51.9	55.1	22.0
	Q,Pex	69.9	50.5	67.4	47.3	62.4	45.8	50.9	16.9

Note: For Ferguson-like disease manifestation and implementation threshold 10 diagnosed. Case-based strategy combinations downward, network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent.

Table 4-18: Uniform transmission infection attack rates, regionally mitigated, 60-percent compliance

S - Schools closed	**CTsd** - Child/Teen social distancing	**ASsd** - Adult/Senior social distancing	**Q** - Household Quantine	**T** - Antiviral Treatment	**P** - Antiviral Prophylaxis	**PEx** - Extended Antiviral Prophylaxis

ID Factor		None	ASsd	CTsd	CTsd, ASsd	S	S, ASsd	S, CTsd	S, CTsd, ASsd
0.75	None	10.1	3.4	10.2	3.5	2.2	1.7	1.7	1.3
	T	2.9	1.8	2.8	1.8	1.5	1.5	1.2	1.1
	Q	4.1	2.6	5.4	2.3	1.9	1.6	1.7	1.4
	P	1.7	1.4	1.8	1.5	1.3	1.3	1.4	1.3
	Q,T	2.2	1.3	2.4	1.5	1.3	1.3	1.3	1.3
	Q,P	1.7	1.3	2.1	1.5	1.3	1.1	1.2	1.2
	Pex	1.6	1.3	1.5	1.3	1.3	1.2	1.1	1.1
	Q,Pex	1.4	1.2	1.4	1.3	1.3	1.2	1.1	1.0
1.00	None	49.6	36.2	50.1	34.2	34.0	14.4	20.5	5.0
	T	34.6	15.9	35.1	13.5	12.2	3.2	4.0	1.9
	Q	40.9	30.7	42.0	29.0	24.8	10.1	12.5	4.9
	P	23.4	7.7	21.7	4.7	4.9	2.0	2.6	1.6
	Q,T	24.6	9.6	25.9	8.3	6.2	2.7	3.2	1.9
	Q,P	15.9	4.7	13.6	4.6	3.3	2.0	2.6	1.6
	Pex	7.1	2.9	6.7	2.5	2.2	1.8	1.8	1.5
	Q,Pex	3.9	2.7	4.3	2.1	2.1	1.6	1.6	1.4
1.25	None	68.6	57.8	68.8	56.7	58.9	47.1	50.4	34.4
	T	58.7	44.5	58.7	43.0	45.3	28.0	33.2	9.5
	Q	61.1	53.9	62.0	52.9	51.9	41.9	45.4	33.2
	P	49.3	33.5	48.8	30.3	33.0	11.3	18.1	4.3
	Q,T	50.4	39.6	51.0	38.4	36.4	21.0	25.9	8.8
	Q,P	43.1	29.6	42.7	25.7	27.0	8.2	14.4	3.7
	Pex	30.3	15.1	29.9	12.8	14.0	4.6	5.3	2.2
	Q,Pex	25.3	10.8	24.7	9.4	8.8	3.7	4.9	2.4
1.50	None	78.9	70.2	78.8	69.6	72.7	64.0	66.6	54.9
	T	72.0	60.3	72.0	59.1	63.2	50.8	54.1	35.9
	Q	72.8	67.3	73.2	67.1	66.6	60.1	62.5	53.9
	P	63.2	50.1	63.1	49.1	52.7	37.7	42.6	19.3
	Q,T	64.0	56.1	64.9	56.0	55.9	45.1	49.5	34.5
	Q,P	57.8	46.8	57.9	45.8	48.2	33.4	39.4	19.4
	Pex	44.0	31.7	44.0	29.8	33.6	17.6	24.4	7.2
	Q,Pex	39.6	28.7	40.2	26.8	28.8	14.4	19.0	6.1
2.00	None	89.4	82.9	88.8	82.7	86.0	80.8	82.4	75.7
	T	85.5	76.9	84.9	76.2	80.8	73.3	75.3	64.7
	Q	85.0	81.4	85.3	81.3	82.0	78.4	79.8	75.4
	P	78.7	68.6	78.4	68.4	73.2	63.7	67.0	53.6
	Q,T	79.5	74.3	80.0	74.0	75.2	69.7	71.7	64.4
	Q,P	73.5	66.4	73.8	65.9	68.4	61.0	64.0	53.1
	Pex	60.8	49.9	60.7	49.1	54.0	43.9	47.1	32.9
	Q,Pex	57.0	47.9	57.0	47.1	50.3	41.1	44.7	32.4
2.50	None	93.9	89.0	93.4	89.0	92.0	88.5	89.7	85.1
	T	91.6	84.8	91.0	84.5	88.8	83.6	85.3	78.2
	Q	91.1	88.2	91.1	88.2	89.3	86.8	87.9	85.0
	P	86.7	78.7	86.3	78.4	83.1	76.5	78.9	69.6
	Q,T	87.5	83.3	87.4	83.2	84.8	81.1	82.6	77.9
	Q,P	82.5	77.1	82.7	76.8	79.3	74.3	76.2	69.5
	Pex	70.9	61.0	70.6	60.5	65.6	57.3	59.8	49.1
	Q,Pex	67.0	59.3	67.5	59.0	62.3	55.3	58.0	49.0
3.00	None	96.3	92.5	95.9	92.5	95.1	92.6	93.6	90.2
	T	94.7	89.4	94.2	89.3	93.0	89.2	90.5	85.5
	Q	94.4	92.0	94.3	92.0	93.3	91.3	92.2	90.0
	P	91.3	84.7	90.9	84.5	88.7	83.8	85.7	78.9
	Q,T	91.9	88.5	91.7	88.5	90.1	87.3	88.5	85.1
	Q,P	88.0	83.6	87.9	83.5	85.8	81.9	83.5	78.7
	Pex	77.4	68.5	77.3	68.4	73.4	66.3	68.5	59.6
	Q,Pex	73.9	67.4	74.2	67.2	70.5	64.4	66.6	59.1

Note: For Ferguson-like disease manifestation and implementation threshold 10 diagnosed. Case-based strategy combinations downward, network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent.

Table 4-19: Uniform transmission infection attack rates, regionally unmitigated, 90-percent compliance

S - Schools closed	**CTsd** - Child/Teen social distancing	**ASsd** - Adult/Senior social distancing	**Q** - Household Quantine	**T** - Antiviral Treatment	**P** - Antiviral Prophylaxis	**PEx** - Extended Antiviral Prophylaxis

ID Factor		None	ASsd	CTsd	CTsd, ASsd	S	S, ASsd	S, CTsd	S, CTsd, ASsd
0.75	None	17.9	8.5	15.4	7.5	11.5	5.9	9.1	4.7
	T	13.8	6.6	12.6	6.0	9.8	4.9	7.8	4.1
	Q	14.1	6.8	13.0	6.5	10.5	5.6	8.8	4.7
	P	11.9	5.7	11.0	5.4	8.7	4.6	7.3	3.9
	Q,T	11.9	5.8	11.1	5.6	8.9	4.7	7.7	4.1
	Q,P	11.2	5.4	10.5	5.2	8.4	4.5	7.3	3.9
	Pex	10.5	5.3	10.0	5.2	8.1	4.4	7.0	3.9
	Q,Pex	10.0	5.1	9.7	4.9	7.9	4.3	6.9	3.9
1.00	None	46.2	27.5	41.4	24.0	33.6	18.8	24.8	12.8
	T	39.6	21.6	35.4	19.0	28.2	15.2	21.1	10.8
	Q	37.2	21.1	34.5	19.3	28.7	16.1	23.6	12.7
	P	33.1	17.2	30.0	15.9	24.4	12.9	19.5	10.0
	Q,T	32.1	17.3	30.0	15.9	24.7	13.3	20.5	10.7
	Q,P	30.2	15.8	27.7	14.7	23.0	12.4	19.0	10.1
	Pex	25.5	14.0	24.2	13.2	20.1	11.4	17.0	9.3
	Q,Pex	24.0	13.3	22.8	12.7	19.2	10.9	16.7	9.3
1.25	None	64.7	44.6	60.5	40.9	53.1	35.0	40.8	22.4
	T	58.6	38.0	54.4	34.5	46.2	28.3	35.3	18.8
	Q	54.5	36.5	51.7	33.5	45.5	29.3	38.4	22.2
	P	50.4	31.2	46.8	28.1	39.6	23.4	31.6	17.1
	Q,T	48.6	30.8	46.2	28.2	39.9	24.4	33.1	18.7
	Q,P	45.2	27.8	42.5	25.4	36.6	21.9	30.5	17.0
	Pex	37.7	23.0	35.8	21.6	30.2	18.7	25.9	14.8
	Q,Pex	34.8	21.3	33.3	20.1	28.7	17.9	25.2	14.8
1.50	None	76.2	57.2	72.9	53.9	67.3	49.7	54.7	33.2
	T	71.5	51.1	67.7	47.9	60.9	42.3	48.4	27.7
	Q	66.7	49.4	64.6	46.9	59.5	42.8	51.6	32.7
	P	63.0	43.8	59.7	40.3	53.1	35.1	43.3	25.0
	Q,T	60.6	43.2	58.6	40.4	53.1	36.2	45.2	27.7
	Q,P	56.7	39.2	54.6	36.6	49.2	32.4	41.5	24.7
	Pex	48.6	32.4	46.3	30.3	40.1	26.6	34.2	20.9
	Q,Pex	44.6	29.6	43.1	28.2	37.8	25.1	33.2	20.6
2.00	None	87.7	71.3	85.3	69.7	82.5	69.0	72.7	51.4
	T	84.9	66.7	82.2	64.7	78.0	62.5	66.4	44.3
	Q	80.2	65.9	79.0	64.3	75.6	62.1	69.0	51.0
	P	77.9	59.6	75.3	57.4	70.1	53.8	59.8	39.0
	Q,T	75.1	60.0	73.7	57.7	69.9	54.9	62.3	43.5
	Q,P	70.5	55.0	69.2	52.6	64.9	49.8	57.0	38.7
	Pex	63.7	46.4	61.3	44.2	54.9	40.0	46.8	31.1
	Q,Pex	58.2	42.8	56.7	40.9	51.2	37.5	45.3	30.7
2.50	None	93.0	78.8	91.3	77.9	89.7	79.2	82.4	64.3
	T	91.2	75.3	89.3	74.2	86.7	74.6	77.4	57.1
	Q	87.3	75.3	86.4	74.3	84.4	73.7	79.2	64.0
	P	86.0	69.6	83.9	68.0	80.3	66.5	70.8	51.0
	Q,T	83.1	70.2	82.1	68.6	79.6	67.6	73.4	56.3
	Q,P	78.7	65.1	77.7	63.7	74.6	61.8	67.6	50.2
	Pex	73.5	56.8	71.3	54.9	65.4	51.0	56.7	40.0
	Q,Pex	67.9	52.9	66.1	51.0	61.2	47.8	54.6	39.7
3.00	None	95.7	83.3	94.5	82.7	93.4	85.1	88.0	72.9
	T	94.5	80.3	93.0	79.6	91.4	81.4	84.0	66.3
	Q	91.4	80.8	90.6	80.2	89.2	80.6	85.3	72.3
	P	90.6	75.7	89.0	74.6	86.2	74.6	77.9	59.9
	Q,T	88.1	76.5	87.2	75.5	85.4	75.4	80.2	65.5
	Q,P	84.0	71.7	83.2	70.6	80.9	70.2	74.8	58.8
	Pex	80.1	64.1	78.0	62.4	72.8	59.6	64.0	47.3
	Q,Pex	74.2	60.4	73.0	58.7	68.6	56.0	61.6	46.8

Note: For Ferguson-like disease manifestation and implementation threshold 10 diagnosed. Case-based strategy combinations downward, network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent.

Table 4-20: Uniform transmission infection attack rates, regionally unmitigated, 60-percent compliance

S - Schools closed	**CTsd** - Child/Teen social distancing	**ASsd** - Adult/Senior social distancing	**Q** - Household Quantine	**T** - Antiviral Treatment	**P** - Antiviral Prophylaxis	**PEx** - Extended Antiviral Prophylaxis

ID Factor		None	ASsd	CTsd	CTsd, ASsd	S	S, ASsd	S, CTsd	S, CTsd, ASsd
0.75	None	17.4	10.4	17.6	10.1	12.3	7.3	10.7	6.3
	T	13.5	7.6	13.9	7.6	10.4	6.1	9.3	5.4
	Q	15.5	9.2	16.1	9.2	11.7	6.9	10.7	6.3
	P	11.9	6.8	12.3	6.8	9.7	5.7	8.7	5.1
	Q,T	12.4	7.3	13.2	7.0	10.0	6.0	9.1	5.6
	Q,P	11.5	6.6	11.8	6.4	9.4	5.7	8.6	5.2
	Pex	10.6	6.1	10.7	6.0	8.9	5.4	8.1	4.9
	Q,Pex	10.1	5.9	10.5	5.9	8.8	5.4	8.2	5.0
1.00	None	45.7	34.4	45.7	33.3	35.5	24.1	30.6	19.3
	T	38.8	26.7	39.0	25.8	30.2	19.7	26.0	16.0
	Q	41.3	31.4	42.3	30.6	32.9	22.2	29.8	19.3
	P	34.2	22.4	34.3	21.5	27.1	17.0	23.7	14.6
	Q,T	34.9	24.4	35.9	23.5	28.1	18.1	25.4	16.1
	Q,P	31.6	21.0	32.3	20.3	25.7	16.5	23.5	14.6
	Pex	26.5	17.3	27.0	16.7	22.6	14.4	20.6	13.0
	Q,Pex	25.4	16.6	25.9	16.2	21.8	14.1	20.4	13.0
1.25	None	64.1	53.1	64.3	52.1	55.4	43.0	49.3	35.5
	T	58.0	45.7	58.0	44.5	49.1	36.0	43.1	29.4
	Q	59.2	49.8	60.0	49.2	51.3	40.1	47.8	35.4
	P	51.9	39.0	51.9	37.7	43.7	30.9	38.8	25.9
	Q,T	52.8	42.0	53.8	41.2	45.5	33.3	41.6	29.2
	Q,P	48.2	36.8	48.9	35.9	41.6	29.4	38.1	25.9
	Pex	39.1	28.5	39.8	27.9	34.2	24.0	31.1	21.2
	Q,Pex	37.1	26.9	37.9	26.5	32.8	23.3	30.5	21.2
1.50	None	76.0	65.7	75.7	65.1	69.5	58.8	64.2	51.0
	T	71.2	59.3	71.1	58.4	64.2	51.6	57.9	43.5
	Q	71.4	62.9	72.1	62.8	65.6	55.6	62.3	50.7
	P	64.8	52.7	64.9	51.8	57.8	45.1	52.6	38.2
	Q,T	65.8	55.8	66.4	55.5	59.5	48.3	55.8	43.3
	Q,P	60.6	50.2	61.6	49.4	54.8	42.9	50.9	38.0
	Pex	50.5	38.8	50.8	38.2	44.8	33.9	41.1	29.9
	Q,Pex	47.8	37.2	48.6	36.7	43.0	32.7	40.2	29.6
2.00	None	87.9	79.6	87.3	79.4	84.6	76.9	80.8	70.9
	T	85.0	75.2	84.3	74.7	80.6	71.4	75.8	64.1
	Q	84.4	78.3	84.6	78.1	81.1	74.5	78.8	70.9
	P	79.7	69.4	79.5	68.7	75.0	64.6	70.3	57.8
	Q,T	80.4	73.0	80.7	72.8	76.5	68.2	73.7	64.1
	Q,P	75.6	67.2	76.2	67.0	71.5	62.5	68.4	57.6
	Pex	65.6	54.0	65.7	53.5	59.9	49.0	55.6	43.8
	Q,Pex	62.3	52.2	62.9	51.9	57.5	47.3	54.2	43.4
2.50	None	93.2	86.9	92.7	86.7	91.3	86.1	88.8	82.2
	T	91.4	83.6	90.8	83.4	88.7	82.3	85.4	76.8
	Q	90.7	86.2	90.8	86.1	88.8	84.3	87.4	82.0
	P	87.6	79.1	87.2	78.7	84.3	76.7	80.5	70.8
	Q,T	88.0	82.3	88.1	82.1	85.5	79.7	83.5	76.6
	Q,P	84.0	77.4	84.3	77.4	81.2	74.4	78.8	70.5
	Pex	75.1	64.5	75.0	64.0	70.1	60.4	65.9	54.9
	Q,Pex	71.7	62.9	72.2	62.6	67.5	58.7	64.6	54.7
3.00	None	95.9	91.1	95.5	91.0	94.7	91.0	93.0	88.1
	T	94.6	88.4	94.1	88.3	93.0	88.1	90.5	84.1
	Q	94.2	90.6	94.0	90.6	93.0	89.7	91.9	88.0
	P	92.0	84.8	91.5	84.6	89.6	83.8	86.7	79.1
	Q,T	92.2	87.6	92.1	87.5	90.5	86.2	89.0	83.9
	Q,P	89.0	83.7	89.1	83.5	87.0	81.8	85.2	78.9
	Pex	81.4	71.9	81.2	71.4	77.1	68.7	73.2	63.4
	Q,Pex	78.3	70.2	78.5	70.0	74.6	66.9	71.9	63.2

Note: For Ferguson-like disease manifestation and implementation threshold 10 diagnosed. Case-based strategy combinations downward, network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent.

5. Design of Effective, Robust Community Containment

The results from simulation studies, such as reported above, can be used to design effective, robust containment strategy combinations in the context of constraints and uncertainties. In the following sections, the team demonstrates such design for the level of infectivity consistent with a 1918-like influenza pandemic, having an *IDfactor* of 1.5, where approximately 71 percent of the population is infected (approximately 36 percent is symptomatic) for the unmitigated epidemic. The team built the base design considering first the Ferguson-like disease manifestation with rapid implementation (10 diagnosed) and 90-percent compliance and then considering the robustness of this design to implementation threshold, compliance, contact with the external unmitigated epidemic, disease manifestation, and social contact network.

5.1 Base Design

Table 5-1, top, shows the infection attack rate with those combinations of strategies that yield an infection attack rate below 10 percent shaded green, and those between 10 percent and 25 percent shaded pink.

An infection attack rate of 10 percent corresponds to a diagnosed rate of 4 percent and a symptomatic illness rate of 5 percent. An infection attack rate of 25 percent corresponds to a diagnosis rate of 10 percent and a symptomatic illness rate of 12.5 percent.

Nearly half of the strategy combinations fall within the combination of green and pink zones. Implementing all case-based strategies without network-focused strategies can yield, at best, an attack rate of 35 percent. Implementing all network-focused strategies alone can reduce the attack rate to 5 percent. The nonlinearity in the combination of social distancing strategies is of note. S or CTsd alone are not very effective; however, in combination, they reduce the attack rate to 17 percent, an efficacy much greater than the sum of their singly imposed reductions. Contrarily, combining S and ASsd reduces the attack rate to 50 percent, less than the linear combination of their singly imposed reductions.

Without the use of antivirals, the model shows 4 effective strategy combinations: 3 with infection attack rates below 10 percent and 1 additional below 25 percent. With antivirals, many additional combinations can be implemented; however, some require more treatment courses than may be available. Table 5-1, middle, shows the percent coverage of the population with antivirals (number of courses given as a percent of the population). Attack rate-based coloring has been maintained and those strategies that require less than 4-percent coverage (U.S. stockpile estimate at the end of the summer 2006) are noted with a yellow circle, while those that require up to 25-percent coverage (planned stockpile estimate for third quarter 2007) are noted with a red circle. Significant amounts of antivirals are required to implement any of the PEx strategies. To be effective, antiviral treatment must be implemented in combination with S+CTsd and S+CTsd+ASsd; however, PEx is not required at this *IDfactor* because treatment alone with either of these effective social distancing strategy combinations is sufficient to yield an attack rate below 10 percent, with 2-percent or less coverage of the population.

Table 5-1, bottom, illustrates the number of days adults remain at home, whether sick, tending sick children, minding children sent home from school, or quarantined. The intersection of colored squares (attack rates 25 percent or less) and colored circles (antiviral coverage 25 percent or less) are superimposed with the average number of adult at-home days. For the unmitigated epidemic, adults

are home 3 days and approximately 70 people die. For containment strategies using less than 4-percent antiviral coverage and yielding infection attack rates of 10 percent or less (green zone), adults stay at home from about 6 days (with 2 deaths for S+CTsd+ASsd combined with P) to 19 days (with 9 deaths for S+CTsd combined with Q). Adding Q to the combined strategies is of little aid and has high social costs. Thus, full social distancing (S+CTsd+ASsd) combined with antiviral prophylaxis (P) is the best choice for design under current constraints with or without a limited stockpile of antiviral courses.

Table 5-1: Base community containment design

Network focused

Case based	None	ASsd	CTsd	CTsd ASsd	S	S ASsd	S CTsd	S CTsd ASsd
None	71	56	65	53	61	50	17	5
T	65	50	57	45	51	39	5	2
Q	60	50	52	44	46	37	9	4
P	56	43	46	36	36	23	3	2
Q,T	53	43	43	35	34	23	3	2
Q,P	49	39	38	29	27	15	3	2
Pex	40	31	31	24	20	11	2	2
Q,Pex	35	27	24	16	13	7	2	2

Infection Attack Rate (% of population)

Case based	None	ASsd	CTsd	CTsd ASsd	S	S ASsd	S CTsd	S CTsd ASsd
None	0	0	0	0	0	0	0	0
T	24	18	21	16	18	14	2	1
Q	0	0	0	0	0	0	0	0
P	53	43	45	36	36	23	3	2
Q,T	19	15	16	12	12	8	1	1
Q,P	49	39	38	30	27	15	3	2
Pex	149	128	142	117	105	61	13	9
Q,Pex	144	122	118	86	68	38	13	9

Antiviral Courses (% of population)

Case based	None	ASsd	CTsd	CTsd ASsd	S	S ASsd	S CTsd	S CTsd ASsd
None	3	2	3	2	15	16	25	13
T	3	2	3	2	18	18	14	8
Q	6	5	5	4	20	21	19	12
P	2	2	2	1	20	21	9	6
Q,T	6	5	5	4	24	23	10	8
Q,P	5	4	4	3	24	21	9	7
Pex	1	1	1	1	25	20	8	6
Q,Pex	3	3	2	2	21	16	8	6

Adult Days at Home (average days per adult)

Note: Ferguson-like disease manifestation, 90-percent compliance, *IDfactor* 1.5, implementation threshold 10 diagnosed, mitigation strategy combination implemented regionally. Case-based strategy combinations downward, network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent; yellow circle, antiviral courses less than 4-percente coverage; red circle, antiviral courses between 4- and 25-percent coverage.

5.2 Pre-pandemic Vaccination

Considering the use of pre-pandemic vaccine at proposed U.S. stockpile levels (7 percent, 700 doses in our community of 10,000) with assumed efficacy of 50 percent, the study team finds little or no added benefit for uniform (Table 5-2) or adult-targeted (Table 5-3) vaccination. However, if the children and teens are targeted with all vaccine available to this community (Table 5-4), the team finds some benefit; the strategy combinations of S + CTsd and S+ASsd+Q+T implemented with a limited antiviral stockpile (yellow circles) move into the 10-percent or lower infection attack rate (green) zone.

However, the best strategy choice remains S+CTsd+ASsd+P with the infection attack rate, deaths, and the number of days adults are home uninfluenced. Further studies should consider if a stockpile size above the current proposed 7-percent coverage with 50-percent effective pre-pandemic vaccine would have added benefit and change the choice of best community containment strategy.

Table 5-2: Pre-pandemic vaccination of general population

Network focused

Case based

	None	ASsd	CTsd	CTsd ASsd	S	S ASsd	S CTsd	S CTsd ASsd
None	67	53	60	48	56	45	12	4
T	61	47	53	41	45	33	4	2
Q	56	46	47	39	40	32	7	4
P	52	40	42	32	31	19	2	2
Q,T	49	39	39	30	27	19	3	2
Q,P	45	35	33	25	20	11	2	2
Pex	37	28	28	20	16	9	2	2
Q,Pex	32	24	19	12	9	5	2	2

Infection Attack Rate (% of population)

Case based

None	0	0	0	0	0	0	0	0
T	22	17	19	15	16	12	1	1
Q	0	0	0	0	0	0	0	0
P	51	40	41	33	31	19	2	2
Q,T	18	14	14	11	10	7	1	1
Q,P	46	37	34	26	21	12	2	2
Pex	145	123	135	104	87	48	11	8
Q,Pex	139	114	100	67	47	28	10	8

Antiviral Courses (% of population)

Case based

None	3	2	3	2	16	17	23	11
T	3	2	2	2	19	20	11	8
Q	6	5	5	4	21	22	16	11
P	2	1	2	1	22	22	8	6
Q,T	5	4	4	3	24	24	10	7
Q,P	5	4	4	3	24	19	8	6
Pex	1	1	1	1	24	19	7	5
Q,Pex	3	2	2	1	18	13	7	6

Adult Days at Home (average days per adult)

Note: Ferguson-like disease manifestation, 90-percent compliance, *IDfactor* 1.5, implementation threshold 10 diagnosed, mitigation strategy combination implemented regionally, uniform vaccination of population with 700 doses of 50-percent efficacy pre-pandemic vaccine. Case-based strategy combinations downward, network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent; yellow circle, antiviral courses less than 4-percent coverage; red circle, antiviral courses between 4- and 25-percent coverage.

Table 5-3: Targeted pre-pandemic vaccination of adults

Network focused

Case based	None	ASsd	CTsd	CTsd ASsd	S	S ASsd	S CTsd	S CTsd ASsd
None	68	54	61	50	57	46	12	5
T	62	48	54	43	47	36	4	2
Q	57	47	48	42	42	35	7	4
P	53	41	43	34	33	22	3	2
Q,T	51	41	40	33	30	20	3	2
Q,P	47	37	35	28	23	14	2	2
Pex	38	29	29	22	18	9	2	2
Q,Pex	34	26	22	16	9	6	2	2

Infection Attack Rate (% of population)

Case based	None	ASsd	CTsd	CTsd ASsd	S	S ASsd	S CTsd	S CTsd ASsd
None	0	0	0	0	0	0	0	0
T	22	17	19	15	17	13	1	1
Q	0	0	0	0	0	0	0	0
P	51	42	43	35	32	22	2	2
Q,T	18	15	15	12	11	7	1	1
Q,P	47	38	36	28	23	14	2	2
Pex	146	126	135	112	94	52	12	9
Q,Pex	141	118	111	84	50	32	10	9

Case based	None	ASsd	CTsd	CTsd ASsd	S	S ASsd	S CTsd	S CTsd ASsd
None	3	2	3	2	16	16	23	12
T	3	2	2	2	18	19	13	8
Q	6	5	5	4	20	21	16	11
P	2	1	2	1	21	22	8	6
Q,T	5	4	4	3	23	24	9	8
Q,P	5	4	4	3	24	20	8	6
Pex	1	1	1	1	25	19	8	6
Q,Pex	3	2	2	2	17	13	7	6

Adult Days at Home (average days per adult)

Note: Ferguson-like disease manifestation, 90-percent compliance, IDfactor 1.5, implementation threshold 10 diagnosed, mitigation strategy combination implemented regionally, targeted vaccination of adults with 700 doses of 50-percent efficacy pre-pandemic vaccine. Case-based strategy combinations downward, network-focused strategy combinations across with: green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent; yellow circle, antiviral courses less than 4-percent coverage; red circle, antiviral courses between 4- and 25-percent coverage.

Table 5-4: Targeted pre-pandemic vaccination of children and teenagers

Network focused

Case based

	None	ASsd	CTsd	CTsd ASsd	S	S ASsd	S CTsd	S CTsd ASsd
None	64	48	57	43	52	39	9	3
T	58	42	48	34	40	26	3	2
Q	52	41	42	33	35	25	5	3
P	48	34	37	25	25	11	2	2
Q,T	46	34	33	22	22	10	2	2
Q,P	42	30	28	17	15	7	2	2
Pex	34	23	24	14	11	5	2	1
Q,Pex	29	19	14	8	6	4	2	2

Infection Attack Rate (% of population)

Case based

None	0	0	0	0	0	0	0	0
T	21	15	17	12	14	9	1	1
Q	0	0	0	0	0	0	0	0
P	48	35	37	26	25	11	2	1
Q,T	17	12	12	8	8	4	1	1
Q,P	43	31	28	18	15	7	2	2
Pex	141	112	122	76	58	30	10	7
Q,Pex	133	98	77	47	35	21	9	8

Antiviral Courses (% of population)

Case based

None	3	2	2	2	17	18	21	10
T	3	2	2	2	21	22	11	7
Q	5	4	4	3	22	24	14	9
P	2	1	1	1	24	20	8	6
Q,T	5	4	4	2	26	19	9	7
Q,P	5	3	3	2	23	15	7	6
Pex	1	1	1	0	21	14	7	5
Q,Pex	3	2	1	1	15	11	7	5

Adult Days at Home (average days per adult)

Note: Ferguson-like disease manifestation, 90-percent compliance, *IDfactor* 1.5, implementation threshold 10 diagnosed, mitigation strategy combination implemented regionally, targeted vaccination of children and teen with 700 doses of 50-percent efficacy pre-pandemic vaccine. Case-based strategy combinations downward, network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent; yellow circle, antiviral courses less than 4-percent coverage; red circle, antiviral courses between 4- and 25-percent coverage.

5.3 Robustness

Tables 5-5 and 5-6 show the importance of quickly implementing the base design strategy combination. Delaying implementation until 30 people are diagnosed still yields strategy combinations that provide infection attack rates of 10 percent or less (shaded green), can be accomplished with a limited antiviral stockpile (yellow circles), and increases the number of adult days at home only slightly.

Delaying implementation until 100 people are diagnosed erodes efficacy much more dramatically. A limited antiviral stockpile is no longer sufficient to implement the best strategy choice (S+CTsd+ASsd+P) and 11-percent coverage is required. More importantly, the infection attack rate slips to 13 percent, deaths rise from 2 to 11, and adult days at home increase from 6 to 12.

Reducing compliance to 60 percent also significantly erodes efficacy (Table 5-7). The best choice remains S+CTsd+ASsd+P, but the infection attack rate increases fivefold to 10 percent, with a concurrent increase in the number of deaths from 2 to 9. Almost 7-percent antiviral coverage is required, and the number of adult days at home increases to 21, 7 times the average period for the unmitigated epidemic.

When in contact with surrounding communities in which the unmitigated epidemic is running its course, the best choice combination (S+CTsd+ASsd+P) remains the same (Table 5-8). If a local community implements this strategy at 90-percent compliance after 10 people are diagnosed, the infection attack (and death) rate quadruples relative to the regionally mitigated scenario, but the implementing community can hold the rate down to 10 percent or less (green). Antiviral requirements increase to 9-percent coverage, and the days adults are at home nearly double.

For the Longini-like disease manifestation (Table 5-9), the best choice of strategy combination remains the same as that found for the Ferguson-like manifestation; however, the cost in terms of adult days at home nearly doubles (to 10 days) for S+CTsd+ASsd+P.

If the bounding case of uniform transmission is assumed, the best choice remains unaltered (Table 5-10), with fewer than 2-percent infected, 2-percent antiviral coverage required, and only 7 adult days at home. Thus, the best choice, S+CTsd+ASsd+P, is robust to a transmission perturbation far from what is considered likely.

Table 5-5: Robustness: relaxation of implementation threshold to 30 diagnosed

Network focused

Case based

	None	ASsd	CTsd	CTsd ASsd	S	S ASsd	S CTsd	S CTsd ASsd
None	71	56	65	53	62	51	24	11
T	66	51	57	46	52	40	10	6
Q	60	50	52	45	47	39	16	11
P	56	43	47	37	37	27	7	5
Q,T	53	43	44	36	36	26	8	5
Q,P	49	39	38	31	29	20	6	5
Pex	40	31	31	24	22	15	5	4
Q,Pex	35	27	25	18	16	11	5	4

Infection Attack Rate (% of population)

Case based

None	0	0	0	0	0	0	0	0
T	24	18	21	16	19	14	4	2
Q	0	0	0	0	0	0	0	0
P	53	42	45	36	36	26	6	4
Q,T	19	15	16	13	13	9	3	2
Q,P	49	39	38	31	29	20	6	4
Pex	145	125	136	111	106	72	25	20
Q,Pex	138	116	116	89	77	56	23	20

Antiviral Courses (% of population)

Case based

None	3	2	3	2	14	14	21	14
T	3	2	3	2	15	16	15	9
Q	6	5	5	4	18	17	17	13
P	2	2	2	1	17	17	11	7
Q,T	6	5	5	4	19	19	12	9
Q,P	5	4	4	3	20	17	9	7
Pex	1	1	1	1	21	17	8	7
Q,Pex	3	3	2	2	18	14	8	6

Adult Days at Home (average days per adult)

Note: Ferguson-like disease manifestation, 90-percent compliance, *IDfactor* 1.5, implementation threshold 30 diagnosed, mitigation strategy combination implemented regionally. Case-based strategy combinations downward, network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infected attack rate between 10 and 25 percent; yellow circle, antiviral courses less than 4-percent coverage; red circle, antiviral courses between 4- and 25-percent coverage.

Table 5-6: Robustness: relaxation of implementation threshold to 100 diagnosed

Network focused

Case based

	None	ASsd	CTsd	CTsd ASsd	S	S ASsd	S CTsd	S CTsd ASsd
None	71	57	65	54	62	52	34	23
T	65	51	58	47	53	43	23	15
Q	60	51	54	47	50	43	29	22
P	56	44	48	39	41	32	17	13
Q,T	54	45	46	38	40	33	19	15
Q,P	50	40	41	34	34	28	16	13
Pex	40	32	33	27	27	21	13	12
Q,Pex	36	29	28	23	23	19	13	11

Infection Attack Rate (% of population)

Case based

None	0	0	0	0	0	0	0	0
T	24	19	21	17	19	15	8	5
Q	0	0	0	0	0	0	0	0
P	52	42	45	37	38	30	15	11
Q,T	19	16	16	14	14	12	7	5
Q,P	47	39	39	32	32	26	14	11
Pex	133	112	120	100	102	80	51	44
Q,Pex	124	104	104	86	87	71	48	42

Antiviral Courses (% of population)

Case based

None	3	3	3	2	12	12	14	11
T	3	2	3	2	13	13	13	9
Q	6	5	5	4	15	14	15	12
P	2	2	2	1	13	12	10	8
Q,T	6	5	5	4	16	15	12	10
Q,P	5	4	4	3	15	13	11	8
Pex	1	1	1	1	15	12	9	7
Q,Pex	3	2	2	2	15	12	9	7

Adult Days at Home (average days per adult)

Note: Ferguson-like disease manifestation, 90-percent compliance, *IDfactor* 1.5, implementation threshold 100 diagnosed (1 percent of population), mitigation strategy combination implemented regionally. Case-based strategy combinations downward, network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent; yellow circle, antiviral courses less than 4-percent coverage; red circle, antiviral courses between 4- and 25-percent coverage.

Table 5-7: Robustness: relaxation of compliance to 60 percent

Network focused

Case based	None	ASsd	CTsd	CTsd ASsd	S	S ASsd	S CTsd	S CTsd ASsd
None	71	66	71	66	64	59	52	43
T	65	60	64	59	55	48	34	24
Q	67	65	67	64	58	54	48	43
P	58	53	57	52	43	37	18	10
Q,T	60	57	59	56	47	42	30	23
Q,P	54	51	53	49	38	32	17	11
Pex	42	38	40	36	27	22	7	5
Q,Pex	38	36	38	34	21	17	6	5

Infection Attack Rate (% of population)

Case based	None	ASsd	CTsd	CTsd ASsd	S	S ASsd	S CTsd	S CTsd ASsd
None	0	0	0	0	0	0	0	0
T	16	14	15	14	13	12	8	6
Q	0	0	0	0	0	0	0	0
P	39	36	38	35	30	25	13	7
Q,T	14	14	14	13	11	10	7	5
Q,P	36	35	36	34	26	22	12	8
Pex	114	109	116	108	97	81	29	19
Q,Pex	110	107	114	106	79	63	26	18

Antiviral Courses (% of population)

Case based	None	ASsd	CTsd	CTsd ASsd	S	S ASsd	S CTsd	S CTsd ASsd
None	3	3	3	3	15	15	19	19
T	3	3	3	3	17	17	25	26
Q	7	6	7	6	19	19	21	21
P	2	2	2	2	19	20	26	21
Q,T	6	6	6	6	21	21	25	27
Q,P	6	5	6	5	22	23	26	23
Pex	1	1	1	1	25	25	19	14
Q,Pex	4	3	4	3	26	25	17	13

Adult Days at Home (average days per adult)

Note: Ferguson-like disease manifestation, 60-percent compliance, *IDfactor* 1.5, implementation threshold 10 diagnosed (0.1 percent of population), mitigation strategy combination implemented regionally. Case-based strategy combinations downward, network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent; yellow circle, antiviral courses less than 4-percent coverage; red circle, antiviral courses between 4- and 25-percent coverage.

Table 5-8: Robustness: regionally unmitigated epidemic

Network focused

Case based	None	ASsd	CTsd	CTsd ASsd	S	S ASsd	S CTsd	S CTsd ASsd
None	71	57	65	53	62	51	34	17
T	66	52	59	47	54	42	25	11
Q	62	51	56	46	51	41	31	17
P	58	45	50	39	43	31	20	9
Q,T	56	45	48	38	42	31	22	11
Q,P	52	41	44	34	37	25	19	9
Pex	43	33	36	27	29	20	15	8
Q,Pex	38	29	31	22	25	16	15	8

Infection Attack Rate (% of population)

Case based	None	ASsd	CTsd	CTsd ASsd	S	S ASsd	S CTsd	S CTsd ASsd
None	0	0	0	0	0	0	0	0
T	24	19	21	17	19	15	9	4
Q	0	0	0	0	0	0	0	0
P	55	44	48	39	41	30	19	9
Q,T	20	16	17	14	15	11	8	4
Q,P	51	41	43	34	37	25	19	9
Pex	146	130	137	121	120	95	74	44
Q,Pex	141	124	126	105	108	82	73	44

Antiviral Courses (% of population)

Case based	None	ASsd	CTsd	CTsd ASsd	S	S ASsd	S CTsd	S CTsd ASsd
None	3	2	3	2	15	15	17	15
T	3	2	3	2	15	16	15	14
Q	6	5	6	5	18	18	18	17
P	2	2	2	1	15	16	14	12
Q,T	6	5	5	4	18	19	16	14
Q,P	6	4	5	4	18	18	15	13
Pex	1	1	1	1	16	17	13	12
Q,Pex	4	3	3	2	17	17	14	12

Adult Days at Home (average days per adult)

Note: Ferguson-like disease manifestation, 90-percent compliance, *IDfactor* 1.5, implementation threshold 10 diagnosed, community connected to external region with unmitigated epidemic. Case-based strategy combinations downward, network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent; yellow circle, antiviral courses less than 4-percent coverage; red circle, antiviral courses between 4- and 25-percent coverage.

Table 5-9: Robustness: Longini-like disease manifestation

Network focused

Case based	None	ASsd	CTsd	CTsd ASsd	S	S ASsd	S CTsd	S CTsd ASsd
None	72	57	65	53	62	51	21	6
T	65	50	56	44	49	37	4	2
Q	59	49	50	43	44	36	10	5
P	54	41	43	33	31	18	2	2
Q,T	51	40	38	31	26	17	3	2
Q,P	46	35	31	23	15	9	2	2
Pex	38	29	28	20	14	7	2	2
Q,Pex	32	23	16	10	6	4	2	2

Infection Attack Rate (% of population)

Case based	None	ASsd	CTsd	CTsd ASsd	S	S ASsd	S CTsd	S CTsd ASsd
None	0	0	0	0	0	0	0	0
T	31	24	27	21	24	18	2	1
Q	0	0	0	0	0	0	0	0
P	64	49	51	40	36	21	2	2
Q,T	24	19	18	15	13	8	1	1
Q,P	57	43	38	28	18	10	2	2
Pex	192	163	173	130	91	50	13	10
Q,Pex	179	145	110	71	39	29	13	11

Antiviral Courses (% of population)

Case based	None	ASsd	CTsd	CTsd ASsd	S	S ASsd	S CTsd	S CTsd ASsd
None	5	4	5	4	23	24	41	24
T	4	3	4	3	27	28	20	12
Q	8	6	6	6	31	31	30	21
P	3	2	2	2	33	32	12	10
Q,T	7	6	5	4	36	32	15	12
Q,P	7	5	4	3	34	25	11	10
Pex	2	1	1	1	36	26	11	9
Q,Pex	4	3	2	1	22	18	10	9

Adult Days at Home (average days per adult)

Note: Longini-like disease manifestation, 90-percent compliance, *IDfactor* 1.5, implementation threshold 10 diagnosed, mitigation strategy combination implemented regionally. Case-based strategy combinations downward, network focused strategy combinations across with: green shading, infection attack rate 10 or less; pink shading, infection attack rate between 10% and 25%; yellow circle, antiviral courses less than 4% coverage; red circle, antiviral courses between 4% and 25% coverage.

Table 5-10: Robustness: uniform transmission

Network focused

Case based	None	ASsd	CTsd	CTsd ASsd	S	S ASsd	S CTsd	S CTsd ASsd
None	78	56	75	52	67	45	49	7
T	72	45	68	38	57	26	31	3
Q	63	41	59	34	50	25	31	5
P	61	31	55	21	42	8	16	2
Q,T	56	28	51	17	38	9	15	2
Q,P	52	22	46	11	32	6	10	2
Pex	42	16	37	10	23	5	6	2
Q,Pex	37	10	29	5	15	3	5	2

Infection Attack Rate (% of population)

Case based	None	ASsd	CTsd	CTsd ASsd	S	S ASsd	S CTsd	S CTsd ASsd
None	0	0	0	0	0	0	0	0
T	26	16	24	14	20	9	11	1
Q	0	0	0	0	0	0	0	0
P	59	32	54	22	42	8	16	2
Q,T	20	10	18	6	14	3	5	1
Q,P	53	23	47	12	32	5	9	2
Pex	179	92	168	57	120	26	35	9
Q,Pex	166	56	144	29	80	18	27	10

Case based	None	ASsd	CTsd	CTsd ASsd	S	S ASsd	S CTsd	S CTsd ASsd
None	3	3	3	2	16	21	21	17
T	3	2	3	2	19	28	26	10
Q	6	4	6	4	22	27	27	13
P	2	1	2	1	22	19	25	7
Q,T	6	3	6	2	26	19	25	9
Q,P	6	3	5	1	26	13	20	7
Pex	1	1	1	0	30	13	17	6
Q,Pex	4	1	3	1	26	10	13	6

Adult Days at Home (average days per adult)

Note: Ferguson-like disease manifestation, 90-percent compliance, *IDfactor* 1.5, implementation threshold 10 diagnosed, mitigation strategy combination implemented regionally, uniform transmission. Case-based strategy combinations downward, network-focused strategy combinations across with green shading, infection attack rate 10 percent or less; pink shading, infection attack rate between 10 and 25 percent; yellow circle, antiviral courses less than 4-percent coverage; red circle, antiviral courses between 4- and 25-percent coverage.

6. Recommendations for Policy

In this study, the NISAC study team has applied a community-scale model that simulates the spread of influenza in an explicit, multiply overlapping network of social contacts within a stylized community. The modeled community can be isolated or embedded within a regional epidemic where other communities are either imposing the same containment strategies or doing nothing to abate the epidemic.

By focusing on a single community, the study team has been able to evaluate an extensive matrix of containment strategy combinations and disease infectivity levels. This exploration has enabled the team to identify community containment strategies that minimize illness, death, and loss of workforce in the face of constrained antiviral or pre-pandemic vaccine supplies.

Building on this foundation, the team has assessed the robustness of containment designs to variations in disease manifestation, social network configuration, strategy implementation threshold, public compliance, and neighboring community behavior.

Based on the findings of this study, the team recommends policy in 3 areas: requirements of robust effective community containment, necessity of uniform national policy, and administration of pre-pandemic vaccine. In addition, summary recommendations are made for the continued evaluation and reduction of uncertainty.

6.1 Requirements of Robust Effective Community Containment Strategies

For a 1918-like pandemic infectivity level, strategies are available that are effective at minimizing illness to below 5 percent of the population (with nearly no deaths), using only the levels of antiviral coverage currently within U.S. stockpiles and limiting cost in terms of adult days spent at home to less than 1 week (about double the amount of time for the unmitigated epidemic). The best community containment strategy combines full social distancing with antiviral treatment and household antiviral prophylaxis.

This best strategy is robust to changes in the social contact network that remove enhanced transmission by children and teenagers and to changes in the disease manifestation within the range currently used in modeling studies found in the literature. However, strategy effectiveness depends on rapid implementation and a high degree of public compliance for both social distancing measures and antiviral application. The latter encompasses administration of antiviral drugs by the healthcare infrastructure and use by the affected persons within the population.

The most important component of effective strategy combinations is the implementation of social distancing with high compliance. For infectivity similar to that of the 1918 pandemic, administration of antiviral prophylaxis at levels above 2-percent coverage adds no benefit and does not remove the necessity of implementing high compliance social distancing, which includes closing schools. Closing schools imposes the largest cost in days adults are at home. However, containment strategies that combine closing schools and implementing social distancing of children and teens are very effective when layered with home antiviral prophylaxis. By adding implementation of social distancing by adults and seniors (including a 50-percent reduction in contacts at work), adult days at home can be minimized to an average of 6 per adult.

Thus, social distancing forms the foundation for effective community containment. Alone, it may be able to hold a pandemic at bay; in combination with case-based strategies such as home prophylaxis, it may minimize deaths and days adults are at home. However, strategies must be implemented quickly and with high compliance.

The first critical recommendation for policy is that planning, education, and training must be designed for the effective triggering and implementation of high-compliance social-distancing measures, first, and case-based strategies, second. This conclusion contradicts the emphasis within the medical and public health community over the past years where antiviral prophylaxis has been the primary consideration and is given further emphasis from recent data that show avian influenza type A, or bird flu (H5N1), is developing resistance to the antiviral oseltamivir (WHO, 2007), our most potent antiviral. Societal support of families with young children is an important component for high-compliance social distancing among children, as families will bear the vast majority of the costs of adult days at home. Mechanisms, including private (company business plans, insurance policies), public (community organization, taxation), and not-for-profit resources, could accomplish such a redistribution of burden.

6.2 Necessity of a Uniform National Policy

Isolated communities implementing effective community containment strategies, and communities embedded within regions implementing effective community containment strategies, perform identically. However, the model simulations, in which communities implementing containment strategies are embedded in a region that is doing nothing to abate the epidemic ("regionally unmitigated" with full contact through the work place), show the importance of regional implementation of community containment strategies.

Without such regional policy, the best community containment strategy (full social distancing layered with household antiviral prophylaxis and 90-percent compliance) still reduces infectious attack rates below 10 percent. However, the attack and death rates quadruple from their values for the regionally mitigated epidemic, as do antiviral requirements (to 9-percent coverage, well above the current stockpile of oseltamivir of 7.2 percent in January 2007[44]), and the number of days adults are at home double. Thus, leaving mitigation policy up to individual communities could cost the nation a great deal.

The second critical recommendation for policy is that a uniform national policy be imposed and supported for the benefit of all.

6.3 Administration of Pre-pandemic Vaccine

The optimal focus of pre-pandemic vaccination at proposed stockpile levels (7-percent coverage and 50-percent efficacy) is on children and teens; however, such targeting only somewhat influences the spread of disease. If the best community containment strategy is implemented (full social distancing layered with household antiviral prophylaxis and 90-percent compliance), pre-pandemic vaccine affords no added benefit. Thus, the third critical recommendation for policy is that the best community containment strategy should be implemented and pre-pandemic vaccine, if available at such low levels and efficacy, should be used primarily to ensure that critical infrastructures continue

[44]HHS (U.S. Department of Health and Human Services), 2007, "Antivirals – State Allocations," Retrieved 18 January 2007, from http://pandemicflu.gov/plan/states/antivirals.html

to function during the period of the pandemic. For highest community benefit, people in positions that cannot be replaced in infrastructures that must remain operable, such as healthcare and first responders, should be given the pre-pandemic vaccine. The vaccine will decrease the probability of them falling ill and increase the probability of them continuing to work. Future studies should consider if a stockpile size above the current proposed 7-percent coverage with 50-percent effective pre-pandemic vaccine would yield enough benefit to change the choice of best community containment strategy.

6.4 Continued Evaluation and Reduction of Uncertainty

The NAS/IOM pointed out in a recent review of "Modeling Community Containment for Pandemic Influenza"[45] that much work remains to evaluate the uncertainty of community containment efficacy. Simulation studies such as this study can aid in evaluating uncertainty and in reducing this uncertainty over time. The current study has taken a step forward along this path and developed a foundational set of results for evaluation. Future studies should systematically consider parametric assumptions for the underlying disease manifestations, social contact network, action of antiviral drugs, and containment strategy implementation. The following outline notes the NISAC study team's assessment of the most important components in each of these areas:

Disease manifestation, including

- Behavior of infectivity in time
- Transmission mechanism (aerosol, particles, surface contact)
- Disease stages and their mean times
- Fraction asymptomatic (invisible versus visible infected)
- Mortality

Social contact network, including

- Subgroup network: structured to fully mixed
- Groups: augmented, relative importance, and makeup (households, neighborhoods/extended families, schools, work, clubs, church, public transport, and so on)
- Location conditions of possible critical importance (college campuses, military reservations, high-rises, and so on)
- Collection and incorporation of contact network data
- Instantiation from community data

Antiviral influences and administration, including:

- Reduction of infectivity (variation with time administered, treatment, prophylaxis)
- Reduction of susceptibility for prophylaxis (variation with time administered)
- Reduction of fraction symptomatic for prophylaxis (variation with time administered)

[45] IOM/NAS, 2006, (See Footnote 1)

Containment strategy implementation, including:

- Reactive behavior on the part of individuals and communities to evaluate compliance with strategy components and design of incentives (social modeling)

Modification of community-scale models and subsequent analytic sweeps of parameter space are feasible to evaluate the uncertainty imposed by extension to the components listed above. Additionally, analysis can be refined in response to evolving constraints and changes in uncertainty from data collected as new influenza strains emerge and combined strategy implementations are undertaken. Ongoing work in this area should include and emphasize community-scale modeling in addition to modeling at the regional or national scales. Modeling activities at all scales should continue into the indefinite future and work to fully integrate with economic analysis and detection/monitoring systems for influenza.

This page intentionally left blank.

Appendix A: Design of Targeted Social Distancing Strategies for Pandemic Influenza

Glass, R. J., L. M. Glass, W. E. Beyeler, and H. J. Min, 2006, "Targeted Social Distancing Design for Pandemic Influenza," *Emerging Infectious Diseases* **12**(11), Centers for Disease control and Prevention, U.S. Department of Health and Human Services, 11 November, http://www.cdc.gov/ncidod/eid/vol12no11/06-0255.htm

This page intentionally left blank.

Appendix B: White House Homeland Security Council Pandemic Implementation Plan Simulation Outline

White House Homeland Security Council Pandemic Implementation Plan simulation outline with annotations and yellow highlighting to show connection to current analyses reported here

This page intentionally left blank.

Appendix C: Unmitigated Base Case Analysis

Analysis of the unmitigated epidemics for both Ferguson-like and Longini-like disease manifestations is compiled in the excel worksheet:

UnmitigatedBaseCase.xls

On this worksheet, the infectious contact sequences generated from 100 runs are analyzed to obtain:

1. Branching factors by age class and generation
2. Maximum branching factors by age class and overall
3. Overall branching factor for combined population of 1M people by generation and its maximum below generation 10 (approximates R_o6)[1]
4. Generation time by age class and generation
5. Generation time by age class (averaged over generation)
6. Average generation time over all age classes
7. Fraction of total transmission within and between each age class
8. Fraction of total transmission within each group type
9. Additionally summary statistics are compiled in the worksheet for:
10. Infection attack rates, illness attack rates, death rates by age class and overall
11. Peak infected, peak symptomatic
12. Number of epidemics
13. Timescales: times to peak, epidemic duration, total time
14. Days adults are home

The Ferguson-like disease manifestation was used in "Targeted Social Distancing Design for Pandemic Influenza"[2] in Appendix A, and results here conform closely to those with slight differences due to the inclusion of babysitting within the community. The NISAC study team pulled from these results to give observations on the influence of disease manifestation, *IDfactor*, and compliance.

Observations on Disease Manifestation:

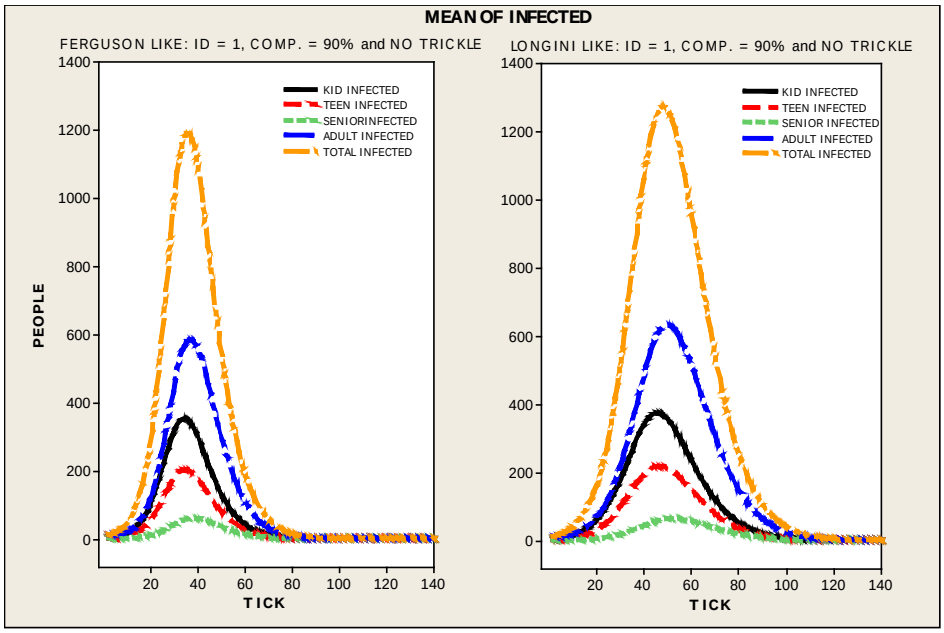
- No difference in summary measures of total infected (or symptomatic) by age class or overall

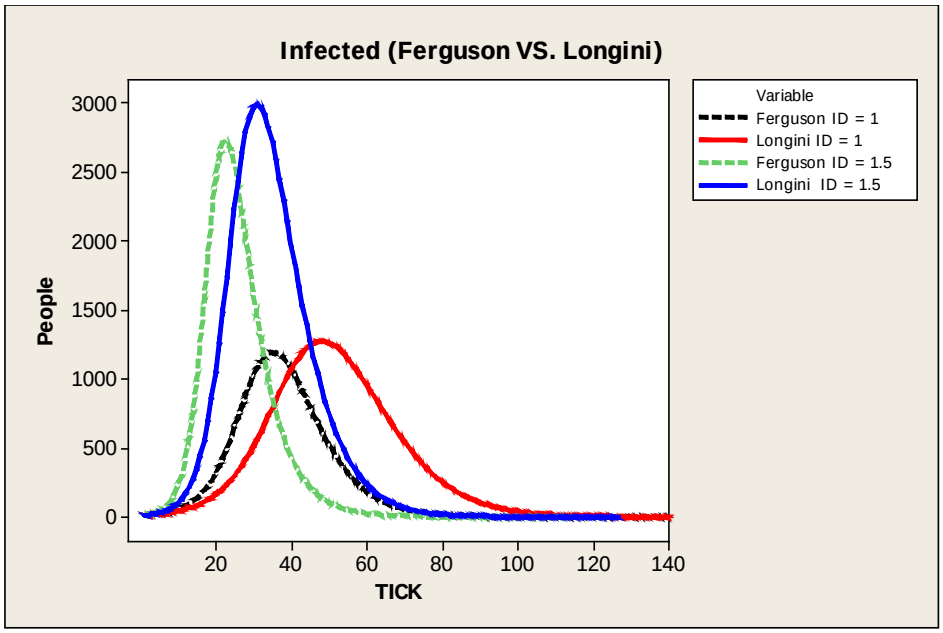
[1] Glass, R. J., L. M. Glass, W. E. Beyeler, and H. J. Min, 2006, "Targeted Social Distancing Design for Pandemic Influenza," *Emerging Infectious Diseases* **12**(11), Centers for Disease control and Prevention, U.S. Department of Health and Human Services, 11 November, http://www.cdc.gov/ncidod/eid/vol12no11/06-0255.htm (hereinafter referred to as Glass et al., 2006)

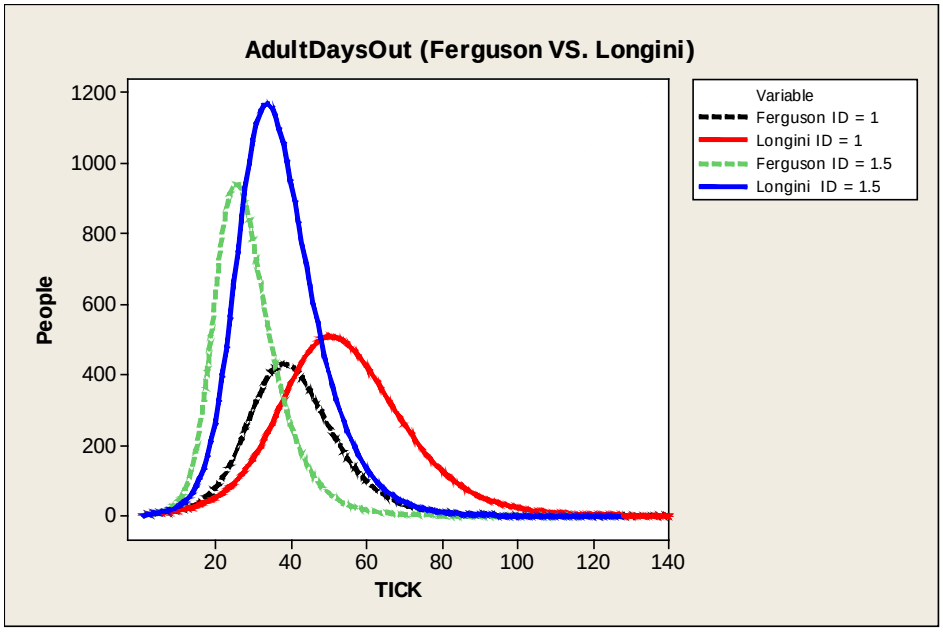
[2] Ibid.

- Longini-like slightly higher for peak infected and peak symptomatic
- Longini-like approximately 33-percent longer time scale and so times to peak, epidemic duration and total time of effects
- Longini-like greater than 50-percent larger adult days out

See plots below.





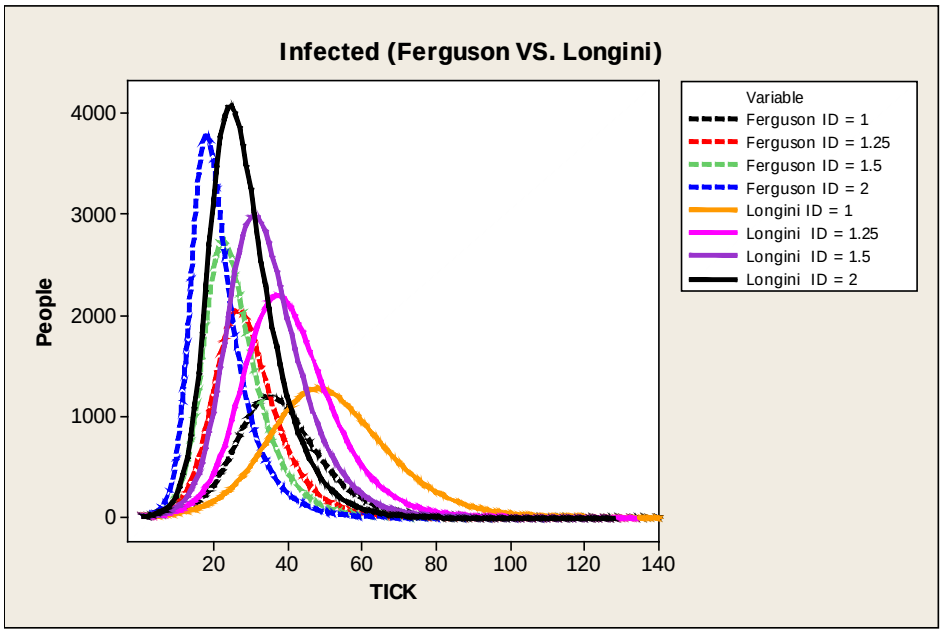


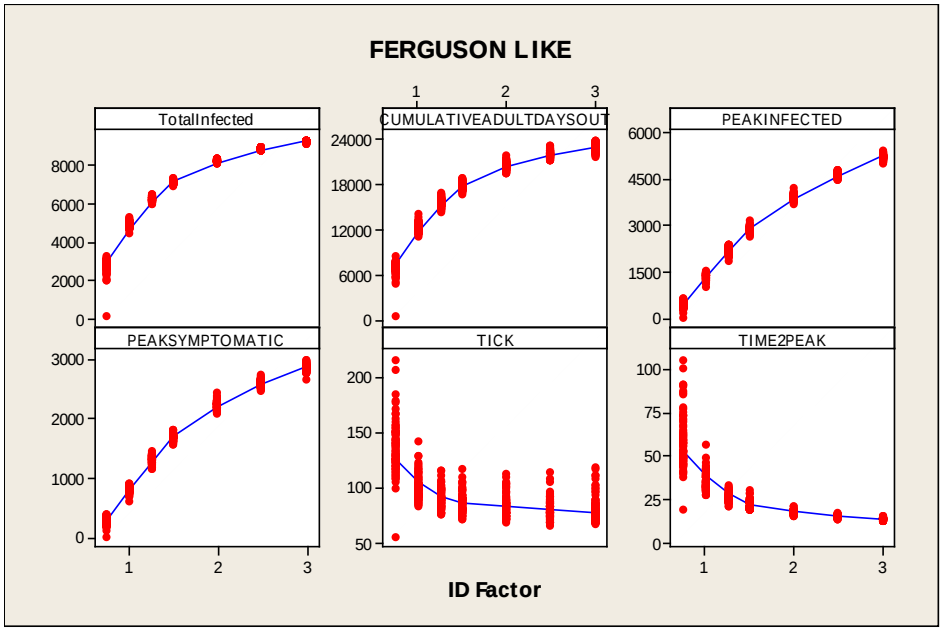
Observations on *IDfactor*:

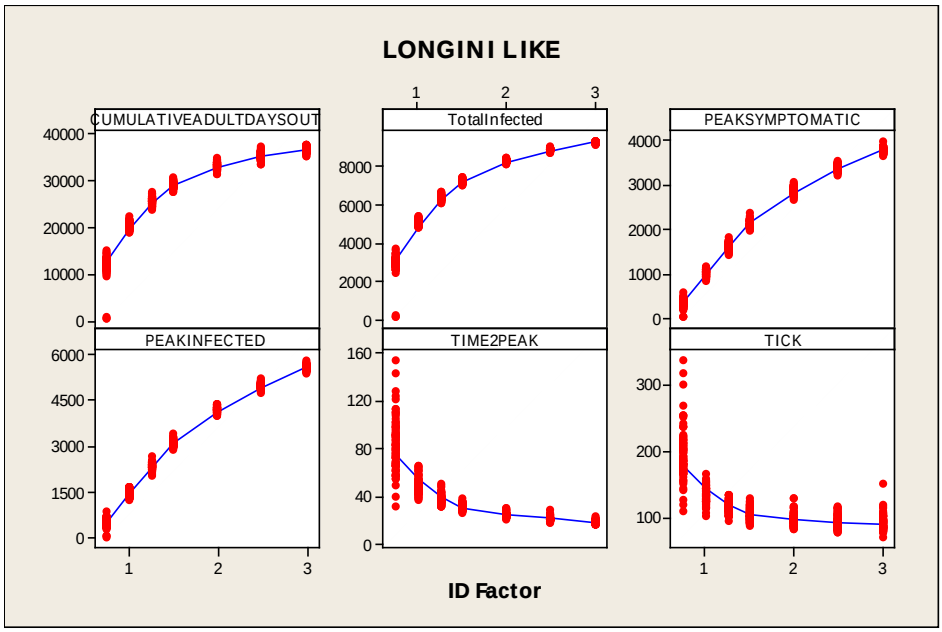
- Increasing *IDfactor* increases the attack rates, peak values for infected and symptomatic, and the number of days adults are at home, while decreasing the times to peak and total time of the epidemic
- Increasing *IDfactor* also shifts the *from-to* contact fractions toward adults and the infectious context fraction from household and school to neighborhood and work. These shifts occur

because the branching factors for adults are pushed above 1 as *IDfactor* increases and so adults become a primary substrate for transmission in addition to children and teens.

See plots below.



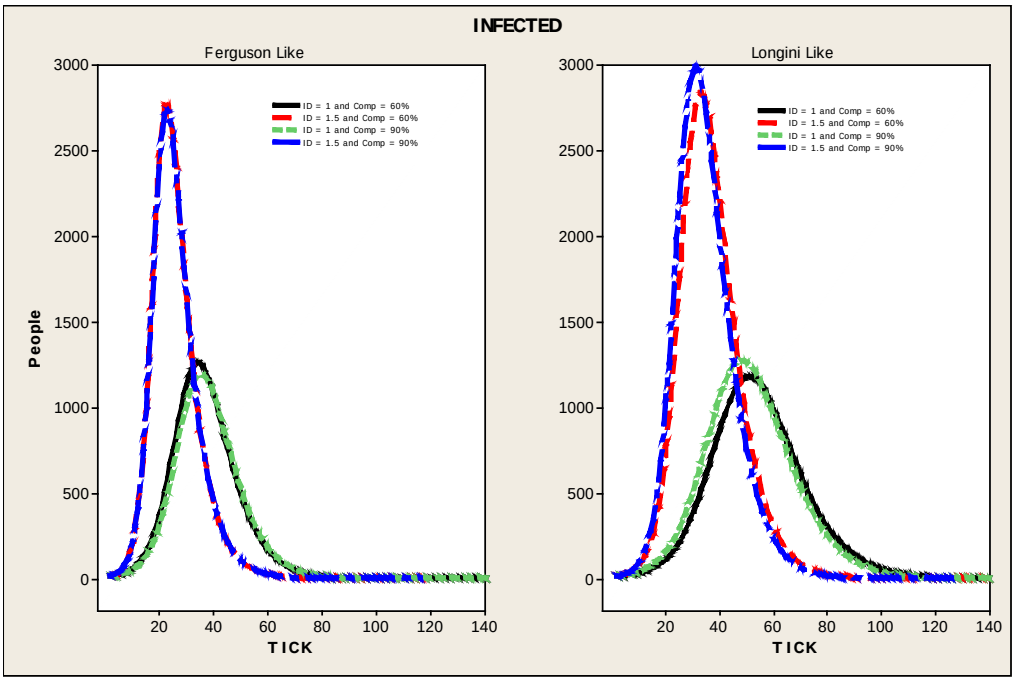




Observations on 90-percent and 60-percent compliance:

- Compliance has essentially no influence on results once I_D has been tuned to a 50-percent infection attack rate except that a change from 90-percent to 60-percent compliance shifts infectious contact fraction a bit (approximately 3–5 percent) from household to non-household contexts. This is consistent with the increase in non-household contacts at 60 percent.

See the following plot.



This page intentionally left blank.

Appendix D: Base Containment Strategy Combination Matrix Results

Statistical measures over 100 runs for the base matrix of containment strategy combinations are compiled in 2 Excel workbooks separated as averages and standard deviations (*SD*):

FergusonEpidemicCases.xls
FergusonEpidemicCases-SD.xls

The first worksheet of each Excel workbook contains a stand-alone description of the simulation matrix and what is contained within the worksheet. Subsequent worksheets create a set of 3-dimensional (3D) bar graphs and tables for the following 15 measures:

1. Number of simulations that yield epidemics (defined as greater than 1 percent of population infected)
2. Infection attack rate
3. Illness attack rate
4. Deaths
5. Peak infected
6. Time to peak infected
7. Peak symptomatic
8. Time to peak symptomatic
9. Epidemic duration (from first 10 diagnosed to last diagnosed)
10. Total time of effects (from initial seeding to last person recovered)
11. Number of days strategies imposed
12. Number of mitigation cycles
13. Number of external infections
14. Number of antiviral courses given
15. Number of days adults are at home (either sick, quarantined, or tending sick or sent home from school children)

In each 3D bar graph and table, strategies were organized with network-focused strategy combinations of S, CTsd, and ASsd in columns and case-based strategy combinations Q, T, P, and PEx in rows, yielding the 64 possible strategy combinations at each of 7 *IDfactors*. To aid in viewing these data, those combinations that yield an attack rate that is 10 percent or less are shaded green and those up to 25 percent are shaded pink in the tables.

Network Based	S	Schools closed
	CTsd	Child & teen social distancing
	ASsd	Adult & Senior social distancing
Case Based	Q	Household Quarantine
	T	Antiviral Treatment
	P	Antiviral Prophylaxis
	PEx	Extended Antiviral Prophylaxis

Time series plots for daily measures averaged over the set of 100 simulations may be made for any of the combinations of strategy (64),

IDfactor (7), compliance (2), boundary condition (2), or disease manifestation (2). An example set of such time series plots for *IDfactor* of 1.5 and Ferguson-like disease manifestation that consider the measures of people infected, given antiviral, adults at home, and symptomatic are presented in the following files:

Sequence1.5-90.pdf
Sequence1.5-60.pdf
Sequence1.5-90ExternalBaseEpidemic.pdf
Sequence1.5-60ExternalBaseEpidemic.pdf

Appendix E: Matrix Extension Results

The NISAC study team considered the following 4 extensions to the base containment strategy combination matrix:

1. Natural history disease manifestation: Longini-like[48]
2. 2 relaxed implementation thresholds (day after 30 or 100 diagnosed within the community)
3. 3 pre-pandemic vaccination strategies with 7-percent coverage of 50-percent efficacy vaccine administered, randomly targeted to children and teens or targeted to adults
4. Uniform transmission within children, teens, and adults (uniform relative infectivity and susceptibility and identical number of contacts within workplaces and schools)

For each extension, the study team conducted 100 runs for the full set of 64 containment strategy combinations, 7 *IDfactors*, 2 compliances (90 percent, 60 percent) and 2 boundary conditions (with or without connection to external unmitigated epidemic). Statistical measures over 100 runs are complied in Excel workbooks, separated as averages and standard deviations:

Excel files for Longini-like disease manifestation:

LonginiEpidemicCases.xls
LonginiEpidemicCases-SD.xls

Excel files for implementation threshold relaxation:

FergusonT1EpidemicCases.xls
FergusonT1EpidemicCases-SD.xls
FergusonT2EpidemicCases.xls
FergusonT2EpidemicCases-SD.xls

Excel files for pre-pandemic vaccination:

FergusonV1EpidemicCases.xls
FergusonV1EpidemicCases-SD.xls
FergusonV2EpidemicCases.xls
FergusonV2EpidemicCases-SD.xls
FergusonV3EpidemicCases.xls
FergusonV3EpidemicCases-SD.xls

Excel files for uniform transmission:

FergusonU1EpidemicCases.xls
FergusonU1EpidemicCases-SD.xls

[48] , T. C., K. Kadau, I. M. Longini, Jr., and C. A. Macken, 2006, "Mitigation strategies for pandemic influenza in the United States," *Proceedings of the National Academy of Sciences of the United States of America*, **103**(15):5935–40, 11 April, http://www.washington.edu/home/international/pdfs/mitigationStrategiesPNAS.pdf; and Longini, I. M., Jr., A. Nizam, S. Xu, K. Ungchusak, W. Hanshaoworakul, D. A. Cummings, and M. E. Halloran, 2005, "Containing pandemic influenza at the source," *Science* **309**(5737):1083–7, 3 August

As in Appendix D, the first worksheet of each Excel workbook contains a stand-alone description of the simulation matrix and what is contained within the worksheet. Subsequent worksheets create a set of 3D bar graphs and tables for the following 15 measures:

1. Number of simulations that yield epidemics (defined as greater than 1 percent of population infected)
2. Infection attack rate
3. Illness attack rate
4. Deaths
5. Peak infected
6. Time to peak infected
7. Peak symptomatic
8. Time to peak symptomatic
9. Epidemic duration (from first 10 diagnosed to last diagnosed)
10. Total time of effects (from initial seeding to last person recovered)
11. Number of days strategies imposed
12. Number of mitigation cycles
13. Number of external infections
14. Number of antiviral courses given
15. Number of days adults are at home (either sick, quarantined, or tending sick or sent home from school children)

In each 3D bar graph and table, the study team organized strategies with network-focused strategy combinations of S, CTsd, and ASsd in columns and case-based strategy combinations Q, T, P, and PEx in rows, yielding the 64 possible strategy combinations at each of 7 *IDfactors*. To aid in viewing these data, those combinations that yield an attack rate that is 10 percent or less are shaded green and those up to 25 percent are shaded pink in the tables.

Network Based	S	Schools closed
	CTsd	Child & teen social distancing
	ASsd	Adult & Senior social distancing
Case Based	Q	Household Quarantine
	T	Antiviral Treatment
	P	Antiviral Prophylaxis
	PEx	Extended Antiviral Prophylaxis

Time series plots for daily measures averaged over the set of 100 simulations may be made for any of the combinations of strategy (64), *IDfactor* (7), compliance (2), boundary condition, (2) or disease manifestation (2), but have not been included in this report.

Appendix F: Presentation to the Institute of Medicine

Glass et al., 2006, "Design of Community Containment for Pandemic Influenza," presented at the review by *Institute of Medicine of the National Academies* on "Modeling Community Containment for Pandemic Influenza," 24 October

AppendixF-RJG-Loki-Infect-IOM.pdf

This page intentionally left blank.

Appendix G: Additional Points of Discussion

Why do targeted social distancing strategies (S, CTsd, ASsd) work?

Network Based	S	Schools closed
	CTsd	Child & teen social distancing
	ASsd	Adult & Senior social distancing
Case Based	Q	Household Quarantine
	T	Antiviral Treatment
	P	Antiviral Prophylaxis
	PEx	Extended Antiviral Prophylaxis

Targeted social distancing strategies work by pushing the infectious contact network below the percolation threshold such that any instigation does not lead to a network-spanning event (epidemic). Schools form the highest zone of infectious contact and contacts there among children and teenagers first rise above the percolation threshold as I_D increases. Removal of these contacts for an *IDfactor* of 1.0 does not quite push the infectious contact network below the percolation threshold. However, the additional reduction of extracurricular contacts for children and teenagers does, even at an *IDfactor* of 1.5 (for a compliance of 90 percent). Increasing I_D further allows other portions of the heterogeneous contact network to rise above the percolation threshold as well and, thus, supports a network-spanning epidemic on their own. At an *IDfactor* of 2.0, adult and senior social distancing is also required and would need to be above the 50-percent compliance used in the current simulations to push the network below the percolation threshold. As an example, distancing all nonhousehold adult and senior groups by 90 percent while maintaining full work contacts for adults is sufficient to reduce the attack rate below 10 percent for an *IDfactor* of 2.0.

Why/when do case-based containments (Q, T, P, Pex) work or not work?

While social distancing strategies can be effective under all conditions if imposed quickly enough, pervasively enough, and with high enough compliance, case-based containments are not. In case-based containment, the portion of the contact network connected to the identified case is illuminated and contained through quarantine, isolation, or prophylaxis with drugs. Such a strategy will be effective if the illuminated zone captures all infectious contacts resulting from the identified case. Satisfying this criterion requires that the speed of disease progression is slow enough that, when case-based containment is applied, the required containment zone has not expanded too far. The speed of disease progression depends on how close the infectious contact network is to the percolation threshold. As the network approaches the percolation threshold from above, the speed at which the disease spreads decreases and reaches a minimum at the threshold. Thus, case-based containments work best at or just above the percolation threshold where there is time for implementation and the zone of containment is local. This requirement for effectiveness is clearly seen in the simulation data within Tables 4-1 through 4-6, Section 4 of the main text. Where social distancing strategies alone have pushed the attack rate to approximately 40 percent and below, adding case-based containments drop the rate to below 10 percent.

The fact that infectious cases are not all identifiable through symptoms confounds the issue with both normal and historical pandemic influenza strains. For influenza, both a presymptomatic infectious state and a nonsymptomatic infectious state occur to thwart detection. In the current model, formulated to reasonably fit the viral shedding data of Hayden, yield a period for a presymptomatic infectious state of 0.5 days before the onset of symptoms, and constrain only half of those that are infected to become symptomatic, a full 2:1 ratio of unknown-to-known infectious contacts occurs within the population at large (where known is defined as those that take place during the symptomatic infectious period). Such a high ratio would suggest that case-based

containment strategies would be very ineffective. But, because unknown infectious agents are associated with known infectious agents, case-based containment is still effective as long as the speed of disease spread is slow enough that all pre-infectious cases fall within the containment zone and can be neutralized.