Learning Environment Simulator: A Tool for Local Decision Makers and First Responders

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Abstract –

The National Infrastructure Simulation and Analysis Center (NISAC) has developed a prototype learning environment simulator (LES) based on the Critical Infrastructure Protection Decision Support System (CIPDSS) infrastructure and scenario models. The LES is designed to engage decision makers at the grass-roots level (local/city/state) to deepen their understanding of evolving crises, enhance their intuition and allow them to test their own strategies for events before they occur. An initial version is being developed, centered on a pandemic influenza outbreak and has been successfully tested with a group of hospital administrators and first responders. LES is not a predictive tool but rather a simulated environment allowing the user to experience the complexities of a crisis before it happens. Users can contrast various approaches to the crisis, competing with alternative strategies of their own or other participants. LES is designed to assist decision makers in making informed choices by functionally representing relevant scenarios before they occur, including impacts to critical infrastructures with their interdependencies and estimating human health & safety and economic impacts. In this paper a brief overview of the underlying models are given followed by a description of the LES, its interface, usage and testing experience.

Introduction

The customers of modeling, simulation and risk analysis efforts at the National Laboratories are often senior policy makers in Washington who request developments and analysis needed to protect the Nation’s critical infrastructures. Policy makers and administrators on the ground in local communities and states, including first responders and hospital administrators, may also benefit from critical infrastructure protection developments at the Laboratories and elsewhere. This more local communication channel may benefit from a different delivery mechanism – simulators.

Models are used to describe the structure of complex systems, understand relationship between structure and behavior, and ask “what if?” questions using a consistent framework. However, it is sometimes difficult to convey understanding of complex systems through static means like view-graph presentations and reports. Using these delivery methods the learning remains in the head of the modeler. This delivery approach benefits from the knowledge that the models are used by developers that understand the relationships, assumptions and limitations inherent in any model. However this approach also necessitates a certain distance between the analysis and the decision maker. But decision makers also need a means of exploring the system themselves and constructing their own understanding. Simulators utilize a model, interface, and well-thought out learning experience to give them this capability.

Simulators can engage decision makers and allow them to test and deepen their understanding by experimenting with their own strategies, conveying a real intuition about how the system works. These systems have the potential to enable them to better understand the strategic implications of their actions including unintended consequences as well as appreciate the importance of systemic thinking--in general and especially about their own problems. In this way the model builder can be removed to some degree as a middleman -- it's not necessary to interpret "what the model is saying."

The Critical Infrastructure Protection Decision Support System (CIP/DSS) simulates the dynamics of individual critical infrastructures [1] and couples separate infrastructures to each other according to their interdependencies [2]. For example, repairing damage to the electric power grid in a city requires transportation to failure sites and delivery of parts, fuel for repair vehicles, telecommunications for problem diagnosis and coordination of repairs, and the availability of labor. The electric power grid responds to the initial damage and to the completion of repairs with changes in its operating characteristics. These models are implemented in system dynamics using Vensim™ [3] which reads input parameters from and writes output time series of "consequence" metrics to a database. These metrics are abstracted into a much smaller set of "decision" metrics.

Decision makers need to understand the consequences of policy and investment options before they enact solutions, particularly for the highly complex alternatives available for protecting our nation's critical infrastructures in today's threat environment. The CIPDSS system has provided support to decision makers in a variety of areas over the last five years including for pandemic influenza [4, 5, and 6], hurricane Katrina [7], and telecommunications [8]. Government (federal, state, local) and industry decision makers can make use of this system to prioritize protection, mitigation, response, and recovery strategies as well as to support red-team exercises and provide support during crises and emergencies.

Here the use of CIPDSS as the underlying modeling system for a learning environment for local decision makers and first responders is contemplated to leverage the effort already expended to develop these capabilities. There is already a great deal of experience in the system dynamics community with these types of learning environments, alternately known as simulators, flight simulators and microworlds [9, 10] which are natural extensions of the system dynamics methodology. These types of simulators have been applied in a variety of applications including for example, banking [11], public health [12, 13] and port security [14]. An excellent review of these applications is given in reference [15]. CIPDSS, being largely based on system dynamics methodology and motivated to bring the analysis capabilities closer to the decision and policy makers, has therefore embarked on developing a learning environment simulator, leveraging the extensive experience available in the System Dynamics (SD) community. A developmental version described herein has been completed and tested with a group of potential users. This initial version was developed using the Sable development environment from Ventana Systems, UK [16]. Sable is designed for the rapid development of interfaces for models developed with Vensim and can leverage Venapp Builder [17] and several scripting languages to expand its built-in capabilities.

The choice was made to focus this first version of the LES on a Pandemic Influenza outbreak because it is timely and has the potential to exercise many of the key features of the LES relevant to local decisions makers [18]. The prototype LES exemplifies the simulation of possible pandemic outcomes on critical infrastructures, public health and economics based on the best possible data and information available [19 – 22]. Other infectious diseases could be handled with minor modifications as the core infectious disease model can easily be adapted and applied to any infectious disease.

The paper continues now by giving an overview of CIPDSS and a few snapshots of the CIPDSS models to provide context on the underlying structure and capabilities of the simulator and follows that with a description of the LES interface and its use. The experience gained through the first application of the LES with real decision makers is described next, followed by a short description of the next steps needed to make the LES operational.

CIPDSS

CIPDSS Overview

The Critical Infrastructure Protection Decision Support System (CIPDSS) is the only DHS risk assessment tool and analysis process that (1) simultaneously represents all major critical infrastructures and key resources in a single integrated framework, and (2) includes a decision aiding procedure that combines multiple, key objectives into a single measure of merit so that alternatives can be easily compared over a range of threat or incident likelihoods. CIPDSS is designed as a computer simulation and decision analytic tool that informs decision makers who must make difficult choices between alternative mitigation measures and operational tactics, or need to allocate limited resources to protect our Nation’s critical infrastructures against an existing threat today and against potential threats into the future. It incorporates a fully integrated risk assessment process, explicitly and rigorously accounting for uncertainties in threats, vulnerabilities, and the consequences of terrorist acts and natural disasters. CIPDSS models the primary interdependencies that link critical infrastructures and key resources together and calculates the impacts that cascade into these interdependent infrastructures and into the national economy.

Examples of questions that this decision support system is designed to address are:

- What are the consequences of attacks on infrastructure in terms of national security, economic impact, public health, and conduct of government—including the consequences that propagate to other infrastructures?

- Are there critical points in our Nation’s infrastructures (i.e., areas where one or two attacks could have extensive cascading consequences)? What and where are these points?
- What are the highest risk areas from a perspective incorporating consequence, vulnerability, and threat?
- What investment strategies can the U.S. make that will have the most impact in reducing overall risk?

CIPDSS includes consequence models for major critical infrastructures and key resources linked via their strongest interdependencies and coupled between the national and metropolitan scales. The system can track the propagation of a disturbance in the telecommunications sector, for instance, into the energy, banking, and government sectors. The outputs of the consequence models are captured in a consequence database from which consequence metrics are convolved with decision-maker risk profiles and value trade-offs. Multi-attribute utility functions are used to compare alternative infrastructure protection strategies and help build consensus among stakeholders in a decision.

The CIPDSS consequence models simulate the dynamics of individual infrastructures and couple separate infrastructures to each other according to their interdependencies. Dynamic processes are represented in the CIPDSS infrastructure sector simulations by differential equations, discrete events, and codified rules of operation. The CIPDSS metro model uses over 8000 variables to coarsely simulate the dynamics of the critical infrastructures at the metropolitan scale: many of these variables are output metrics estimating the human health, economic, or environmental effects of disturbances to the infrastructures.

Each critical infrastructure sector is divided into a number of sub-sectors that have a more uniform character and for which separate Vensim™ views are developed. For example, the emergency services sector is divided into 1) fire services, 2) emergency medical services, 3) law enforcement, and 4) emergency support services. A custom-built Vensim™ model “linker” called the ‘Conductor’ is used to assemble unified multi-sector models from individual files each containing a single sector model as well as to do numerous syntax checks. The linker identifies “shadow variables” present in models with dependencies on other sectors and resolves the references when the models are combined. This allows for the development and testing of models at the sector level, while running analyses at the multi-sector level.

The type of model chosen for each sub-sector depends on: 1) the characteristics of the particular infrastructure domain; 2) the data available to populate the model parameters; 3) questions to be asked of the model; 4) the amount of time available for development; and 5) any software constraints. Below are short descriptions of one of the critical infrastructure models (public health) and the infectious disease model that represents the disruption or scenario model for the prototype simulator. This provides a flavor of the types of models involved, typical output metrics and inputs and policies that will be exploited by the Sable interface. More detailed discussion of the public health, telecommunications and other sector models are given elsewhere, for example [23].

Metropolitan Public Health Sector Model

This model is required to represent the main activities of the Public Health sector and its primary interdependencies with other infrastructure sectors. The ability of the system to respond to emergency situations, such as natural disasters, terrorist attacks, large-scale accidents, or other unanticipated events is of particular interest. The system estimates the number of patients treated, the treatment outcome categories, the dispositions of patients, and costs of care. Other metrics of public health care may be calculated as appropriate. The dependence of the system on other infrastructures, for example, water, food, energy, government, transportation, banking, etc., is integrated into the overall system model. The system is capable of expanding its treatment capacity to accommodate the patient load on the system as well as move patients in an evacuation.

The public health model is divided into nineteen different views that partition out different functions and features of the public health system but that are also closely linked to one another. The public health views are: mortuary, physicians office and clinics, EMS capacity, emergency treatment, ER capacity, hospital inpatient care, hospital capacity, long term care, pharmaceutical and supply availability, alternative sources of personnel and facilities, chronic population, health care cost, special fatality rates (to account for poor care), alternative hospital beds, patients not admitted, patients treated at home, backup power and ventilators. The Public Health sector also interacts closely with the Emergency Services sector, accounting for the effect of emergency situations on the public health and emergency services labor force and any reduction of their capabilities due to direct or indirect effects of the disruption.

A small section of the model is shown in Figure 1. This section tracks the movement of afflicted persons into the hospital as emergency and non-emergency patients, their admittance if appropriate, treatment and release. A closer examination reveals linkages to other models (blue and red variables) such as affliction rate that is generated from the infectious disease model or other disruption model. Treatment rates in the model can also be affected by staffing levels and bed availability [19, 24]. Death rates are coupled with the infectious disease model so that the quality of care can affect the outcomes [25]. A more detailed and complete description of the public health model is available [26].

Infectious Disease Model

The infectious disease model is a modified susceptible-exposed-infected-recovered (SEIR) model using an extended set of stages; demographic groupings; an integrated model for vaccination, quarantine, and isolation; and demographic and stage-dependent behavior. As a variant on the SEIR model paradigm, this implementation represents the populations as homogeneous and well mixed, with exponentially distributed residence times in each stage (characterized with a nominal residence time) [27]. However, the use of additional stages and demographic groupings is designed to add additional heterogeneity where it can be useful in capturing key differences between subpopulations for disease spread and response. The stages are represented in a generic manner so that the model can be used for a number of infectious agents by adjusting the input parameters appropriately.

The basic reproductive number R_0 is the average number of people infected by a typically infectious individual in an otherwise susceptible population. If the basic reproductive number is greater than one, the disease has the potential to spread. If it is less than one, the disease will die out after only a few generations [28]. The parameters that impact R_0 include the ease of transmission of a disease and the contact rates among the populations. The CIPDSS infectious disease model can either use R_0 as an input into the model or it calculates it as an output of the model.

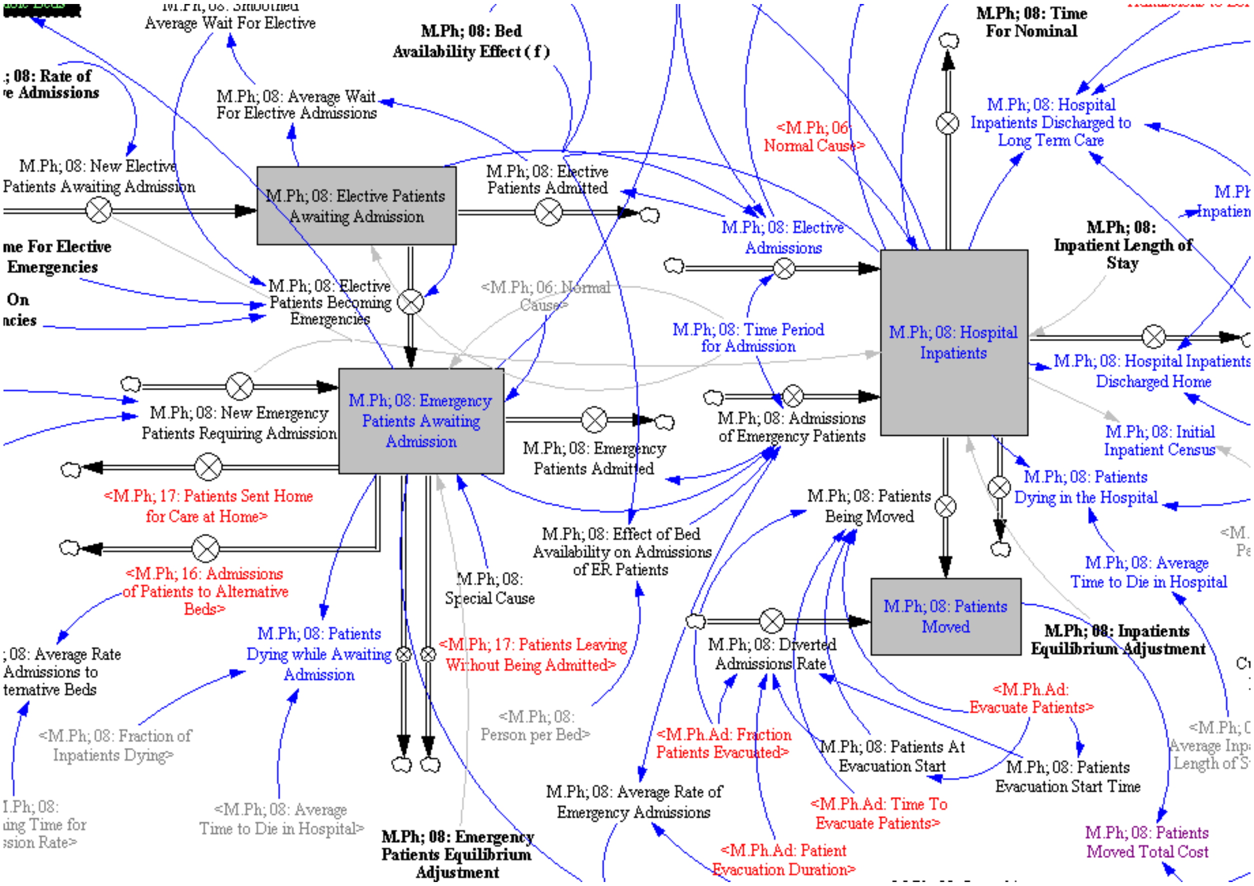


Figure 1: A section of the hospital inpatient care model in public health

Government response in the model in the form of quarantine and vaccination programs is initiated after recognition of the first cases in the public health system. The model represents the mitigation strategies for under a variety of policy assumptions. Mitigation options include vaccines (targeted vaccination, mass vaccination, or a combination) [29, 30], antivirals [31, 32], and isolation and quarantine [33, 34]. Vaccination can be biased toward particular subpopulations to model priority vaccinations of children or healthcare personnel. Allowances for refusing vaccination and separating segments of the population who cannot tolerate vaccination out of the queues can also be made. Schools themselves are not included in the generic infectious disease model; but school closing can be modeled by including age-group-dependence for R_0 or contact rates thus allowing age-specific control of the transmission and infections of school-age children.

The model also responds to investments in better hospital care, isolation, and antiviral treatments, which can affect fatality and recovery rates in the population. The model keeps track of the state of the population in terms of immunity, health status, unavailability (sick and/or in quarantine), and fatalities. Unavailability and fatalities are passed to the population and infrastructure models, whose effects can then feed back into the infection model. Examples of this behavior include sickness and fatalities leading to reductions in healthcare staff, which in turn can raise fatality rates in the infection model due to poorer and less timely care.
A portion of the model is shown in Figure 2 where the focus is on the movement of the unexposed population due to infection and a number of different mitigating actions such as contact tracing, vaccination by targeted and mass allocation methods, and similar allocation for antivirals. Not visible in the diagram is the fact that each stock, flow and auxiliary variable is indexed by six demographic groups divided by age with one of these groups corresponding to first responders (medical and emergency response personnel). This sampling of characteristics suggest a variety of factors including mitigating actions and disease and treatment parameters and options that can be exploited in a simulation, allowing the user to explore possible actions and outcomes. The user can affect not only the type of intervention used but the assumptions behind strategies such as the availability of antivirals or the effectiveness of a vaccine.

LEARNING ENVIRONMENT Simulator

A demonstration Learning Environment Simulator was built based on the goals associated with making NISAC capabilities available to local and regional decisions makers, CIPDSS model strengths and capabilities, and the features of the Sable development environment. The work is based in part on a prototype system developed in 2007 [35] and benefits in particular from extensive experience with simulation and learning environments in the SD community (see, for example [36, 37]). The simulator is divided into six pages that are easily accessible yet organized so that the user is led to appropriate areas depending on their interest. Here, an overview of the LES page organization and purpose is given followed by a brief discussion of the key features of each page.

The six pages of the simulator are as follows:

- Main View
- Health Care Dashboard
- Vaccines and Anti-virals
- Quarantine
- Comparisons
- Detailed Disease Information

The main page is the starting point for each session, containing the controls for advancing the simulation and the key output metrics in tabular and graphical form. The remaining pages revolve around a key theme for disease related scenarios, typically containing user selected inputs and key outputs relevant to that theme. The dashboard provides primarily health related information with a few controls while the vaccine and quarantine pages are largely used to set strategies for dealing with the scenario. The comparison page is used to compare the results of multiple executions of the simulation so that the user can compare the different strategies they employ.

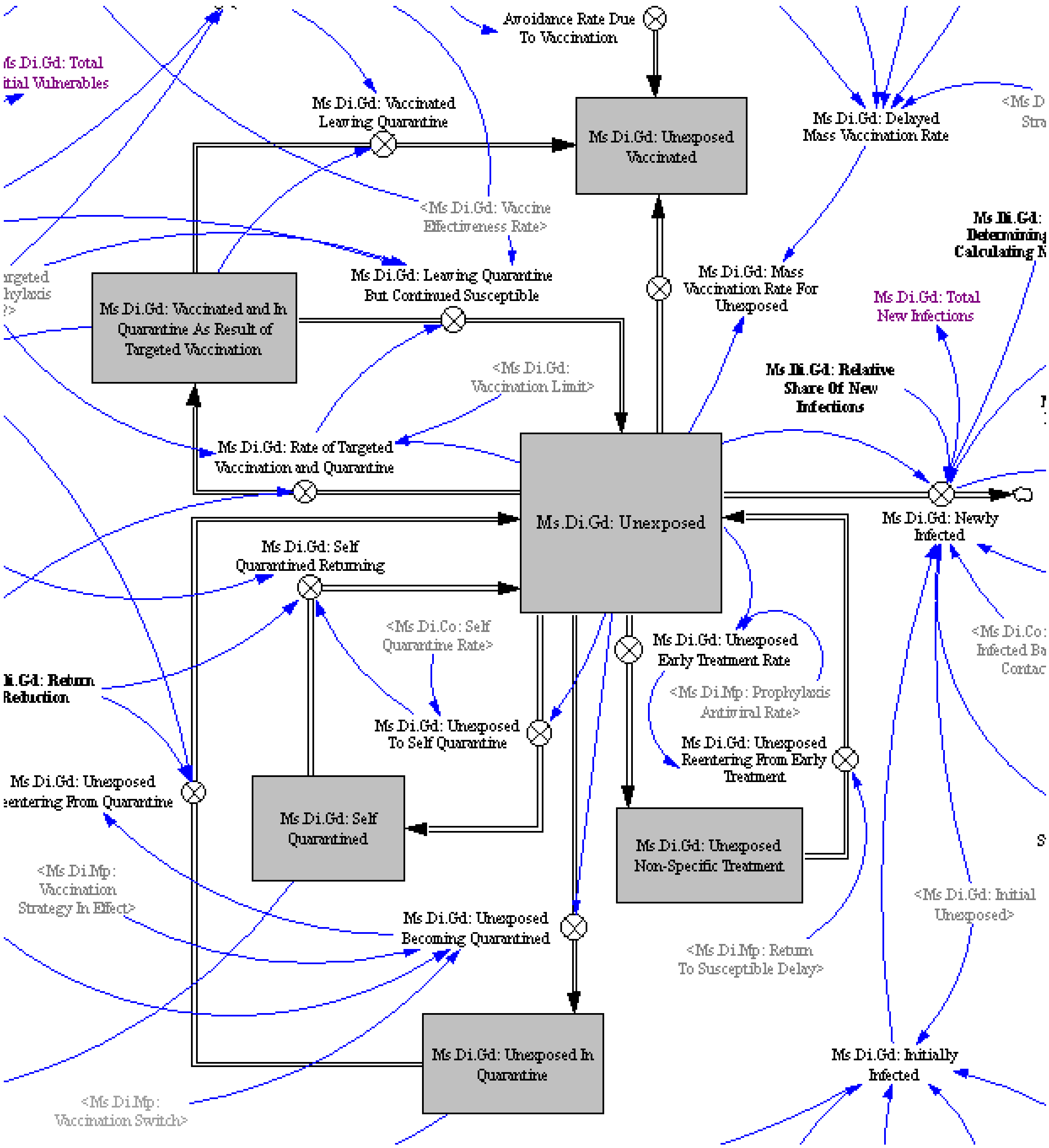


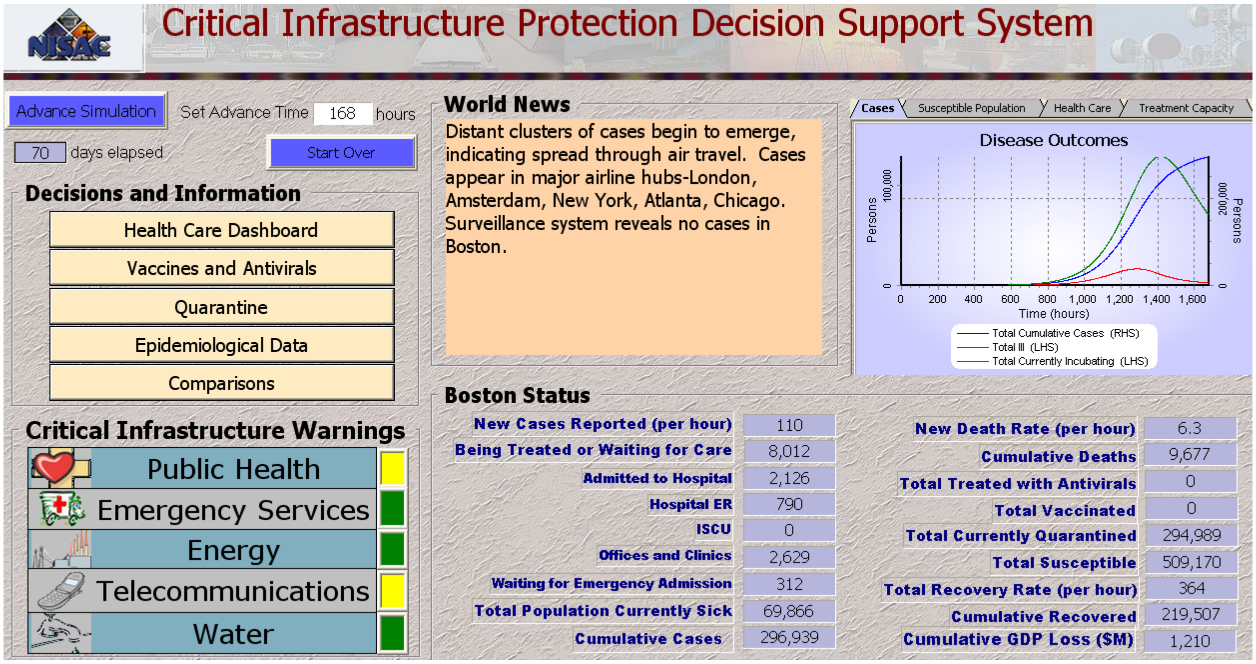
Figure 2: A section of the infectious disease model handling the unexposed population

Each of the pages has navigation buttons in the upper left corner that will take the user to any other page as well as a display on the elapsed time of the simulation in days. Output is presented in both tabular and graphical form on most of the pages. The majority of the graphs are presented in tab format so that multiple graphs can be displayed in the same space on the page - the desired graph is displayed by clicking on the desired tab label.

Main Page

The simulation is controlled from the main page (shown in Figure 3) where the user can step the simulation forward at a user selected interval that can change with each advance of the simulation (upper left corner). For example the user can step the simulation forward in large increments at first and then, as the dynamics become of greater interest, advance the simulation in smaller increments to better observe behavior or pause and make some decisions before continuing. No decisions are made on this page – rather the main page gives the user a high level view of the status of the local area in terms of new cases, the disposition of cases, hospitalized persons, vaccinations, recovered persons and GDP loss.

The main page contains a view of the day's news items which may provide clues regarding the progression of the disease which may assist the user in anticipating their own needs. Also on the page is a table (lower left corner) that summarizes at a high level the status of several of the key infrastructures – public health, emergency services, energy, telecommunications and water. These infrastructures may be impacted by the scenario as it unfolds as well as by user actions. They also may be the source of factors that may complicate the capability to respond as desired to the crisis. The status of the infrastructures is summarized with a simple stop light metaphor, with green meaning the infrastructure is in good shape, yellow meaning it is under stress and red meaning the infrastructure is in poor shape and may limit the decision-makers options. The point where the stop lights change depends on a combination of several metrics in each of the infrastructure CIPDSS models reaching pre-determined levels. For example the public health state is measured on the basis of available beds, available health care staff and available medical supplies. At this time these levels are not user selectable.



Set Advance Time 168 hours

70 days elapsed

Public Health 🟨
Emergency Services 🟩
Energy 🟩
Telecommunications 🟨
Water 🟩

Distant clusters of cases begin to emerge, indicating spread through air travel. Cases appear in major airline hubs-London, Amsterdam, New York, Atlanta, Chicago. Surveillance system reveals no cases in Boston.

New Cases Reported (per hour)	110	**New Death Rate (per hour)**	6.3
Being Treated or Waiting for Care	8,012	**Cumulative Deaths**	9,677
Admitted to Hospital	2,126	**Total Treated with Antivirals**	0
Hospital ER	790	**Total Vaccinated**	0
ISCU	0	**Total Currently Quarantined**	294,989
Offices and Clinics	2,629	**Total Susceptible**	509,170
Waiting for Emergency Admission	312	**Total Recovery Rate (per hour)**	364
Total Population Currently Sick	69,866	**Cumulative Recovered**	219,507
Cumulative Cases	296,939	**Cumulative GDP Loss ($M)**	1,210

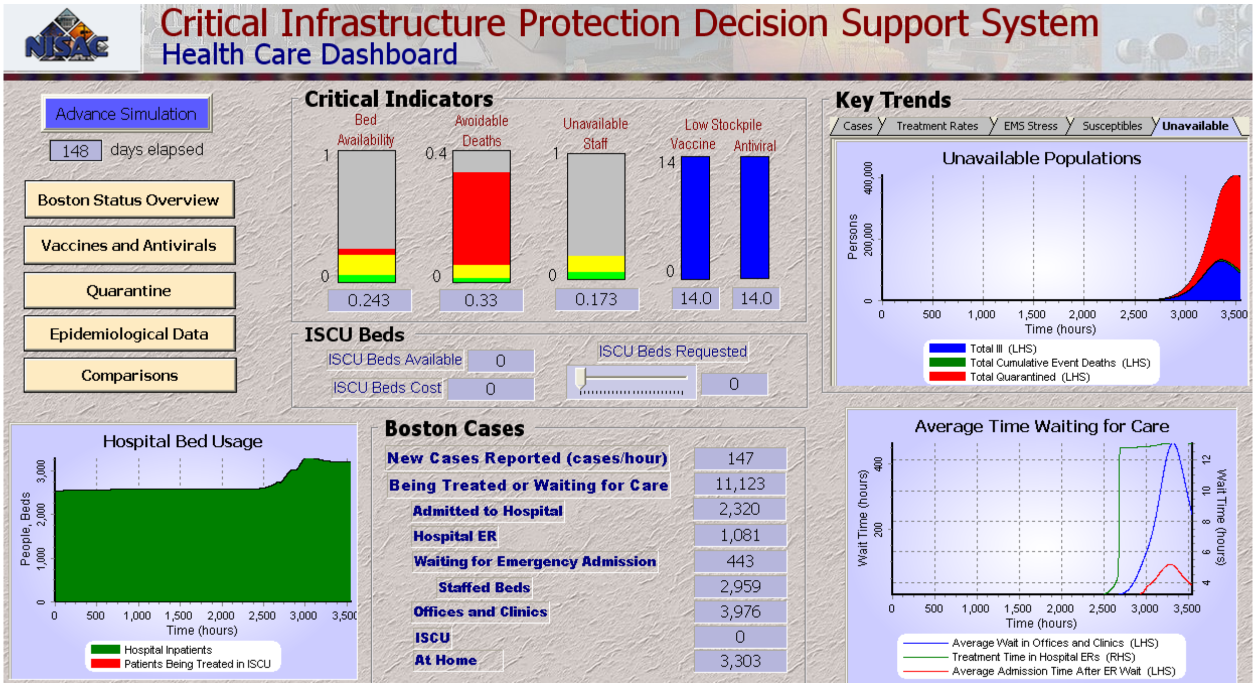
Figure 3: Learning Environment Simulator main view

Healthcare Dashboard

The healthcare dashboard is a compilation of numerous indicators on the status of the healthcare system in normal operations and as it deals with disruptions. Prominently displayed on top in the center of the page (Figure 4) are four critical indicators that provide at a glance the status of four key metrics of the healthcare infrastructure: bed availability, avoidable deaths, availability of staff and vaccine and anti-viral stockpile status. Three of the indicators provide a measure of the availability of resources needed to provide adequate healthcare (beds, staff and treatments). The metric of avoidable deaths is a measure of the degree to which the constraints on available treatments and staff have resulted in additional deaths due to inadequate treatment.

Many of the same key parameters are displayed in different forms on the dashboard, recognizing that different users and practitioners will be comfortable with different methods of getting information. For example, the available beds can be viewed using the critical indicator described above, in graphical form in the lower left corner of the dashboard and in tabular form in the lower center portion of the screen. Additional graphs available include the number of cases, treatment rates, the number of susceptible and unavailable populations, stress on the emergency services infrastructure and average waiting times. In the same way that different methods of displaying information are useful for different people or under different circumstances, a number of different measures of the position of the healthcare system are useful to meet the needs of users with different responsibilities. The unavailable population is a measure of how many people are not available to the general population and the workforce because they are sick, have been quarantined or have decided to quarantine themselves.

One decision point is available on the dashboard – the user can request that Influenza Special Care Unit (ISCU) beds be invested in to alleviate the overflows of bed space. The user selects the number of beds using a slider control, making more beds available but incurring a cost.



148 days elapsed

Bed Availability: 0.243
Avoidable Deaths: 0.33
Unavailable Staff: 0.173
Low Stockpile Vaccine: 14.0
Low Stockpile Antiviral: 14.0

ISCU Beds Available: 0
ISCU Beds Cost: 0
ISCU Beds Requested: 0

Boston Cases	
New Cases Reported (cases/hour)	147
Being Treated or Waiting for Care	11,123
Admitted to Hospital	2,320
Hospital ER	1,081
Waiting for Emergency Admission	443
Staffed Beds	2,959
Offices and Clinics	3,976
ISCU	0
At Home	3,303

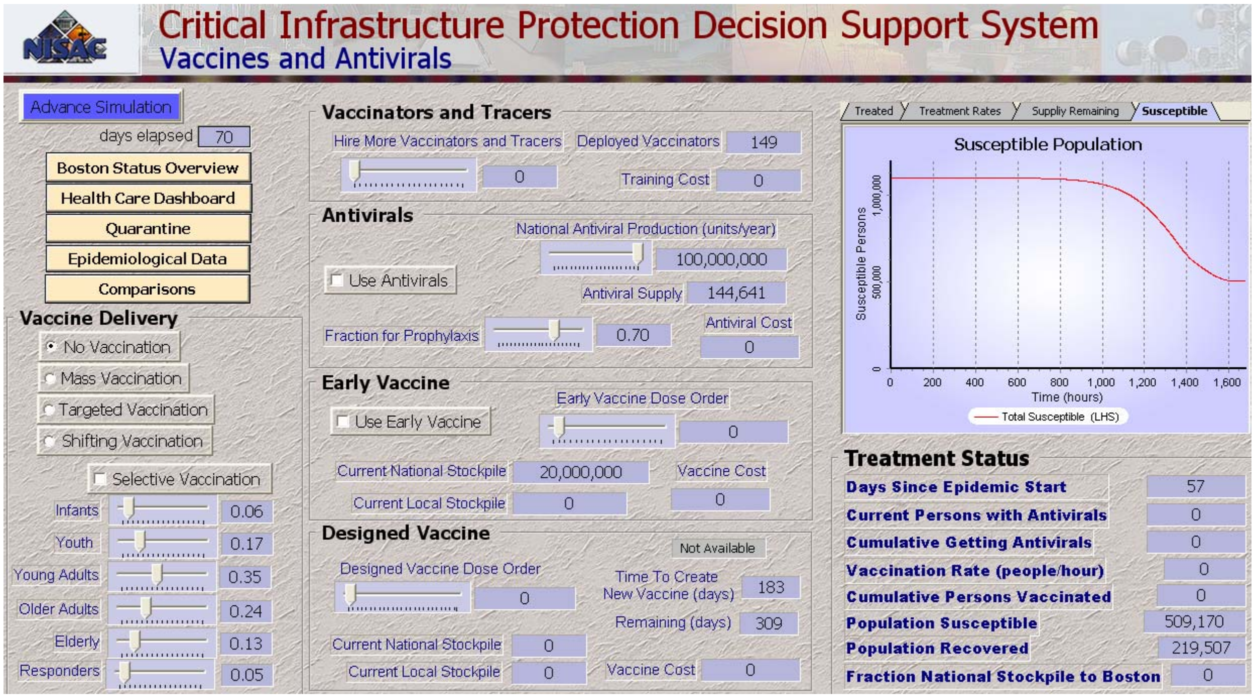
Figure 4: LES Dashboard view

Vaccines and Anti-virals

The vaccines and anti-virals page (Figure 5) is one of two pages that offer most of the decision making capabilities of the interface (the other is the quarantine page, discussed next). This page has numerous controls for deciding treatments and who those treatments should be administered to. For vaccines the user can decide amongst four strategies: no vaccination, mass vaccination, targeted vaccination and shifting vaccination. Targeted vaccination is targeted to an estimate of the contacts with individuals infected and shifting vaccination shifts the vaccination policy from targeted vaccination to mass vaccination.

Vaccines can also be targeted at specific age groups (such as infants and the elderly, or adults - the majority of the workforce). Two types of vaccine can be invested in by placing orders for the vaccine – an early vaccine and a designed vaccine. The early vaccine is available immediately but is not targeted at the specific strain of the virus. That is, when a pandemic influenza mutates into a form that is transmissible amongst humans then vaccines currently available will only be somewhat effective against it. Thus, an investment can be made, once the precise form of the vaccine is known, in developing the designed vaccine that will be much more effective. However, it takes time and money to develop this more effective vaccine. The user can also invest in anti-viral treatments which can be useful, particularly in the early stages of an outbreak.

In addition to these decision points the interface also displays information in graphical and tabular form about the investments that have been made and their effectiveness. These measures include the number of treated persons, treatment rates, remaining treatment supplies and the number of susceptible persons (people not already exposed or immune due to previous exposure or treatment) as well as the number of recovered persons.



days elapsed 70

Vaccine Delivery

● No Vaccination
○ Mass Vaccination
○ Targeted Vaccination
○ Shifting Vaccination

☐ Selective Vaccination

Infants	0.06
Youth	0.17
Young Adults	0.35
Older Adults	0.24
Elderly	0.13
Responders	0.05

Vaccinators and Tracers

Hire More Vaccinators and Tracers 0
Deployed Vaccinators 149
Training Cost 0

Antivirals

☐ Use Antivirals
National Antiviral Production (units/year) 100,000,000
Antiviral Supply 144,641
Fraction for Prophylaxis 0.70
Antiviral Cost 0

Early Vaccine

☐ Use Early Vaccine
Early Vaccine Dose Order 0
Current National Stockpile 20,000,000
Current Local Stockpile 0
Vaccine Cost 0

Designed Vaccine

Not Available
Designed Vaccine Dose Order 0
Time To Create New Vaccine (days) 183
Remaining (days) 309
Current National Stockpile 0
Current Local Stockpile 0
Vaccine Cost 0

Treatment Status

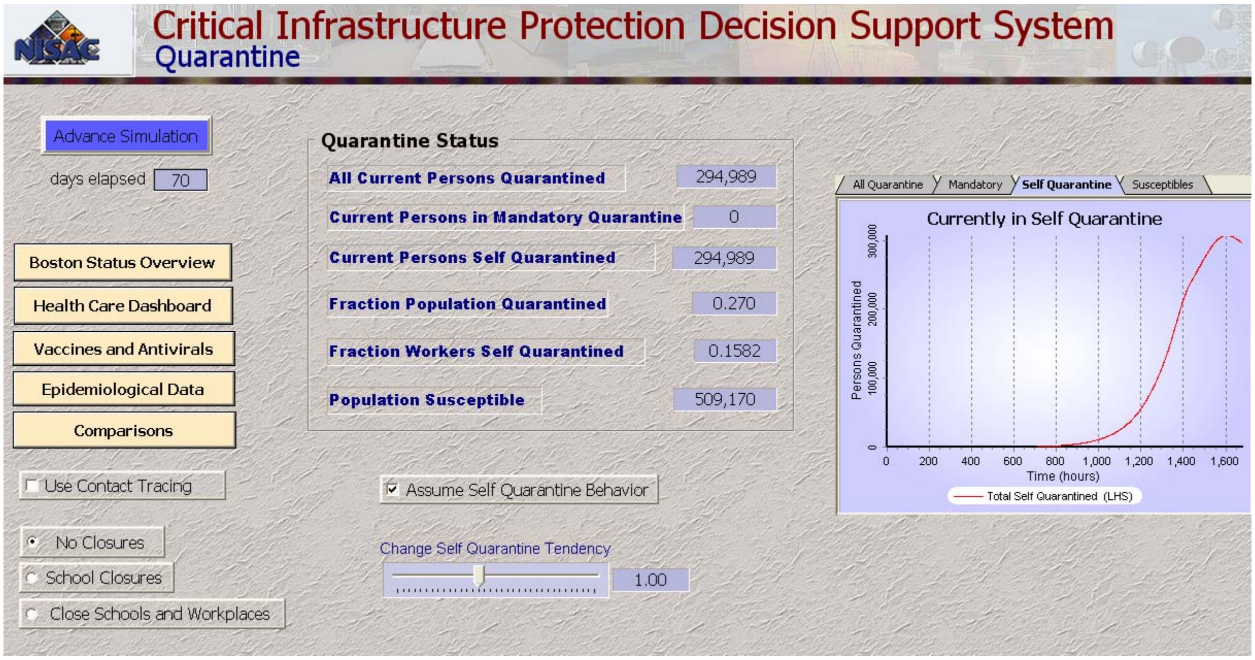
Days Since Epidemic Start	57
Current Persons with Antivirals	0
Cumulative Getting Antivirals	0
Vaccination Rate (people/hour)	0
Cumulative Persons Vaccinated	0
Population Susceptible	509,170
Population Recovered	219,507
Fraction National Stockpile to Boston	0

Figure 5: LES vaccines and anti-virals view

Quarantine

The quarantine page (Figure 6) allows the user to decide among several quarantine strategies: institute contact tracing, close schools and close workplaces. Contact tracing refers to finding the recent contacts of people who have been exposed in an attempt to quarantine or treat them before they can manifest the disease and further spread it. The user can also assume that self-quarantine behavior occurs as news gets out about the outbreak and influence the fraction of people likely to behave in this manner. These assumptions about behavior can modify the spread of the disease but also have significant impacts on the economy as people failing to show up for work for extended periods results in lower productivity - impacting GDP.

As before, the results of the quarantine choices are displayed in graphical and tabular form. The number of persons in various types of quarantine (mandatory due to being contact traced, self quarantine) are shown as well as the fraction of workers who are unavailable. Also displayed is the number of susceptible persons remaining in the population – an example of the practice of displaying the same information on several pages of the simulation because the information is relevant at multiple decision points and to reduce the need for wandering around the interface looking for information.



days elapsed 70

Quarantine Status

All Current Persons Quarantined	294,989
Current Persons in Mandatory Quarantine	0
Current Persons Self Quarantined	294,989
Fraction Population Quarantined	0.270
Fraction Workers Self Quarantined	0.1582
Population Susceptible	509,170

☐ Use Contact Tracing

☑ Assume Self Quarantine Behavior

● No Closures
○ School Closures
○ Close Schools and Workplaces

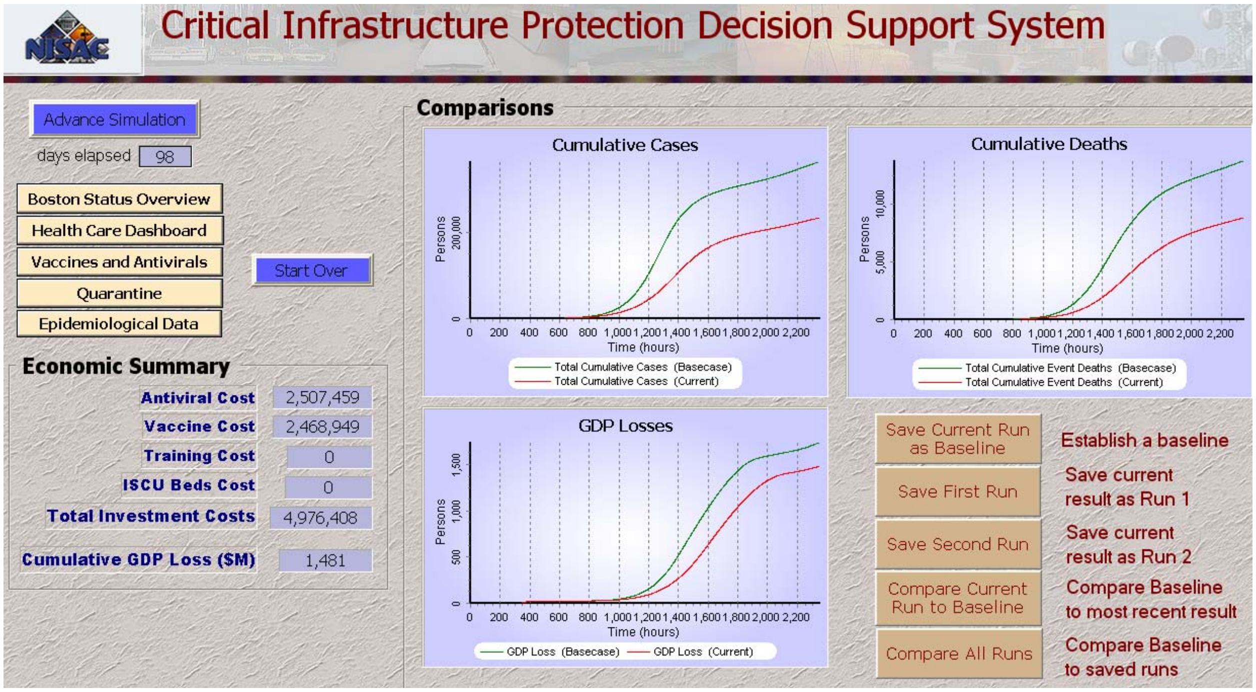
Change Self Quarantine Tendency 1.00

Figure 6: LES quarantine view

Comparisons

The comparison page presents the ‘bottom line’. Throughout the simulation the user has made decisions that will impact the progression of the outbreak, but at a cost. Three key measures of the effectiveness of the user’s strategy are presented in graphical form: cumulative cases, cumulative deaths and GDP losses as shown in Figure 7. Cases and deaths are key measures of how effective the user has been in controlling the outbreak while GDP loss is the ultimate measure of how those strategies have impacted the economy. Also summarized here are the investments that were made to deal with the outbreak including investments in ant-virals, vaccine, training and ISCU beds.

From this page the user can save results from multiple runs of the simulation so the results of different strategies employed can be compared. The user can establish a baseline case for themselves (perhaps with relatively straight-forward responses to the outbreak) and save two more simulation runs with different strategies. These strategies can then be compared with one another and with the baseline at the user's discretion, displaying all results on the same graph.



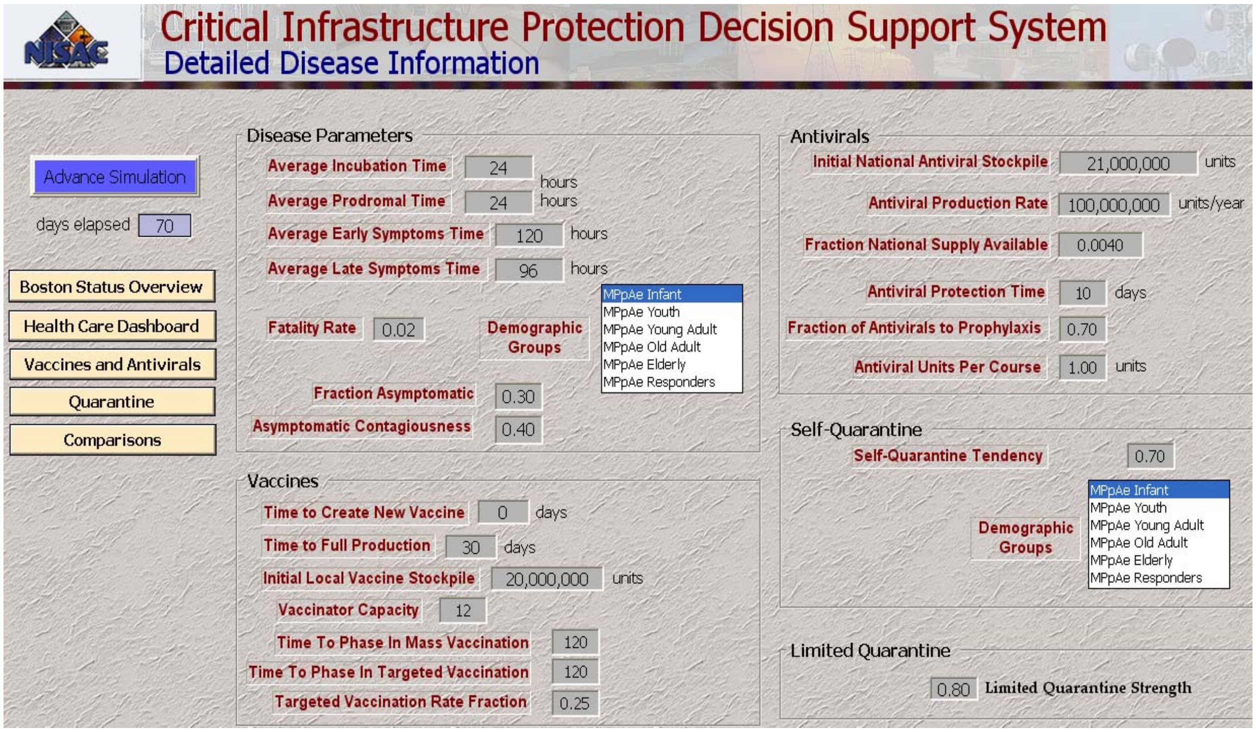
days elapsed 98

Antiviral Cost	2,507,459
Vaccine Cost	2,468,949
Training Cost	0
ISCU Beds Cost	0
Total Investment Costs	4,976,408
Cumulative GDP Loss ($M)	1,481

Figure 7: LES comparison view

Detailed Disease Information

The final page (figure 8) exists only for informational purposes, showing the user various assumptions that have been made in the simulation about the length of the disease stages (incubation, prodromal, early and late symptoms), fatality rates given an infection, the number of asymptomatic infecteds (who are able to spread the disease most effectively because their ability to spread it is less obvious) and the production rates and requirements for producing vaccine and anti-virals. These parameters are not variable in the current version but nothing about the implementation of this simulator and the underlying models would prevent the user from exercising more control over these and other parameters in the future (to, for example, run scenarios for outbreaks of other diseases).



days elapsed 70

Disease Parameters

Average Incubation Time 24 hours
Average Prodromal Time 24 hours
Average Early Symptoms Time 120 hours
Average Late Symptoms Time 96 hours
Fatality Rate 0.02
Demographic Groups: MPpAe Infant, MPpAe Youth, MPpAe Young Adult, MPpAe Old Adult, MPpAe Elderly, MPpAe Responders
Fraction Asymptomatic 0.30
Asymptomatic Contagiousness 0.40

Vaccines

Time to Create New Vaccine 0 days
Time to Full Production 30 days
Initial Local Vaccine Stockpile 20,000,000 units
Vaccinator Capacity 12
Time To Phase In Mass Vaccination 120
Time To Phase In Targeted Vaccination 120
Targeted Vaccination Rate Fraction 0.25

Antivirals

Initial National Antiviral Stockpile 21,000,000 units
Antiviral Production Rate 100,000,000 units/year
Fraction National Supply Available 0.0040
Antiviral Protection Time 10 days
Fraction of Antivirals to Prophylaxis 0.70
Antiviral Units Per Course 1.00 units

Self-Quarantine

Self-Quarantine Tendency 0.70
Demographic Groups: MPpAe Infant, MPpAe Youth, MPpAe Young Adult, MPpAe Old Adult, MPpAe Elderly, MPpAe Responders

Limited Quarantine

0.80 Limited Quarantine Strength

Figure 8: LES detailed disease information view

LES Usage

The ability to navigate amongst these pages allows the user to control the progress of the simulation, observe the progression of the disease and key measures of outbreak severity and make numerous decisions and investments that can alter the course of the outbreak. The interface is designed to be relatively easy to use but present enough information so that the user feels they have control over decisions and investments they or other decision makers would have access to, and to be able to understand the implications of their actions. As the simulator is tested by actual decisions makers, many opportunities will likely arise to improve the interface readability, to present information in forms more natural and realistic and allow for the correct level of flexibility in decision making they are likely to experience in an outbreak.

It is essential that LES be used in the context of a workshop with a trainer who understands NISAC capabilities and limitations of the models used within the simulator. LES is not a predictive tool but rather a simulated environment allowing the user to experience the complexities of a crisis before it happens. This dynamic simulation can be interrupted by the user at their discretion to make investments, react to changing conditions, alter policies, observe outcomes and access a wide variety of response options. Users can contrast various approaches to the crisis, competing with alternative strategies of their own or other participants.

Unlike mass casualty drills or table tops where it typically takes a whole day to go through a single simulation, the LES allows participants to go through several scenarios in a single session, varying strategies and conditions, enabling participants to get a much better sense of how to respond under different circumstances and develop more resilient strategies. This capability adds a whole new dimension to training for first responders, administrators and other local officials.

LES Workshop Session

The first workshop session using LES was conducted at the DelValle Institute for Emergency Preparedness in Boston, Massachusetts on October 4, 2007. The goal was to put a developmental version of LES in front of a group of actual potential users to assess assumptions about the utility of the simulator and improve key elements of the simulation including interface usage and clarity and the plausibility of the behavior of the system in response to user decisions. The session was very successful in that the participants were strongly engaged in the exercise and many useful comments, both general and detailed in nature were received.

Sixteen officials in hospital administration and emergency preparedness, with titles such as “Deputy Director for Hospital Preparedness”, “Medical Director for Homeland Security”, “Program Manager, Community Planning”, “Emergency Planning Coordinator” and “Epidemiologist”, participated in the workshop. The session began with an introduction to the purpose of the workshop and a brief introduction to the simulation and its use but then, within about thirty minutes, moved into hands-on experience with the LES. Three facilitators from the LES team were available at all times to answer specific questions about the interface or its use.

The simulation was scaled to Boston's population, available hospital beds and other factors to make the exercise more meaningful. This sort of customization is achieved through changes to input files and can be accomplished on site. The sixteen participants were split into two groups of eight, interfacing with separate copies of the simulation and asked to run through two complete scenarios. During each scenario the participants were asked to observe the events and dynamics in the scenario and make decisions, at simulated time intervals of their own choice that they felt would be useful in reacting to the outbreak. Most decisions had costs associated with them that were tallied up at the end as well as a cumulative effect on the total deaths and economic impact (in terms of lost GDP). At the end of the first session the participants were brought together again to compare notes, experiences and outcomes. The participants were then able to take their experiences and outcomes and try a new set of investments and strategies in the second round.

Throughout this process and at the end of the session comments were gathered that covered general impressions of the LES and the entire workshop experience as well as very detailed comments and questions of specific behavior observed in the simulation, the intuitive nature of the interface, the design of the interface elements and other details about the experience. Some of the general comments are quoted here:

> “Real value of the simulator is it makes you talk about things”
>
> “This quantifies the strategies we’ve been talking about”
>
> “Interface is remarkably easy to use”
>
> “Can LES address the labor effects on infrastructure operations?”
>
> “People don’t realize what staying at home costs”

“Should try sessions with different groups working together, like public health school superintendents, politicians, financial people, the media and private companies”

“Provides various stakeholders the opportunity to work through issues and discuss strategies and outcomes”

“Would be great for students”

“Very effective way of visualizing decisions that are discussed frequently but never seen in this capacity”

“This quantifies the strategies and then you can show it to people”

“Liked the use of the GDP measure because you can show to industry/government/ media/schools what quarantine/stay home can really mean financially”

There were many detailed comments that will be helpful in future development efforts leading to a Version 1.0 implementation. A small sample of these comments is included here:

“Add more comparison charts”

“Allow for user to institute a media campaign that costs money but allows for the user to select higher self quarantine behavior (for example)”

“Use of selective vaccination by demographic group is confusing”

“Users felt they wouldn’t hire or train vaccinators but rather divert existing resources”

“Emergency services indicators should be divided into EMS, public safety and hospital related warnings”

“Wanted more information on what was going on with the critical infrastructures”

“Be able to keep a record of inputs that users select over the simulation”

“More data could be provided, but not too much more”

As evidenced by this sampling of the feedback received, there was strong engagement by the participants, validating the assumptions about the utility of this type of simulation for local and regional decision makers. The session was also extremely valuable in eliciting the detailed comments needed to complete initial development and improve the utility of the experience for all.

NEXT STEPS

The next steps will take the LES to operational status by completing the build-out of the demonstration version, developing appropriate course materials and taking LES to additional stakeholder groups, incorporating those experiences into Version 1.0. Completing the build-out will include:

- Incorporating learning from the Boston session and additional sessions
- Introducing additional features such as budgetary constraints so that people can't simply decide to do everything, but must choose more thoughtfully

- Add additional drill down capabilities so that users can go deeper to understand why they're getting particular results
- Provide a more engaging interface that gives additional information in the form of more elaborate messages tied to conditions being experienced in the simulation
- Possibly implement different roles for participants (public health, hospital, public safety, general government employer, etc.) vs. functioning as a single team.
- Develop help systems in the simulator
- Develop the course materials needed to integrate LES into a well-designed experience

Once this initial version has been completed similar learning environments could be developed rapidly for other scenarios (hurricanes, physical disruptions, chemical events, etc.) that have been examined in the NISAC program. Thus these efforts can benefit from investments DHS has already made and extend the benefits to a much larger audience.

ACKNOWLEDGMENTS

The authors greatly acknowledge the assistance of Tony Kennedy at Ventana Systems UK in transitioning to the Sable software and answering our numerous questions.

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