Infectious Disease Outbreak Decision Support System (IDODSS)

The Threat

Public health organizations around the world are raising the alarm about potential pandemics caused by cross-species migration of avian influenza (H5N1). The Centers for Disease Control estimate that a "medium-level" outbreak in the US could cause: 89,000 to 207,000 deaths in the first six months; 314,000 to 734,000 hospitalizations; 18 million to 42 million hospital outpatient visits; infection of 15% to 35% of all employees; and an overall economic impact between $71B to $116B.

In November 2005, the Bush administration announced a $7B emergency preparedness program to respond to this critical threat in the US. Proposed funding focuses on stockpiling anti-viral drugs and existing vaccines for a related strain of avian flu, and for developing new vaccines.

The Bush plan allocates $583M for pandemic preparedness and planning. This program element is absolutely critical. Outbreaks must be detected and contained aggressively; otherwise, virulent pathogens will spread rapidly, accelerated by high population densities and high personal mobility afforded by modern air travel. Regardless of medicinal inventories, outbreaks that escape containment will overwhelm public health resources, producing catastrophic loss of life and socio-economic damage. The key questions, then, are what kinds of systems are available for (1) detecting outbreaks and (2) for preparedness planning and execution of containment strategies? This summary describes our work on the second key question of decision support.

Decision Support for Infectious Diseases – Preparedness Strategies

DecisionPath is currently developing IDODSS, a decision support system to help public health organizations develop, validate, and execute strategies for managing outbreaks of infectious disease. IDODSS applies at multiple levels – national, state, and local – and to both natural and engineered outbreaks (viz., bio-terrorism).

IDODSS targets two kinds of critical decisions:

- Preparedness – proactive, anticipatory planning of strategies, supporting processes, systems, and supplies
- Operational strategies – reactive planning, to respond to outbreaks in real-time

Preparedness hinges on modeling (archetypal) outbreaks, formulating responses, and assessing likely impacts of those interventions against outbreaks. Operational planning focuses on depicting (actual) emerging outbreaks; selecting and tailoring responses (from predefined plans); and adapting those responses as outbreaks progress and government and public health organizations attempt to contain and address them. Responses encompass logistics (stockpiling drugs and supplies); medical services; public safety; infrastructure continuity, etc.

Current decision support solutions for infectious disease fall into two fundamentally disjoint categories:

- Epidemiological models
- Crisis management tools for reporting and tracking infection cases; capacity planning and resource allocation (e.g., staffing, stocking medicines); continuity and recovery planning; This category also includes live role-playing exercises that simulate disasters and test responders' plans in specific communities

Epidemiological models simulate the progression of disease outbreaks, generally through so-called compartmentalized models. The classic models define various compartments – Susceptible, Exposed, Infected, and Resistant patient populations – and model disease outbreaks by projecting rates of transfer between these populations. Analytic techniques include differential, partial differential or difference equations; Monte Carlo (statistical methods); and more recently, dynamic network (agent-based) models. These models tend to be overly schematic, with relatively simplified inputs and dynamics. Exact solutions are rare and models often fail

to converge. Analyses of interesting or realistic models tend to be confined to qualitative analyses around threshold conditions. Most such formal models cannot incorporate actual patient case data from real outbreaks.

Tracking and reporting applications constitute *situational awareness* tools. This category of systems, often called "business intelligence" (or BI), includes databases, data warehouses, analytics, dashboards and other summary/visualization tools. BI tools provide insight into current status, historical performance, and some short-term trending. However, true decision *support* systems *actively enable or enhance* decision-making *processes.* By this standard, BI is a necessary prerequisite to decision support, but clearly not sufficient.

Capacity planning tools tend to be coarse-grained, inflexible and unrealistic. For example, the Weill/Cornell Bio-terrorism and Epidemic Outbreak Response Model (BERM) produces mainly linear (non-adaptive) projections that do not reflect contagion and capability degradation within health care systems. Live exercises are clearly important as well, but they are time-consuming and costly, and feasible only in limited numbers.

IDODSS Approach and Capabilities (in development)

Our IDODSS prototype allows users to rapidly define environmental conditions that precede or occur during outbreaks of infectious diseases. This model characterizes environments at multiple scales (global, national, state, local). Within these enviroments, IDODSS further characterizes populations (plant, animal, and human), diseases, intervention strategies, vaccines, and treatments, and their inter-relationships.

Given a set of initial or current conditions, IDODSS allows users to define alternate *Scenarios*, which consist of possible futures defined by assumptions about trends and events that could influence the progression of outbreaks. IDODSS Scenarios also encompass alternate intervention strategies (e.g., different approaches to stockpiling drugs and supplies, quarantine, immunization, treatment, and triage processes, etc.).

Given a particular Scenario of initial conditions, assumptions about future conditions, and a preparedness strategy, IDODSS simulates the likely outcomes of that proposed intervention. That is, IDODSS projects a set of key performance metrics (e.g., number of infections, deaths, healthcare resource utilization, costs) entailed by government and health care organizations executing the given strategy over the evolving future.

The IDODSS methodology calls for exercising the proposed strategies *across* diverse possible futures. IDODSS provides analytic tools for exploring *and* comparing these projected outcomes. Intuitively, the strategy that results in the best outcomes across the possible futures represents the most *robust* course of action, since it produces the most attractive results despite the uncertainties spanned by the Scenarios. IDODSS provides true decision support by enabling users to evaluate the inevitable cost-benefit trade-offs across alternatives.

The IDODSS methodology applies not only at the initial point of decision (i.e. for pre-outbreak preparedness), but also downstream, for managing outbreaks in real time. As outbreaks evolve, IDODSS Scenarios can be updated with current information, in order to re-project and re-assess strategies. If the updated outcomes are favorable, this process effectively re-validates the chosen strategy. If not, IDODSS acts as an Early Warning System, alerting public health users quickly to deviations from plan. IDODSS can then be used to diagnose the causes of failure and devise mid-course corrections. In essence, IDODSS offers "lifecycle decision support", helping users to "sense and respond" and adapt effectively in the face of inevitable environmental changes.

IDODSS incorporates an intuitive Graphical User Interface (GUI) and extensive on-line help to guide users in building Scenarios, running simulations, and analyzing results. For ease-of-use, IDODSS includes a library of pre-defined building blocks for rapidly building Scenarios and strategies (e.g., quarantine methods, diseases, drugs). Scenarios can be copied and adapted to quickly develop a suitable spectrum of possible futures. IDODSS interfaces with Geographical Information Systems (GIS) to project simulated events onto maps and read from map-based databases. It also provides import and export facilities based on open-system exchange standards (SQL, XML, CSV) for loading data from public health systems.

IDODSS analytics include time series plots, frequency histograms, statistical analyses, and tabular reports that summarize key metrics and simulated dynamics (e.g. events, trends, actions taken). These products summarize

what happened, when, and why, as well as how different strategies produce different results. Analytic outputs can be saved to graphic files for inclusion in documents or viewgraphs. In addition, IDODSS simulation data can easily be exported for use by external analytic tools, first responder systems etc.

We are currently building out IDODSS baseline dynamics, which consist of (user-tunable) epidemiological, crisis intervention, and capacity models. When completed, these models will drive IDODSS projections of the likely outcomes of candidate preparedness plans and crisis response strategies across outbreak Scenarios.

Benefits

How does IDODSS differ from existing decision support systems in this domain? IDODSS targets the fundamental gap or disconnect between epidemiological and crisis management systems. DecisionPath believes that effective decision support for infectious diseases is possible only if these two kinds of tools are explicitly coupled together, to capture the critical interactions *between* evolving outbreaks and strategies to prevent or contain them. This requires a *unified* analytic framework.

Thus, IDODSS integrates and unifies previously disjoint epidemiological and intervention management models. It applies adaptive modeling and simulation techniques to account for inter-model interactions such as (1) outbreak-induced impairment of response capabilities and (2) social/psychological/political factors, such as panic, resistance to quarantines, evacuations, vaccinations. Finally, to support reactive planning, IDODSS has the capability to import and exploit available outbreak data, such as patient case records.

IDODSS also provides a platform for capturing and disseminating best practices decision methodologies regarding infectious disease preparedness and crisis management. IDODSS produces *audit trails* in the form of annotated Scenarios and simulation logs, which make explicit the facts, assumptions, and analyses grounding a preparedness or crisis management strategy. IDODSS thereby provides a dynamic, interactive basis for communication, team buy-in and alignment, training, and exercises.

IDODSS also provides a baseline for codifying and distributing lessons learned, driving continuous improvement. As such, IDODSS represents a powerful platform for updating and exchanging knowledge between public health and safety organizations, across levels and locations, and for coordinating responses to pandemics.

Bottom line: In essence, IDODSS provides a low-risk virtual environment for playing out critical decisions about pandemics and understanding their potential consequences, much as consumers test-drive cars before buying them. IDODSS reduces risk and improves confidence and consistency in long-range and operational strategies to prepare for, and respond to outbreaks of infectious diseases such as avian flu.

About DecisionPath

DecisionPath helps government and business organizations make and manage critical decisions more effectively. To accomplish this, we created ForeTell®, a patent-pending platform for rapidly developing custom decision support solutions. ForeTell combines a decision support methodology derived from scenario planning with powerful object-oriented modeling simulation, and analysis software. By incorporating key participants and candidate strategies into its "what-if" projections, ForeTell makes scenario planning *actionable*.

We are implementing IDODSS with ForeTell. Other ForeTell solutions have been developed for critical problems such as counter-terrorism preparedness, training credit union executives in operational strategy, managing organizational change, and optimizing investments across drug marketing and sales channels.

DecisionPath invites inquiries about IDODSS from public health and other government agencies, hospitals, epidemiologists, and consultants to these parties. Please contact Dr. Richard Adler at rich@decpath.com or 617-794-9036.