

# Development of a Quick Look Pandemic Influenza Modeling and Visualization Tool

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## ABSTRACT

Federal, State, and local decision makers and public health officials must prepare and exercise complex plans to contend with a variety of possible mass casualty events, such as pandemic influenza. Through the provision of quick look tools (QLTs) focused on mass casualty events, such planning can be done with higher accuracy and more realism through the combination of interactive simulation and visualization in these tools. If an event happens, the QLTs can then be employed to rapidly assess and execute alternative mitigation strategies, and thereby minimize casualties. This can be achieved by conducting numerous “what-if” assessments prior to any event in order to assess potential health impacts (e.g., number of sick individuals), required community resources (e.g., vaccinations and hospital beds), and optimal mitigative decision strategies (e.g., school closures) during the course of a pandemic. In this presentation, we overview and demonstrate a pandemic influenza QLT, discuss some of the modeling methods and construct and visual analytic components and interface, and outline additional development concepts. These include the incorporation of a user selectable infectious disease palette, simultaneous visualization of decision alternatives, additional resource elements associated with emergency response (e.g., first responders and medical professionals), and provisions for other potential disaster events.

## Keywords

Pandemic influenza, quick look tool, mass casualty, disaster, mitigation strategy, public health.

## INTRODUCTION

In recent years significant natural and man induced disasters such as the September 11, 2001 terrorist attacks on the United States, the Indian Ocean Tsunami in 2004, Hurricane Katrina in 2005, and the earthquake in Haiti in 2010, have all called for rapid response and mitigation measures to cope and minimize resulting casualties from these events. Of even greater potential health risk is a pandemic, such as the Spanish Flu in 1918 or the H1N1 pandemic that emerged in 2009. To this end, the nation and the world has geared up and conducted a myriad of planning activities focused on responding to these types of disasters. Some of this planning involves sophisticated modeling and simulation in order to demonstrate and forecast the potential magnitude of a pandemic, as well as the number of infected individuals and casualties. In our research, we have focused on developing a pandemic quick look tool that can rapidly model a pandemic of user specified disease traits and origin, model potential mitigation measures, and provide an interactive visual environment to enable decision makers at multiple levels to investigate decisions and consequences.

## A PANDEMIC INFLUENZA QUICK LOOK TOOL

Our initial pandemic influenza QLT is focused on providing a state level impact assessment, with a granularity down to the county level of detail. Figure 1 shows a screenshot from the basic user interface screen of our pandemic influenza QLT which is setup for the State of Washington. In this case it was an assumed the

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pandemic originated (i.e., the first case entered Washington) in Seattle. The QLT allows the user to vary the origin assumption and then many other parameters about the pandemic, to include the mortality rate, the hospitalization rate, and the mean time for infected individuals to recover. Finer details can also be chosen such as those related to the basic reproduction number, gross attack rate, and other epidemiological factors that might describe a pandemic. For a selected county in Washington, such as Benton County as shown in Figure 1, the QLT returns information on the forecasted the number new sick individuals each day, the number of new hospitalizations each day, and the number of projected new deaths each day. The QLT also returns the cumulative number of these metrics over a 30 and 60 day timeframe. As the user selects a different county, the QLT automatically updates with information/metrics about that county.

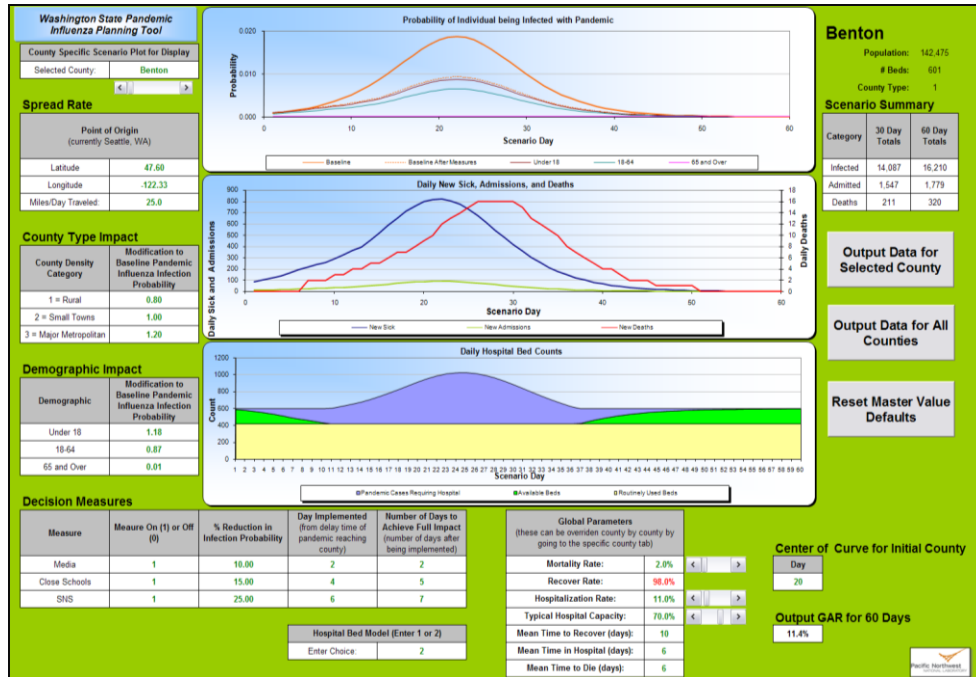


Figure 1. Pandemic Influenza Quick Look Tool Screenshot

As seen in Figure 1, the user can also select some potential decisions in regard to mitigation measures, such as media announcements, school closures, or distribution of strategic national stockpile (SNS) resources (e.g., vaccines and antiviral medications). The timing of the decision and the potential benefit of the decisions can also be specified. These decisions have the effect of reducing the prevalence of the pandemic. Lastly, the model tracks and examines the required need for hospital beds over time and compares this to the available beds within the county. Shortfalls are displayed graphically (i.e., shaded blue as seen in Figure 1). This information could be used by planners decide on potential resources that might be needed to make up these shortfalls.

The pandemic QLT operates using a mathematical epidemic model to calculate population dynamics and infection rate data. Specifically, disease dynamics are calculated per county by a system of non-linear difference equations derived from traditional compartment epidemic models with homogeneous population mixing [Anderson and May R (1992); Diekmann and Heesterbeek (2000)]. Many of the model parameters can be set by the user as indicated earlier. Individuals in the population are assigned to a compartment by disease state -- susceptible, infectious/sick, and recovered. The population is demographically stratified by age into three groups: infant to 18, 18 to 64 and over 64 years old. Population numbers for each age group are taken from the 2000 U.S. Census. We also track infection severity by tabulating those hospitalized and mortality as deceased because of infection by pandemic influenza. The mortality rate is the percentage infected that will ultimately die due to complications from pandemic influenza with average time to death as specified by the user. Conversely, the recovery rate is the percentage of those infected with pandemic influenza that will ultimately recover, with average time to recover also user specified.

Individuals are hospitalized for an average number of days set by the user. In the model, the user is asked to specify typical hospital capacity which is set to a default value of 70% (research indicates that typical hospital capacities may be as large as 80-90%). Hospital capacity is the typical percentage of total beds routinely used out of total beds available. This is used to compute the available beds that can be drawn upon for supporting a pandemic and the corresponding shortfall mentioned earlier.

Currently, the primary methodology used for the pandemic to migrate within the state is done via a comparison of distance and population density of the other counties relative to the origin county. Hence, for Washington which has 39 counties, there are 39 different delays computed for the pandemic to reach the county under consideration for analysis/display. Thus, the user would see the prevalence curve (shown as the probability of individual being infected with pandemic curve in Figure 1) shift in time from county-to-county as different counties are examined by the user. This notion is shown in Figure 2 which compares Benton County to Adams County (which has a much lower population density than Benton County, hence the pandemic would tend to arrive in Adams County from Seattle later than Benton County). In this setup, the pandemic arrives in Benton County just two days after originating in Seattle, but does not arrive for 21 days to Adams County.

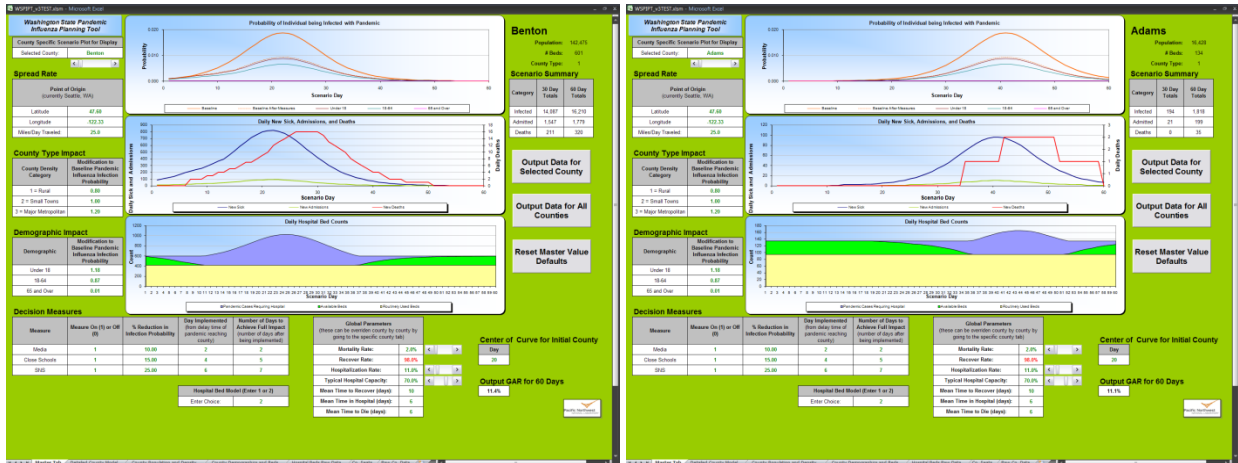


Figure 2. Comparison of Delay of Pandemic to Reach Adams County Compared to Benton County

**Pandemic Visualization Aspects**

Whereas the QLT is useful for doing a more detailed assessment of each county individually, it is beneficial for planners to examine the situation across the state. To this end, we have coupled the QLT methodology with an interactive visualization component called PanViz. PanViz allows the user to visual “see” the potential impact of a pandemic across an entire state, as well as interactively scroll forward and backward in time to better understand the temporal characteristics of the pandemic spread. Figure 3 shows a screenshot from PanViz again for the state of Washington, with King County (Seattle is located in King County), Benton County, and Adams County highlighted. Note that PanViz can also provide some of the similar metrics as the QLT in a graphical format as shown on the right side of the figure. In this figure, the color shading represents the percentage of the county population that is infected (i.e., sick) with the pandemic.

In essence, PanViz becomes an interactive graphical front-end to the QLT modeling program that is designed for end-users at multiple levels, from the public, to state decision makers, to local management personnel. In the PanViz interface, all of the parameters of QLT can be accessed through detailed menus, but the most common decision measures and outcome information are presented on the main display. This abstracted view is beneficial for presenting information to the public as well as training local decision makers. The ability to scroll through time, adjusting the decision points for action and immediately see the effect of pandemic spread, hospitalization, and deaths provides an intuitive understanding of decisions and consequences through an active visual learning environment. This interactive environment easily accommodates exploration of planning alternatives and different scenarios in both training and real situations. From initial feedback from users, the dramatic effect of delaying interdiction measures was made clear in using the tools.

We are currently exploring the further use of these tools in training exercises where we add visualization components to show not only the progression of the pandemic with the user chosen action, but also showing the progression without intervention. This environment will allow the user to explore the impact of alternative interdiction and response activities, providing more information in making decisions that have not only health benefits, but public and financial costs as well.

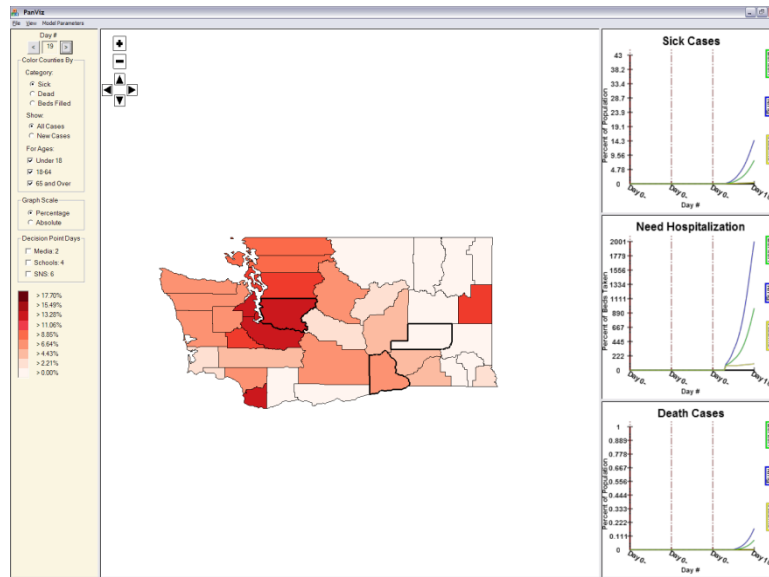


Figure 3. Screenshot from PanViz for Washington State

**ADDITIONAL DEVELOPMENT CONCEPTS**

In this section we outline additional concepts and development plans for our quick look tool modeling efforts.

**Increasing QLT Granularity and Fidelity**

Our next steps in the development of a quick look tool for pandemic influenza are to increase the granularity and fidelity of the model. We intend to increase the granularity by updating the model to operate on a census tract level of detail. Census tracts are small, relatively permanent geographic subdivisions of a county. Per the U.S. Census Bureau, census tracts usually have between 2,500 and 8,000 persons and are designed to be homogeneous with respect to population characteristics, economic status, and living conditions [U.S. Census Bureau]. These characteristics lend themselves to the second development goal of additional QLT fidelity.

Currently, even though the QLT does account for and model different demographic groups, this is limited to the spread and prevalence of the pandemic by age group dependencies only, and not other characteristics that might be found in census tract data. Such characteristics could potentially be used to stratify disease spread, societal response, and mitigation effectiveness as a function of varying beliefs, ethnicities, and economic conditions.

There are some potential computation difficulties of migrating to a census tract level of detail. For instance, while Washington State has 39 different counties, King County alone is comprised of about 380 different census tracts [State of Washington]. Hence, one can see at least a magnitude increase in the computational complexity of the model just by going to census tracts. Moreover, we also intend model not only two way spread functions between counties (i.e., we currently only spread the pandemic from the origin county to other counties), but all ways spread functions between each county and every other county. It turns out for Washington that there would be 741 (i.e.,  $39 \times 38 / 2$ ) all way interactions among its 39 counties. The problem then becomes significantly larger by considering all way interactions among each census tract.

An additional goal in future modeling is to provide the ability to examine not only impacts at the state level, but also at a national level. PanViz has already made strides in this manner. At the same time it has also been updated to incorporate additional refinements to the algorithm for the spread between counties by virtue of considering air travel. A sample of this updated capability is presented in Figure 4 which shows the progress of a pandemic across the United States which originated in Chicago, Illinois.

At the national level, there are 3,141 different counties across the United States. In total, the 2000 U.S. Census delineates nearly 63,000 census tracts for the entire nation among these counties. Thus, extending the model to a national level by considering all way two county interactions for disease spread implies nearly 5 million computations ( $3,141 \times 3,140 / 2$ ). Likewise, the census tract level of detail would require nearly 2 billion computations ( $63,000 \times 62,999 / 2$ )! The ability to increase the granularity/fidelity of QLT modeling, while still providing a tool that can respond instantaneously to parameter changes, will be explored in our future research.

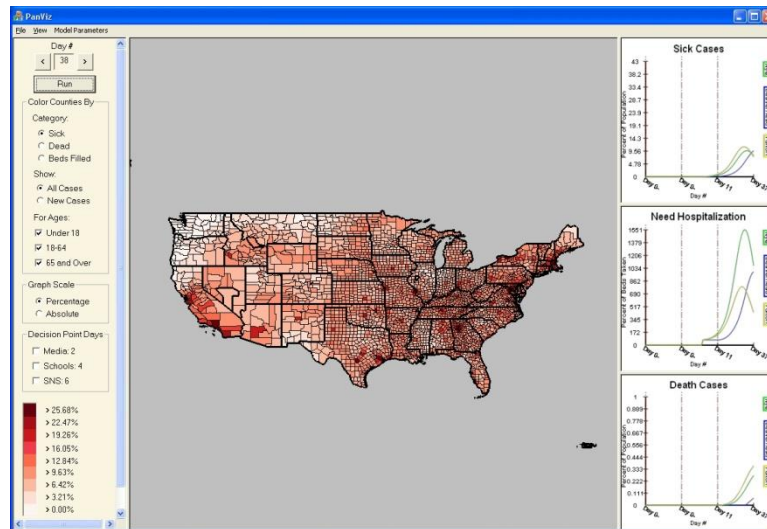


Figure 4. PanViz Applied at a National Level

### QLT Extensions

We have two major motivations in additional QLT development – these are 1) incorporation of a user selectable “disease palette” and 2) making our QLT extendable to support planning, impact, and mitigative assessments associated with other potential mass casualty events. In the first extension we propose to have the QLT equipped with a palette whereby users could simply click a potential disease of interest to be studied in addition to pandemic influenza (e.g., swine flu, cholera, SARS, smallpox, or infectious TB). The palette would contain a set of default parameters for the disease of concern; each of these could still be adjusted by the user.

The second extension involves the notion of “prevalence” as a framework for analyzing the impacts and mitigation measures for other large scale public health incidents such as might be associated with a hurricane, earthquake, or a bioterrorism or radiological weapon attack. Here we would view prevalence as a way to indicate the probability of individuals being affected by the event. In simple terms, affected would be used in an analogous sense to infected as in the case of a disease, but in this case more specifically referring to those individuals that are injured, contaminated, or disabled by the event. Thus, a prevalence curve could still be generated for the event by a census tract or a county. In turn, mitigative measures and resource requirements (e.g., the number of first responders or medical professionals needed to respond to the event) could be estimated. Shortfalls could be computed and planning to prepare for the event could be effectively carried out.

### CONCLUSION

It is our contention that through the provision of QLTs geared at mass casualty events, Federal, State, and local decision makers and public health officials can better plan and be able to more effectively respond to disasters. By “provision,” we mean that these decision makers and officials have the tools on their own computers so that they are familiar with and can operate the tools themselves. Ultimately, if (when) an event happens, the QLTs can then be employed to rapidly assess and execute alternative mitigation strategies, and thereby minimize casualties. Optimization of decisions (e.g., the best timing to employ mitigation measures) is also potential in QLTs through the use of software add-ins, such as the Solver optimization tool in Microsoft Excel.

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