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Cesar Ariel Pinto
Old Dominion University

Ipek Bozkurt
Old Dominion University

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C. Ariel Pinto, *Old Dominion University*
Ipek Bozkurt, *Old Dominion University*

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Rapid Sensor Technology: A Risk and System Complexity Analyses of Early Detection of Influenza-Like-Illnesses

C. Ariel Pinto and Ipek Bozkurt

Abstract

The development of effective and reliable methods to defend the nation against biological terrorism remains an urgent challenge to researchers in the areas of risk, bio-defense, public health, and emergency medicine. The emerging threat of the avian flu pandemic also highlights the unpreparedness of our nation's health care system to meet a highly contagious and infectious disease outbreak. The implementation of a rapid sensor technology for early detection of influenza-like-illness provides possible opportunities, as well as problems. Bounding and defining such a complex problem is one of the first challenges this research addresses. Approaching this problem from various perspectives such as risk management, critical infrastructures and emergency medicine proves to be a valid strategy for an efficient solution. After defining the problem and laying out a strategy, discussions on possible tools and techniques for the solution of the problem is presented in this paper, together with the compounding sources of and issues with complexity.

KEYWORDS: biosensor, critical infrastructure, biodefense, risk, pandemic, complex

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1 INTRODUCTION

In 2006, Old Dominion University (ODU) and Eastern Virginia Medical School (EVMS) conducted a study on a future generation of rapid sensor technology (RST) that could detect impending flu-like pandemic and related factors, and analyzed the implications of implementing such a sensor technology in terms of improved effectiveness. The study established that the implementation of sensor systems can have an impact on standard operation procedures in the medical, business, government and military infrastructures (Pinto et al., 2007).

The main issue that is being dealt in this paper is the potential use of RST as surveillance tool of influenza-like-illnesses (ILI) in emergency rooms, and the problems of complexity that arise with this implementation. The impacts of a possible pandemic have been researched within different perspectives, including emotional effects (Reissman et al., 2006), cultural differences (Peng, 2008), planning (Thompson and Gorder, 2007) and management (Thorson and Ekdahl, 2005; Scanlon, et al., 2007), among others. In the Pandemic Planning Update (2006) given by the Department of Health and Human Services, five primary objectives are stated: 1) monitoring disease spread to support rapid response, 2) developing vaccines and vaccine production capacity, 3) stockpiling antivirals and other countermeasures, 4) coordinating federal, state and local preparation, and finally, 5) enhancing outreach and communications planning. The first priority (i.e. monitoring and rapid response) is the main focus of this research, with the implementation of the RST. As noted in the same report, early detection provides the opportunity to respond, to attempt containment and to quickly gain the virus samples necessary for the development of a true pandemic vaccine.

The main focus, as stated above, is on the effectiveness of the RST that is currently being developed in hopes of overcoming the obstacles of late detection of ILI. The development of the sensor technology is expected to move in three major directions: 1) Towards more direct detection of an influenza-type virus in patient samples, 2) towards more remote sensors in the medical exam and waiting rooms, and 3) towards more strategic and non-traditional deployment of sensors such as public and high-traffic spaces in an urban setting.

However, aside from the main topic of the study - the implications of implementing the RST - the researchers also realized the high degree of complexity of the problem. This realization led them to look closer into the research methodologies that were applied and how these methodologies dealt with the complexity and the nature of the problem. RST has an impact on every phase of a pandemic attack system. With so many varieties of entities, such as doctors, patients, labs, emergency procedures, both state and federal health departments, it is undeniable that this is a system has a varying degrees of complexity in each level, has a high degree of emergence and is non-trivial to analyze - as such is a *wicked problem* (Rittel and Weber, 1973). The complexity is not only initiated by the variety of components within the larger system, but also because of the high levels of interrelations between these components. The stream of events starting from the first instance when a patient walks into an emergency room, the detection of the influenza virus and to the state-wide high-level alerts, have implications that go beyond their boundaries.

There are several intersecting domains of knowledge in the RST study. Among these are risk management, epidemiology, emergency management, public health, and organizational behavior. All of these domains of knowledge are worthy of being examined with regards to complexity and wicked problems. Looking at all these domains from the risk managers' view can provide an encompassing discussion possibly not allowable if viewed from any other domain. The remainder of the paper is organized as follows: The next section will present an overview on the different pandemic periods and their related phases. Following this, implementation of the rapid sensor technology will be presented. Having established an understanding of what constitutes a pandemic, why dealing with such an event and implementing an RST can be considered as a risk activity is discussed in the next section. How this risk management activities and the complexity of implementing such a technology can be seen as a wicked problem is discussed in this section as well. After discussing the systems approach that is necessary to deal with such problems, and presenting a discussion on the multi-disciplinary nature of the problem at hand, effective resource allocation is presented in the next section. The conclusion presents a summary of the highlights of this research, as well as the possible future research areas that may arise.

2 PHASES OF A PANDEMIC

According to the World Health Organization (WHO), a pandemic is an epidemic on a global scale. An influenza pandemic, for instance, occurs when a virus that may cause severe diseases spreads among humans. The WHO states that each country, city and area must have a pandemic preparedness plan, since the impact of such an event is not only a health crisis, but also a social issue that may have disastrous implications. Figure 1 represents the main pandemic phases (compiled from WHO), together with their levels of risk, conditions and the actions necessary to be taken.

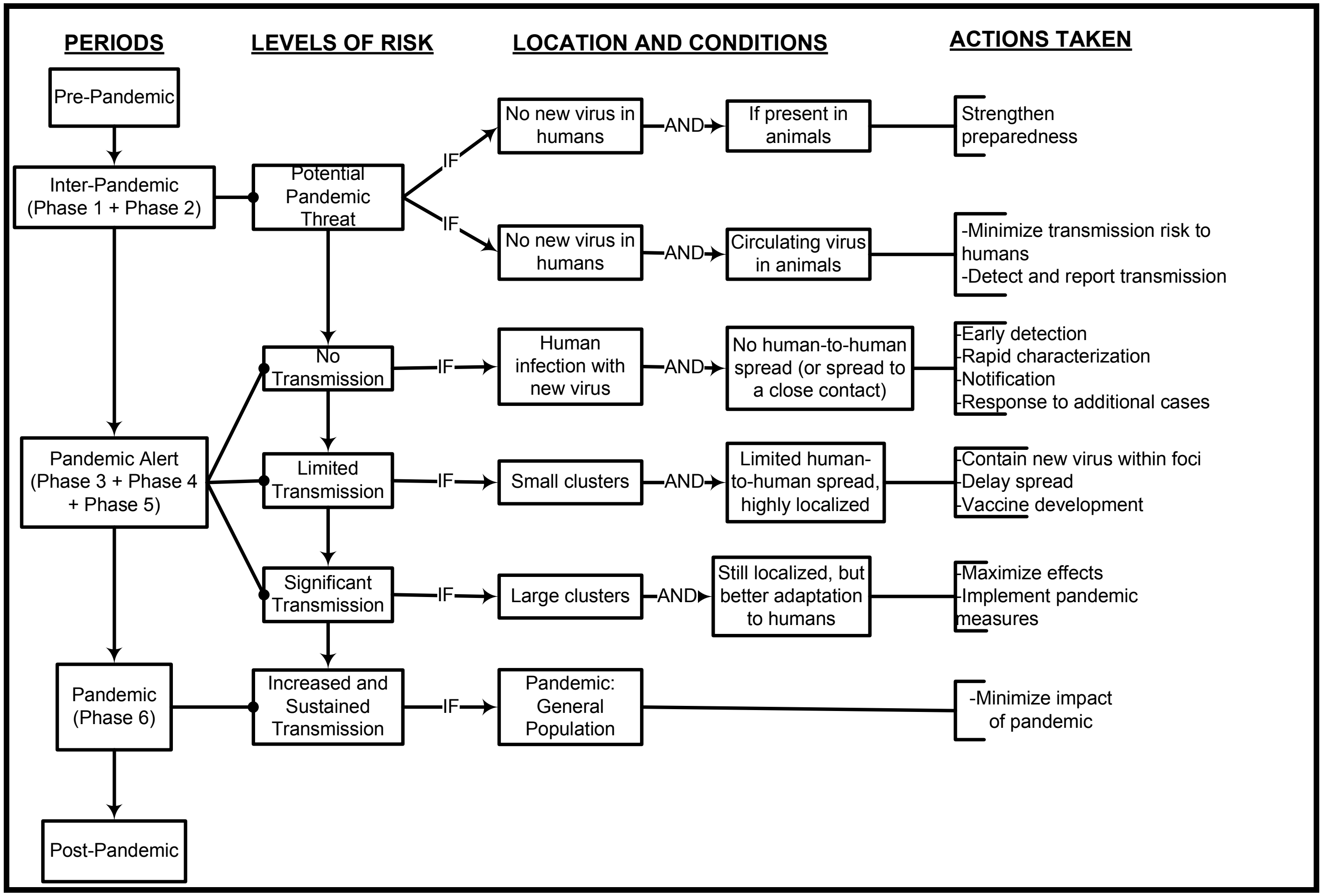

Figure 1. Pandemic Periods

2.1 Pre Pandemic Period

The Pre-Pandemic period consists of three main surveillances: The Passive Surveillance (PS), Active Sentinel Physician Surveillance (ASP) and Laboratory Surveillance (LS). In PS, the information is collected from the physicians, persons in charge of the medical care and from the directors of laboratories. The information is then reported to the local health department and then to the state health department. The reports from the state health department are tabulated on a weekly basis and forwarded to the Centers for Disease Control and Prevention (CDC).

During the ASP surveillance, the physicians volunteer to monitor and report the number of Influenza-Like-Illnesses (ILI) to the local health department and then to the State Health Department (DSI). Following this, the DSI classifies this information and tabulates it to find out the level of Influenza.

The Laboratory Surveillance helps identify the type of influenza virus strains and prepare a vaccine for the same virus. They then provide this information to the local and state health departments.

2.2 Inter Pandemic Period

The Inter-pandemic phase is a function of pathogenicity in animals and humans, domestic or wildlife, localized or widespread, etc. There are two phases in the inter-pandemic period: In Phase One, there are no reports of humans being infected due to an animal influenza virus circulating among animals; and if they are found or are present in animals, then the action taken is to strengthen the preparedness at global, regional, national and sub national levels.

In Phase Two, there is a potential threat for a pandemic if an animal influenza virus which circulates among animals has been reported to have caused infection in humans. If that is the case, then the necessary action is trying to minimize transmission risk to humans, detecting and reporting such transmission rapidly if it occurs.

2.3 Pandemic Alert Period

Pandemic alert period is a function of the rate of transmission, geographical location, spread and severity of illnesses, and it is based on the risk of a pandemic. There are three main phases in this period: In the first phase (Phase 3 overall), if human infection with a new subtype virus is found, but there is no human to human spread, this possesses a no transmission risk. In this phase, there may be limited human-to-human transmission under certain circumstances, such as a close contact between an infected person and an unprotected caregiver. However, such circumstances do not indicate the transmissibility of the virus among humans to the extent that in may cause a pandemic. If at all transmission is found, in rare instances, it then spreads to a close contact. As a result, for Phase 3, the measures taken are early detection, rapid characterization of new virus subtype, notification and response to additional cases. According to the newly revised 2009 Pandemic Influenza Preparedness and Response Guide developed by WHO, pandemic influenza viruses may arise through either *genetic reassortment*, in which genes from animal and human influenza viruses mix together to create a human-animal virus, or through *genetic mutation*, in which genes in an animal virus change, which allows the virus to infect humans and transmits easily among them.

The second phase (Phase Four overall) is considered to have limited transmission if the virus subtype is found in small clusters with limited human to human transmission but spread is highly localized. In this phase, the virus is not well adapted to humans. Therefore, the new virus subtype within the local focus are should be contained or the spread should be delayed to gain time in order to implement preparedness measures, including vaccine development.

In the third and last phase (Phase Five overall), there is a substantial pandemic risk, i.e. significant transmission but not fully transmissible if the clusters get larger but the human to human spread is still localized, suggesting that the virus is becoming increasingly better adapted to humans. During this phase the efforts to contain or delay spread are maximized in efforts to possibly avert a pandemic. This also provides enough time to implement pandemic response measures.

2.4 Pandemic and Post Pandemic Period

In this period, there is increased and sustained transmission and the impact of the pandemic needs to be minimized. Once this stage is reached, suspicious situations are constantly checked, and a high level of alert is maintained.

3 IMPLEMENTATION OF THE RAPID SENSOR TECHNOLOGY

In order to identify and discuss the issues of complexity in this research, it is crucial to have an understanding on how the sensor technology would effect the epidemic/pandemic phases. The effectiveness of the sensor technology may be validated if proper context for the applicability and use of sensor technology can be provided. Benefits in both clinical and operational areas (such as staffing) will be more apparent once the technology has been placed into the epidemic/pandemic phases.

One of the most important issues WHO deals with during an influenza pandemic is preparedness planning; more specifically, how to enable countries to be prepared and how to make them recognize and manage an influenza pandemic. The planning aspect becomes crucial here, especially when it comes to reducing transmissions of the pandemic virus, decreasing the infected cases, maintaining essential services, and finally reducing the economic and social impact of a pandemic (WHO, 2009). Simulation models on how an influenza pandemic would affect a community and national services can include estimates of impact measures. Incorporating the suggested Rapid Sensor Technology in such simulation models can result in more accurate estimates in all levels of emergency preparedness and planning.

Figure 2 represents the Pre-Pandemic Influenza Surveillance Activities and the Pandemic Alert period, where the Rapid Sensor Technology is placed.

The patient arrives to the hospital with some symptoms of high temperature and one of the 3 signs: either cough, sore throat or dyspnea. The patient is then taken and admitted into the ER (at time t = 0); the physician then does the required checkup. Once the patient is admitted to the ER and is checked by the physician, he or she will be treated under two categories, clinical criteria and epidemiologic criteria. If the patient is in clinical criteria but not in epidemiologic criteria, then he/she is treated clinically and re-evaluated. If he/she falls in both clinical and epidemiologic criteria, then certain actions are taken, like implementing precautions, notifying local health departments, collecting and sending specimen to state lab (DCLS), evaluating alternative diagnoses, initiating antiviral treatment, and identifying potentially exposed contacts. If the tests come out to be negative, then a specialist should be consulted, as well as state health department and CDC, as there is a chance of false negative (FN-infected, undetected) results. These FN results are the source of the biggest concern, since the infected individuals are not isolated and treated (Malone et al, 2009). As Bravta et al (2004) state, performing confirmatory tests after the completion of initial tests could minimize both false-negative and false-positive results. This is the reason why a specialist is consulted, together with the CDC; to eliminate the chance of any false results. Also if alternative diagnosis is established, antiviral treatment is discontinued. If the tests come out to be positive, then the antiviral treatment is continued, as well as infection control precautions (isolation etc.).

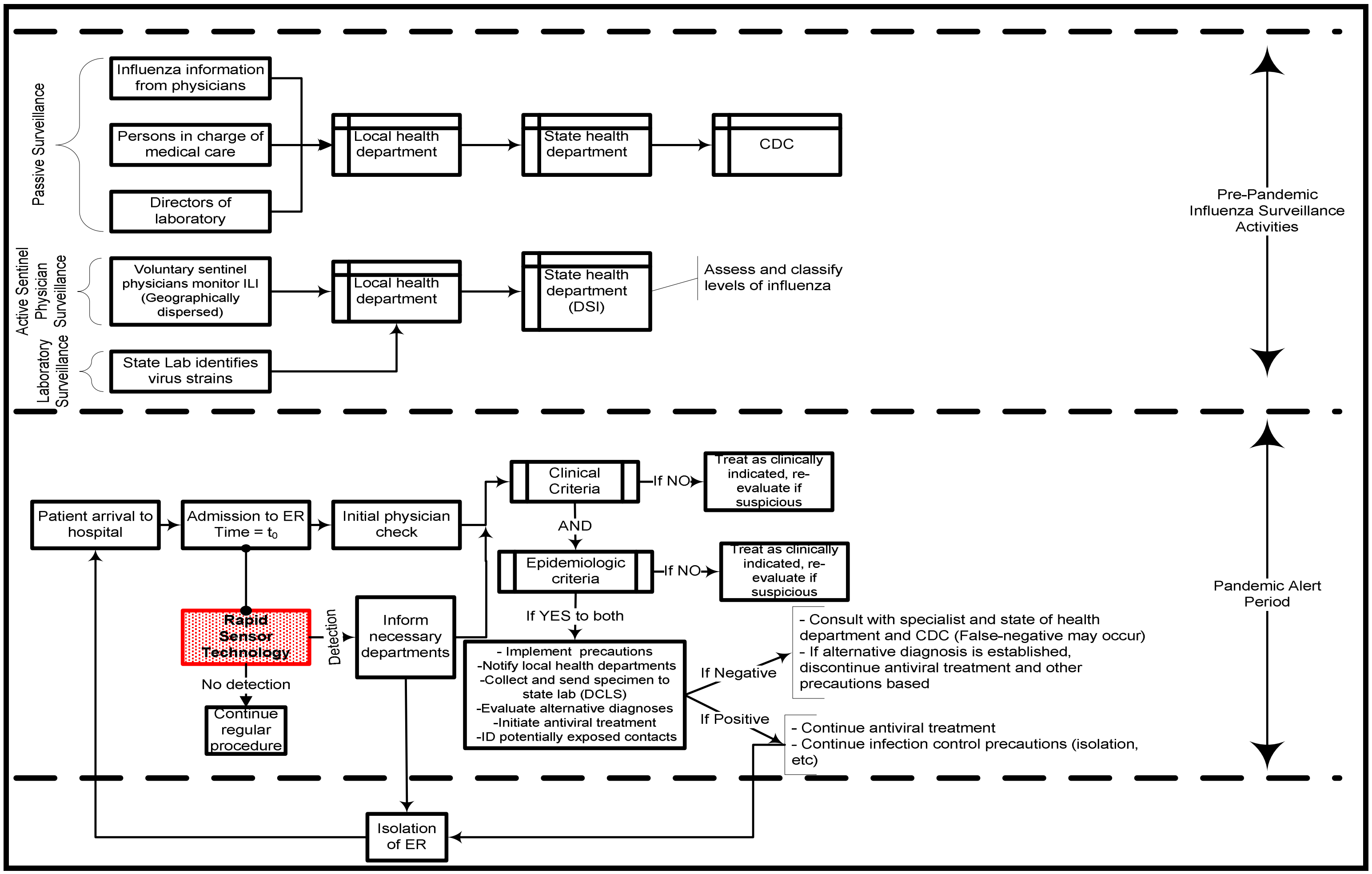

Figure 2. Pre-Pandemic and Pandemic Alert Activities

However, in this research, the Rapid Sensor Technology (RST) is introduced between the stage when the patient enters the ER and the physician check up. With this step, information will be obtained if a virus is present and, if the RST is more specific, the kind of virus may also be ascertained. This will reduce the detection time, which otherwise would be significantly longer if the traditional procedure is followed. This will also eventually reduce the patients visiting the ER as with early detection the tendency is to narrow the spread if not completely eliminate it. Once the virus is detected (either just its presence or its type) the information can be sent to the required department for further treatment or procedures, which is performed after the isolation of the patient. The patient might not be detected as an individual with a virus, but in a group, even if a single person is infected, the RST will alert the necessary personnel and all the patients will have to be isolated for further treatment. If no virus is detected, then the regular procedure is followed.

3.1 Strategic Effects of the RST on the General Plan

The first and the highest level of Pandemic hierarchy that will be affected with the implementation of the RST is the strategic level. Placing the RST in the Pandemic Alert Period will change the detection cycle. As discussed in the previous section, the time between admission to the ER and the initial physician check and then detection of a virus will significantly decrease with the addition of the RST. Instead of waiting for laboratory results for detection of a certain virus, the RST will detect the presence of any ILI and will set off another cycle, which brings the total effects into the next level.

3.2 Procedural Effects of RST on the Health Organization

Together with the strategic changes, there will be significant changes in the procedures of related departments, once the RST is integrated as a main component of the department. For instance, if the RST is placed in an Emergency Room of a hospital, the ER should have an isolation plan should there be any virus detections. Therefore, in addition to the many emergency procedures the ER has, new procedures and systems should be developed and implemented. The standard operation procedures would also need to be modified to accommodate the actual implementation of the RST. The placement of rapid sensors would change the planning layout of the emergency rooms, and other areas. Therefore, the modifications in the procedures should take into account the physical placement of the RST, as well as the implications on how to proceed once such technology is implemented.

The Department of Health and Human Services provided a checklist to the Medical Offices and Clinics (2006), which identified the key areas for pandemic influenza planning. The first component of this checklist is the structure for planning and decision making, which ensures that the organization has incorporated the pandemic influenza into the emergency management planning, and also makes sure that a person has been assigned for coordinating preparedness planning for the practice or the organization. The second component of the list is to develop a written pandemic influenza plan. This is another addition to the procedural effects under discussion. Not only would there be strategic change in the bigger picture of an emergency flu pandemic, the smaller component, being the ER, will need to update their procedures according to new installments.

3.3 Operational Effects of RST on Internal Components

The implications of having the RST at the lowest level bring the discussion to operational concerns. Operational problems are an extension of the discussion in the previous section about procedural issues. Together with the new procedures that need to be developed and implemented, operational issues need to be dealt with. One of the first new additions to the ER would be new personnel, necessary to possibly collect and analyze the signals from the RST and interpret the data according to specifications. The RST is assumed to have different levels of detection. Whether the type or amount of the detected virus is sufficient enough for isolation of the ER or the implementation of other procedures will be dependent on the analysis from the sensor by the related analyst.

Another important component that has been advised by the Department of Health and Human Services is the creation of a system to monitor and review influenza activity in patients cared for by clinical staff (i.e. weekly or daily number of patients calling or presenting to the office or clinic with ILI). Implementation of such a system would correspond to the RST and data obtained from the sensor.

The implementation and use of the RST will also bring more interaction between departments. Once virus is detected, the analyst will need to have the necessary communication channels with the ER and the laboratories so that the procedures to be followed can be implemented smoothly. This has also been an important part in the planning checklist. Development of a communication plan, together with identifying and arranging contact persons for external communication will improve the relations between the office, organization or hospital in focus and the external departments. Both internal and external coordination efforts are crucial in operationalizing the RST.

4 THE RISK MANAGEMENT APPROACH

The problem of preventing a flu-like pandemic using improved RST is, to most extent, a large-scale risk management activity. This is due to the fact that the overall goal of the RST study is to *minimize* the risk of flu-type pandemic. This brings the discussion to an important topic - what is risk? The Society for Risk Analysis describes risk as "…the potential for realization of unwanted, adverse consequences." And thus, to manage risk involves all the activities commonly associated with managerial process, except that the explicit objective is to minimize risk. On the other hand, the generally accepted quantitative definition of *risk* is:

Risk = f (likelihood of the significant threat or hazard scenarios, given the scenario the ability of the target to withstand the threat or hazard confronted, and the magnitude and type of worst reasonable consequences)

Since the seminal work of Kaplan (1997), risk has often been expressed as a function of the descriptions of the complete set of scenarios, and their respective probabilities of frequency and likelihood of various consequences. For the practitioners, risk management approach (RMA) can be best described in terms of the process in search for answers to a set of six questions (Kaplan and Garrick, 1981, and Haimes, 1981):

- Question 1: What can go wrong?
- Question 2: What is the likelihood that it could go wrong?
- Question 3: What are the consequences?
- Question 4: What can be done?
- Question 5: What are the tradeoffs?
- Question 6: What are the impacts on future options?

In the context of RST, some answers to the above questions are obvious while others are completely perplexing for researchers: *What can go wrong* - a catastrophic flu-like pandemic. *What is the likelihood that it could go wrong* - unfortunately, there is no definite answer. Most researches on predicting pandemic outbreaks use mathematical simulation paradigms; however, as stated by Jewell et al (2009), there are various issues with these simulation tools. Late detection of the infection, the probability that there are undetected infected individuals who are not included in the data, and providing predictions based on only past epidemics or pandemics are some of these issues. For instance, one of the latest researches done on predicting the H1N1 influenza virus that uses a simulation model has a confidence level of 95% (Towers and Feng, 2009), and the researchers state that the studies on the periodic functions underlying seasonal forcing of influenza are not sufficient, and the uncertainties that arise from this is not quantifiable yet.

Even at the onset, the RST study (or any risk management study for that matter) has all the underpinnings of a wicked problem. Though no published document explicitly describes a risk management problem as a wicked problem, Hofstetter et al. (2002) and Pinto et al. (2004) describe some strong indicators:

- Risk can transcend through elements of a system, as well as beyond the system boundaries.
- Planning for risk often needs information about future events, which by its very nature is dynamic and uncertain.
- Emergence of additional risks resulting from the actions of managing the original risk of interest (aka countervailing risk).
- Emergence of desirable consequence other than simply reducing the original risk of interest (aka synergistic effect).
- That these emerging countervailing risks and synergistic effects come in various forms, magnified as time passes, and may have various effects for various perspectives (aka the *ripples-in-the-pond* effect).

4.1 Risk Management Approach and Wicked Problems

Rittel and Weber (1973) initially proposed the term “wicked” to describe problems which are inherently complex. In their 1973 paper, they present ten major characteristics that wicked problems possess:

1. There is no definitive formulation of a wicked problem.
2. Wicked problems have no stopping rule.
3. Solutions to wicked problems are not true-or-false, but good-or-bad.
4. There is no immediate and no ultimate test of a solution to a wicked problem.
5. Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial-and-error, every attempt counts significantly.
6. Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.
7. Every wicked problem is essentially unique.
8. Every wicked problem can be considered to be a symptom of another problem.
9. The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution.
10. The planner has no right to be wrong.

Wicked problems have been a vital component within various research areas, including homeland security (Kendra, et al, 2008; Rubin, 2009), and is closely related to uncertainty. Uncertainty can be defined as "the inability to determine the true state of affairs of a system" (Haimes, 2004, pg. 237). This inability may have different sources, including lack of information, incorrect information, the ambiguous nature of the environment, limited understanding of a process, among others. The uniqueness of each wicked problem, lack of correct solutions to the problem, and the fact that there is no learning opportunity puts the wicked problems in an "uncertainty" context.

The two main sources of uncertainty, according to Haimes (2004), are *variability* and *knowledge*. Both of these sources are present within the project currently at hand. In order to correctly and successfully implement the Rapid Sensor Technology, detailed information on both the technology itself, and also the implications of this implementation is needed. This, as stated previously by Pinto et al (2004), becomes a dynamic and uncertain situation. Unpredictability (or randomness), which is another parameter of uncertainty (Morgan and Henrion, 1990), is also part of the nature of a wicked problem. Even though detailed planning and forecasting is a major component of implementing the RST, the unpredictable nature of a pandemic may create an additional level of complexity.

RST is definitely not the only technology that can be used to manage the risk of flu-type pandemic. However, for RST to even make a contribution towards the management of this particular type of risk, many scenarios have to be considered and acted upon accordingly. Exactly how many scenarios need to be analyzed?

As Kaplan and Garrick (1981) and Kaplan (1997) emphasized, all scenarios need to be analyzed to accurately quantify risk, an otherwise very abstract concept. However, most risk managers will admit that not all scenarios can be identified, much less be analyzed. As such, all quantitative risk measurement is a *best-effort* endeavor - meaning that the risk analyst will exert the best effort to accurately quantify risk subject to the usual constraints of resources and irreducible uncertainty.

This limitation is further exacerbated by the difficult and complex nature of wicked problems, with all of the accompanying properties. On the other hand, practitioners and researchers have responded to the realization that risk management is a best-effort endeavor in two ways: 1) by more efficient identification of scenarios and 2) by more efficient allocation of resources among identified scenarios. This brings to light what Rittel (1972) identified as some principles of the second generation systems approach, particularly the need for a multidisciplinary approach

4.2 Risk Management and Systems Approach

It is noticeable that the six questions in the RMA have close semblance to the phases of a general systems approach to solving problems, except that particular interest in RMA is not the desired outcome but the wrong event, e.g. asking “what can go wrong” instead of “what needs to be right”. As such, one can surmise that if special interest is on how RMA addresses wicked problems, then many if not all shortcomings of the systems approach in addressing such type of problems must also be present in the RMA.

Rittel (1972) described in length the shortcomings of the first generation systems approach. Furthermore, he also described how to deal with wicked problems embodied into the principles of the so-called second-generation systems approach. The following sections explore some of these shortcomings as reflected to RMA and what has been done to address them towards mastering wicked risk management problems.

4.3 Multi-disciplinary Risk Management Approach

In trying to avoid a flu-type pandemic by effectively using RST, the analysis goes beyond the technical study of the actual physical RST but rather extends farther to the realm of epidemiology and virology (how the flu virus is transmitted), the practice of medical triage (what actions needs to be taken after indications of flu incidents), medical practice management (scaling up resources right before a pandemic, see Figure 1), and a host of other domains. All these domains essentially need to be represented at the very early stage of the risk management process related to RST.

There has been recognition that most risk management problems encompass diverse fields of discipline and domains of knowledge to the extent that no one person can claim contextual expertise (Conrow, 2004). Flu-type pandemic and the application of RST is definitely one example. As a result, several tools and techniques such as the Surrogate Worth Tradeoff Method (Haimes, et al. 1971; Haimes, et al. 1975), and the Hierarchical Holographic Modeling (Haimes, 1981) have been proposed and used to help risk managers involve many domains of knowledge i.e. so-called subject matter experts throughout the various stages of the risk management process.

The underlying principle behind these tools and techniques is that by involving more perspectives in the risk management process, more scenarios will be identified in the same period of time. Having identified many scenarios produces more robust alternatives and solutions at the tail end of the risk management process. The abundance of perspectives also has the tendency to dilute whatever bias the analyst may have (Sharit, 2000).

However, simply having a robust set of alternatives to mitigate risks does not imply that risks will be effectively managed. In fact, a robust, i.e. larger set of alternatives burdens the risk manager to discriminate and compare among more alternatives in terms of their potential to reduce overall risk. As such, another concern for the risk manager is the allocation of limited resources among the identified alternatives to mitigate various scenarios.

5 EFFICIENT RESOURCE ALLOCATION IN RMA

In analyzing how RST can be effectively deployed to prevent a flu-type pandemic, the team of researchers have identified that aside from a more sophisticated sensor, another critical factor for effectiveness is a reliable and fast communication infrastructure to relay information from the RST to laboratory technicians and eventually to medical emergency managers (e.g. CDC). And there are other factors identified that are all essential for effective deployment of RST, more often organizational rather than purely technical in nature. The next question for the team then becomes how to discern the relative importance of these factors in minimizing the risk of flu-type pandemic.

Various methods for more efficient allocation of risk management resources have been devised, such as risks ranking and filtering (e.g. Leung, et al. 2004), or some form of pseudo-efficient investment allocation (e.g. Arora, et al. 2004, Pinto and Pathak, 2008). These types of tools compares alternatives by rating them based on a set of criteria that are expressive of how each one can reduce the total risk.

Another property of any risk management activity is the inherent difficulty of consistently gauging the relative importance of risks. This is particularly relevant in the context of flu-type pandemic where controversial and alarming media coverage may lead to an over-estimated risk judgment, effectively resulting in irrational risk-averse decisions. Alhakami and Slovic (1994) have identified several psychological factors in an individual or societal judgment on risk that have relevance in the context of RST. Some of these are:

- Inverse relationship between risk & benefit judgment (e.g. someone who views flu vaccine to be risky will also view it to have minimal benefits)
- Halo effect when people judge risk in terms of general attitude and not by objective means (e.g. someone who views face mask as effective deterrence because many people wear them rather than actual test results)
- Cognitive consistency when people try to be consistent, something beneficial may also be viewed as having low risk – not by objective means.

6 CONCLUSION

Ivnitski et al (2006) very clearly describes the shortcomings of conventional biodetection systems: The slow rate of recognition of the presence of a pathogen, the inability to discriminate a full set of pathogenic versus nonpathogenic microorganisms in the environment, inadequate sensitivity, non-portability, the need for highly trained and qualified personnel and the high cost of purchase, maintenance and operation. The RST under study in this research will eliminate some of these shortcomings. First of all, the main objective and focus of this new technology is to increase the rate of detection of any kind of virus that may cause a threat. Both by decreasing the detection time and also by-passing some of the steps-such as physician control, etc- will be of help in this rapid technology. The need for additional personnel was discussed in the previous section, but because this effort will be interrelated, the new personnel need not be employed by the hospital.

It has been addressed in this paper that the implementation of RST will also have an impact on standard operation procedures of the medical, business, government and military infrastructures. In search of ways to master wicked problems, the RST research team looked at how risk management approach deals with wicked problems and complexity. RMA has similarities with the systems approach to solving problems and shares a number of its shortcoming in dealing with wicked problems. The initial source of complexity is the abstract and highly conceptual nature of *risk.* The quantitative description of risk also brings forth the fact that not all risk can be managed. In response, practitioners and researchers have suggested tools, methods, techniques, and paradigm shifts aids in implementing multi-disciplinary risk management as wells as more efficient allocation of resources to risk mitigation alternatives. However, there are still a lot of challenges that need to be addressed, including the organizational factors in RMA, as well as the inherent nature of risk to transcend elemental, system, and even meta-system boundaries.

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