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Evaluation of the System Attributes of Timeliness and Completeness of the West Virginia Electronic Disease Surveillance System' NationalEDSS Based System

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This is to certify that the doctoral dissertation by

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Abstract

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Virginia Electronic Disease Surveillance System – NationalEDSS Based System

by

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Dissertation Submitted in Partial Fulfillment

of the Requirements for the Degree of

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Abstract

Despite technological advances in public health informatics, the evaluation of infectious disease surveillance systems data remains incomplete. In this study, a thorough evaluation was performed of the West Virginia Electronic Disease Surveillance System (WVEDSS, 2007-2010) and the West Virginia Electronic Disease Surveillance System – NationalEDSS -Based System (WVEDSS-NBS; March 2012 - March 2014) for Category II infectious diseases in West Virginia. The purpose was to identify key areas in the surveillance system process—from disease diagnosis to disease prevention—that need improvement. Grounded in the diffusion of innovation theory, a quasi-experimental, interrupted, time-series design was used to evaluate the 2 data sets. Research questions examined differences in mean reporting time, the 24-hour standard, and comparison of complete fields (DOB, gender etc.) of the data sets using independent samples t tests. The study found (a) that the mean reporting times were shorter for WVEDSS compared to WVEDSS-NBS ($p < .05$) for all vaccine-preventable infectious diseases (VPID) in Category II except for mumps; (b) that the 24-hour standard was not met for WVEDSS compared to WVEDSS-NBS ($p < .05$) for all VPID in Category II except for mumps, and (c) that most fields were complete for WVEDSS compared to WVEDSS-NBS ($p < .05$) for all VPID in Category II except for meningococcal disease. Healthcare professionals in the state can use the results of this research to improve the system attributes of timeliness and completeness. Implications for positive social change included improved access to public health data to better understand health disparities, which, in turn could reduce morbidity and mortality within the population.

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Dedication

I dedicated this dissertation to my parents, Karen & Michael Fahey, who have always been a beacon for me in my life. Thank you Mom & Dad for being the lights that you are in my life.

Acknowledgments

I would like to take the opportunity to thank all of those people both friends, family, and faculty who have given me inspiration and encouragement along my journey. I appreciate each and every one of you and the light you have provided to help me achieve this goal.

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Chapter 1: Introduction to the Study

Introduction

There is an increased need for state infectious disease surveillance systems

(IDSS) to be integrated with the National Electronic Disease Surveillance System

(NEDSS) and for)the creation of a national electronic health record (EHR) system. Title

64, Legislative Rule of the West Virginia State Legislature requires health professionals

to report communicable diseases to their local health department. Prior to March 2012,

practitioners, hospitals, providers, and laboratories reported infectious diseases to the

West Virginia Electronic Disease Surveillance System (WVEDSS) by mail or fax. The

Centers for Disease Control and Prevention (CDC) developed a new system model to

interface with National Electronic Disease Surveillance System (NEDSS) and EHR. The

West Virginia Electronic Disease Surveillance System –NationalEDSS Based

Surveillance (WVEDSS-NBS, Department of Health and Human Resources [DHHR],

2011) went live in March 2012. Since then, local health departments have required health

professionals to report infectious diseases via the newly developed WVEDSS-NBS. The

WVEDSS-NBS, is an electronic disease reporting system for West Virginia hospitals,

state public health departments, health professionals, laboratories, and local public health

departments.

The newly developed WVEDSS-NBS, now on a Web-based server, was

established to improve the efficiency and accuracy of infectious disease reporting.

According to Doyle, Glynn, and Groseclose (2002), evaluations of electronic disease

surveillance systems are insufficient, imperfect, and incomplete. Baker (2010) stated that

reviews at the state level organize and identify improvements that can be applied at the national level. In this study, I evaluated the old WVEDSS (during the period 2007-2010) and the newly developed WVEDSS-NBS (from March 2012 to March 2014) to compare and identify system attributes (specifically timeliness and completeness). The results of these data are expected to give public health officials the information they need to make informed decisions about disease outbreaks.

Public health officials rely on the timeliness and completeness of the surveillance system data reported by the WVEDSS-NBS to design public policies and interventions. According to Baker, Easther, and Wilson (2010) and the World Health Organization's (WHO) International Health Regulations (IHR, 2005), the timeliness of infectious disease reporting is an essential component of any evaluation where early intervention is a factor. For Category II infectious diseases, healthcare practitioners and public health professionals in West Virginia use this research to improve timely reporting, prevention, and interventions. Doyle et al. (2002) defined infectious disease mandatory reporting as the routine gathering of individual cases to organize timely prevention and interventions to control infectious disease outbreaks (p. 1). With accurate and timely reporting, public health officials have the data needed to plan, organize, and implement public health interventions and policies to prevent and control infectious disease outbreaks in West Virginia. In this study, I examined the WVEDSS-NBS for sustainability; I compared system attributes using the diffusion of innovation theory as a way to understand the scope of the technological innovation, WVEDSS-NBS.

Background

In a breakthrough 1988 report, the Institute of Medicine (IOM) identified the core functions of public health as assessment, policy development, and assurance. Public health surveillance falls under the assessment function, which consists of collection of surveillance information, management or assembly of surveillance information into data, analysis of the data, data interpretation, dissemination, and stimulation. According to Thacker, Qualters, and Lee (2012), public health surveillance is the foundation of practice in public health and a vital component of the assessment function. A survey was conducted by the CDC to establish a baseline for the growth of public health surveillance at the agency. Of the 434 individuals who responded to the 2009 Web-based survey, nearly 60% stated that surveillance at the CDC is sound; only 33% stated that the CDC examines and publishes surveillance data in a timely manner, and only 20% agreed that the CDC surveillance systems are adaptable and malleable to the mutable environment of health informatics in the 21st century. The CDC outlined six factors to advance public health surveillance in the 21st century (Thacker et al., 2012):

- A shared lexicon of terms needs to be developed.

- Surveillance needs around the world need to be identified.

- Informatics concerns and emerging information technologies need to be maintained,

- A competent workforce needs to be trained.

- The analytical concerns of data use and access need to be addressed.

- The management, storage, and analysis of data must be organized.

All of these factors are discussed here and applied throughout the study by integration with the research variables.

Lexicon

From surveys, research, and interviews, the CDC developed six factors to advance public health surveillance in the 21st century. The principal factor is the lexicon that health professionals use in their day-to-day working environments. Many medical terms, acronyms, data-source terms, surveillance system modifiers, types of surveillance systems, and emerging terms will need to be addressed to design and maintain a national system to interact at the local and state levels to integrate the gathered information at the international level. Thacker, Qualters, and Lee (2012) emphasized the need for increased health situation awareness (Appendix C) and a working knowledge of the theoretical flowchart of public health surveillance (Appendix D). All states in the U. S. have laws that identify reportable infectious diseases that must be reported to the state. However, the CDC has established notifiable infectious diseases that must be reported to the CDC, these notifiable infectious diseases may or may not be reportable to the state. In order to address this variance, the CDC and the Council for State and Territorial Epidemiologists (CSTE) published a report outlining specific requirements for case definitions in 1990 with an update in 1997. The list contains past, current, and future notifiable conditions that have been validated by the Association of Public Health Laboratories (APHL) for use in public health practice and surveillance. All states are currently using a shared lexicon when they use the standard CDC case definitions.

Global Surveillance Needs

The emergence of new deadly viruses, mutating strains of influenza, and the rise of bioterrorism in the last few decades of the 20th century has increased the awareness of global public health issues. The WHO orchestrates global public health surveillance (much like the CDC organizes the public health concerns within the United States). Each country is responsible for monitoring diseases and organizing a response, but the IHR 2005 is the only mandatory international contract on disease control. The IHR constitute an international legal mechanism to incorporate the global public health concerns of 194 countries, including the Member States of WHO. The IHR was revised in 2005 to include more diseases and to extend the regulations to other areas of international public health concern. IHR 2005 took effect in June 2007 and requires countries to report infectious diseases and other public health events of concern to WHO by disregarding border disputes and focusing on the source, control, and prevention of the disease. The IHR 2005 defined the responsibilities of member countries and the WHO for public health security and surveillance to strengthen their capacity for public health surveillance and response at the source of the outbreak. The CDC has been called on to provide technical assistance and emphasize important IHR 2005 surveillance requirements at world meetings and summits. According to St. Louis (2012), the CDC proposed a vision for global public health to incorporate national surveillance systems into a world surveillance network. An essential step in this process is creating a shared lexicon for a global network of public health and health professionals. To create a social network so that they

can communicate among one another and share surveillance data to target disease outbreaks in a timely manner.

Informatics

Public health informatics is part of a larger field called biomedical or health informatics; they both require a thorough knowledge and understanding of the integration of technology, information science, and computer science with respect to public health and biomedicine. Public health surveillance has used advances and created new technologies in informatics to investigate and solve public health problems. Savel and Foldy (2012) identified three public health informatics work areas: the investigation and explanation of multifaceted systems, the recognition of prospects to enhance the efficacy and competence of public health systems through inventive data compilation or the application of data, and the application and upkeep of procedures and systems to accomplish these enhancements. The evolving field of surveillance informatics must find innovative ways to incorporate numerous sources of intricate statistics into significant intelligence that enables officials to implement interventions (Savel and Foldy, 2012).

The investigation, explanation, and integration of multifaceted systems began in 1951 (Appendix E) when the National Office of Vital Statistics began receiving state data by phone and mail. In 1961, the CDC took over and began publishing the *Morbidity and Mortality Weekly Report* (MMWR) with communicable disease information and statistics. In 1985, the CDC launched the Electronic Surveillance Project (ESP), a national 5-year project. States are charged with developing their own systems while the CDC is charged with developing ways to integrate the state data. Thus, the electronic era

of public health commenced over 25 years ago. The National Notifiable Diseases

Surveillance System (NNDSS) includes all aspects of disease surveillance from the local

to national level. The NNDSS developed the National Electronic Telecommunications

System for Surveillance (NETSS) in 1990 to incorporate state and national records.

NETSS was a DOS-based system and in 1995 the Epidemiology Program Office (EPO)

suggested that an update to NETSS, a Windows-based system. In 1998 an integration

project was started but stopped in 1999 when the CDC Office of the Director's

Information Resource Management Office created NEDSS.

NEDSS was developed to incorporate local, state, and national electronic

surveillance systems and simplify the transfer of electronic data. The EPO and NETSS

are still the primary sources of surveillance in 2012. In 2000 the CDC provided states

with funding through the Epidemiology Laboratory Capacity (ELC) cooperative

agreement and the CDC developed the NEDSS Base System (NBS), a platform for states

to begin electronic surveillance by utilizing detailed disease modules. In 2004, the CDC

created the Public Health Information Network (PHIN) to broaden the scope of NEDSS

surveillance and the EPO moved to the new Division of Public Health Informatics. The

next year, 27 health departments entered data using the Internet-based systems and 26

jurisdictions received lab results via electronic laboratory reporting (ELR). In 2008, the

CDC and NNDSS received the first Health Level Seven (HL7) messages for disease case

notifications. The HL7 was developed to incorporate clinical and laboratory data into

NEDSS. The CDC reorganized in 2009 by establishing the Office of Surveillance,

Epidemiology, and Laboratory Services. As of 2011, every state used NEDSS-compliant

surveillance systems and one-third used the NBS. Currently, the CDC receives case notifications from 57 jurisdictions. One of these jurisdictions is the state of West Virginia. The WVEDSS was established in 2007 and in March 2012 was converted to the WVEDSS-NBS.

Skilled Workforce

In order to keep up with the challenges of national and international public health surveillance, the initial education of new recruits, training, and continuing education of the growing surveillance workforce is a necessity. According to Drehobl, Roush, Stover, and Koo (2012), the education of the workforce has not kept up with the expansion of public health in the 21st century. The American Recovery and Reinvestment Act (ARRA) of 2009 and the 2010 Patient Protection and Affordable Care Act (ACA) provided opportunities for the country to increase and educate the public health workforce. The ARRA provided $50 million to offset budget cuts in state and local public health departments and the ACA has the initiative to increase the public health workforce and expand grants to public health surveillance related activities. A sufficient, cultivated, well informed, and competent health workforce that is prepared to use the appropriate tools is fundamental for a successful public health surveillance system.

Data Access and Usage

A public health grid (see Appendix F) was used to illustrate the complex nature of data access and usage within surveillance systems. The grid contains five main hubs consisting of public health departments, providers, consumers, federal agencies, and health information exchange. Within this network, information can be shared securely

and privately. Thacker, Qualters, and Lee (2012) indicated that 77% of the CDC's survey respondents replied that a more timely system of information sharing is required for future development. The grid provides access points and the interrelationship between hubs in the public health network.

Data Management, Storage, and Analysis

Examining the scientific evidence and applying this knowledge to infectious disease epidemiology establishes the foundation of effective disease control. In this day and time, this evidence must be extracted and translated from mountains of data. Surveillance is the process of collecting, organizing, and analyzing this data to make health care decisions. Rolka, Walker, English, Katzoff, Scogin, and Neuhaus (2012) stated that to achieve surveillance goals, an analytical process must be followed, the process requires hardware and software design, programming, statistical analysis, topic proficiency, creating models, and successful communication. The ability to translate pure data sets into epidemiological facts about diseases to policy makers is imperative for successful surveillance systems.

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Purpose of the Study

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The purpose of this study was to identify key areas in the process, from disease diagnosis, to disease prevention in order to improve the surveillance system. A major limitation among the variables was the reporting behavior of the patients and identifying where in the reporting process this behavior should occur. This clearly indicated an opportunity for public health officials to develop education and awareness programs in this area. Yoo, Park, Park, Lee, Jeong, Lee, & Cho (2009) stated that the most frequent

measures that affect disease reporting are disease onset, going to the physician, and recording the diagnosis. Yoo et al. further stated that WHO has issued extensive guidelines on the evaluation and examination of the steps in the surveillance process. Healthcare practitioners and public health professionals in the state use this data to improve the system attributes of timeliness and completeness. The difference between mean reporting times and the 24-hour standard between the two data sets was evaluated for timeliness. The required fields were assessed for completeness. Nicolay, Garvey, Delappe, Cormican, and McKeown (2010) stated that the completeness of the essential fields on intake forms could affect the sensitivity—and therefore the efficiency—of the system.

Problem Statement

The problem addressed in this study was the incomplete evaluation of the reporting of infectious disease surveillance systems data. Doyle et al. (2002) conducted a quantitative study to determine disease completeness in the United States. They found that the completeness of infectious disease reporting was related to the disease being reported. Doyle et al. clarified that underreporting by health professionals and laboratories may be related to deficits in knowledge of the legal requirement to report, what diseases to report, how to report diseases, and the consequences of not reporting. To address this problem, the WVEDSS and the WVEDSS-NBS system attributes (timeliness and completeness) were compared, and the results evaluated, to recognize and make improvements in the monitoring and evaluation process. The scope of the system, system attributes, and existing flaws were examined in order to clarify and address the social,

structural, technological, and environmental atmosphere that include the complexities of technological innovations, such as electronic infectious disease surveillance systems and electronic health records. This study used the system attributes of timeliness and completeness to identify areas in need of improvement.

To examine the gap of incomplete evaluation of the reporting of infectious disease surveillance system data, WVEDSS was divided into separate levels in order to ascertain at what level problems, errors, and nonconformity arose. Nicolay et al. (2010) suggested that an evaluation of surveillance systems data should include timeliness, completeness, sensitivity, positive predictive value, and case definitions. Greenhalgh et al. (2008) stated that shared electronic records are multifaceted systems and all stakeholders and their practices must accept improvements before the system can run smoothly and efficiently. Rogers (1995) stated that the diffusion of innovation model encompasses these levels and further subdivides them into specific definitions and organizational elements. Electronic disease surveillance systems are intricate innovations that must be accepted, adopted, and integrated into the daily workload of all participants in the organization. Greenhalgh et al. (2008) illustrated that the more complex the technology behind an innovation, the greater the chances of its failure. The importance of this study was that it identified key areas in the process, from disease diagnosis to disease prevention, in order to pinpoint steps in the process where data may be missing.

If communicable diseases are consistently being missed, then a different method for collection of this data is essential for infectious disease prevention and response to outbreaks. The key variables in this study (timeliness and completeness) were essential to

identifying the basic structural problems in disease reporting. According to Baker et al. (2010), evaluating surveillance systems has the added benefit of locating gaps or areas where information is lost in the system. A clear definition of the steps in the process of infectious disease surveillance is the primary action in improving the overall performance of the system. Thacker, Berkelman, and Stroup (1989) suggested that the best way to accomplish this task is to list the uses of the system and then translate those into goals. Baker et al. (2010) listed the definition of public health surveillance as "the ongoing systematic collection, analysis, interpretation and dissemination of data regarding a health-related event for use in public health action to reduce morbidity and to improve health" (p. 2). Essential to the elimination and control of infectious diseases in West Virginia and the United States are the timely reporting of diseases, and complete accurate data (Averhoff et al., 2006). The objective of this study was to examine these system attributes to ensure that accurate and timely data are being collected for the system.

The objective of this study after examination was complete was to establish baseline standards for disease comparison across state lines in the United States and to establish current levels of infectious diseases within West Virginia. Averhoff et al. (2006) evaluated the U.S. level of proficiency in detecting endemic rubella transmission and that rubella might have been eliminated in America. They stated that rubella detection in the United States is sensitive but that there are no standards to compare this data across the country. Evaluating the system attributes of timeliness and completeness identified missing data essential for the local health department to make policy decisions. The study was based on the following three objectives:

1. To use the two data sets to calculate the mean reporting time and identify differences among Category II infectious diseases in West Virginia.

2. To use the two data sets to determine the time difference above or below the 24-hour standard of the Category II infectious diseases in West Virginia.

3. To examine the intake forms on a case-by-case basis for the required fields (identifier, dob, gender, state, county, identifier for reporting facility, program area, jurisdiction, date received by public health, specimen source, date specimen collected, resulted test, organism, add test result button) of the two data sets to determine the baseline for reporting completeness for Category II infectious diseases in West Virginia.

Research Questions

This study examined the following three research questions.

1. Is there a difference in mean reporting time of Category II reportable infectious diseases between the two data systems (WVEDSS & WVEDSS-NBS) in West Virginia?

   $H_0{}^1$ - There is no difference in mean reporting time of Category II infectious diseases between WVEDSS and WVEDSS-NBS.

   $H_a{}^1$ - There is a difference in mean reporting time of Category II infectious diseases between WVEDSS and WVEDSS-NBS.

2. Is there a difference from the 24-hour standard (time delay) of the infectious diseases under Category II of the West Virginia reportable infectious diseases for both data sources?

$H_0{}^2$ - There is no difference from the 24-hour standard for one or both data sources.

$H_a{}^2$ - There is a difference from the 24-hour standard for one or both data sources.

3. Are the required fields (Identifier, DOB, Current Sex, State, County, Reporting Facility Identifier, Program Area, Jurisdiction, Date Received by Public Health, Specimen Source, Date Specimen Collected, Resulted Test, Organism, Add Test Result Button) complete for both data sources?

    $H_0{}^3$ - There is no difference in completeness of the required fields for one or both data sets.

    $H_a{}^3$ - There is a difference in completeness of the required fields for one or both data sets.

Theoretical Framework for the Study

The diffusion of innovation theory was used to describe the scope of the study and to establish the foundation for the dissemination of the WVEDSS-NBS. Everett Rogers developed the diffusion of innovation theory several decades ago and it provides a "hypothetical scenario of what usually happens when information is spread into a population" (Bauman, Nelson, Pratt, Matsudo, and Schoeppe's, 2006, p. 57). Healthcare surveillance systems are multifaceted and encompass managerial, technical, privacy, and security aspects that must be processed, adopted, and mastered by individuals and groups within the system.

To address innovation in the surveillance system, several essential components of WVEDSS-NBS structure were examined and evaluated using the diffusion of innovation theory. These data was used to establish baselines to assess WVEDSS's timeliness and completeness. The theory matched this research because it provided the examiner with the capacity to look at the surveillance system as a whole and the ability to examine system attributes on a case-by-case basis. An organization may be prepared for innovation overall but still unequipped for a specific innovation, especially a technologically based innovation. Rogers (1995) understood that an organization must achieve a state of system coherence to accept or reject the innovation. A prospective innovation that is successfully embraced in an organization will have the following attributes: apprehension for the transformation process, the ability of the innovation to incorporate into the existing scheme, and evaluation of the consequences of implementing the innovation. An organization must be prepared at all respective levels in order for the innovation to be successfully incorporated and maintained. The theoretical foundation will be discussed in more detail in Chapter 2.

Nature of the Study

This study used quantitative methods to perform a comparative study of the infectious disease reports that were manually entered into WVEDSS between 2007 and 2010 to the infectious disease reports reported by Web-based server on the newly developed WVEDSS-NBS, which was established from March 2012 to March 2014. The research design was a quasi-experimental, interrupted time-series design with non-random assignment of groups. Timeliness was assessed by the difference in mean

reporting times and the 24-hour standard reporting time, using the two independent

samples *t* tests. The required fields (Identifier, DOB, Current Sex, State, County,

Identifier for Reporting Facility, Program Area, Jurisdiction, Date Received by Public

Health, Specimen Source, Date Specimen Collected, Resulted Test, Organism, Add Test

Result Button) were evaluated for completeness using the two independent samples *t*

tests.

Definitions

Definitions include an example of different infectious diseases specific to

Category II of the West Virginia Reportable Infectious Diseases (Table 1), certain aspects

of the diffusion of innovation theory, timeliness, completeness, sensitivity, and positive

predictive value.

Table 1

Category II Infectious Diseases (WVDHHR, 2014)

Category II Infectious Diseases	Clinical Description	Case Definition Probable	Case Definition Confirmed	Laboratory Evidence

haemophilus influenza, invasive disease	Invasive disease may manifest as pneumonia, bacteremia, meningitis, epiglottitis, septic arthritis, cellulitis, or purulent pericarditis, less common are endocarditis and osteomyelitis.	Meningitis with detection of haemophilus influenza type b antigen in cerebrospinal fluid (CSF).	Isolation of haemophilus influenza from a normally sterile body site.	Detection of H. Influenza type b in blood or CSF or less commonly joint, pleura, or pericardial fluid. Positive antigen test results from urine or serum samples are unreliable for diagnosis of H. influenza disease.
hepatitis A, acute	hepatitis A is a viral illness that results in jaundice, fever, and loss of appetite, nausea, malaise, and sometimes diarrhea. Affected individuals may have abdominal pain, an enlarged liver, dark urine, and light stool. The majority of infected infants and preschool children have no signs or symptoms of the disease; however, they are just as infectious as adults. In contrast to hepatitis B and C, fulminant disease or death	An acute illness with discrete onset of any sign or symptom consistent with acute viral hepatitis (fever, headache, malaise, anorexia, nausea, vomiting, diarrhea, and abdominal pain) and either a) jaundice or b) elevated serum aminotransferase (ALT or AST) levels.	A case that meets the clinical definition is laboratory confirmed. And is not known to have chronic hepatitis B. OR A case that meets the clinical case definition who has laboratory-confirmed hepatitis A (i.e., household or sexual contact with an infected person during the 15-20 days before the onset of symptoms.	Immunoglobulin M (IgM) antibody to hepatitis A virus (anti-HAV) positive.

	occurs only rarely, and there is no carrier state. Severe disease is more likely to occur in the elderly or in persons with underlying liver disease (including hepatitis C); however, complete recovery is the rule.			
hepatitis B, acute	An acute illness with discrete onset of any sign or symptom consistent with acute viral hepatitis (fever, headache, malaise, anorexia, nausea, vomiting, diarrhea, and abdominal pain) and either a)jaundice or b) elevated serum alanine aminotransferase (ALT) levels > 100 IU/L	Persons who have chronic hepatitis or persons identified as HBsAg positive should not be reported as having acute viral hepatitis unless they have evidence of an acute illness compatible with viral hepatitis (with the exception of perinatal hepatitis B infection).	A case that meets the clinical definition is laboratory confirmed. And is not known to have chronic hepatitis B.	IgM antibody to hepatitis B core antigen (anti-HBc) positive or hepatitis B surface antigen (HbsAg) positive. IgM anti-HAV negative (if done).
pertussis	Whooping cough usually starts with cold or flu-like symptoms, such as runny nose, sneezing, fever and a mild cough. These symptoms can last up to two weeks and are	In the absence of a more likely diagnosis, a cough illness lasting > 2 weeks, with at least one of the following symptoms: • Paroxysms of coughing; or • Inspiratory	Acute cough illness of any duration, with isolation of B. pertussis from a clinical specimen; OR Cough illness lasting > 2 weeks, with at	The culture is the gold standard for diagnosis of *bordetella pertussis*. All suspected cases of pertussis should have a nasopharyngeal aspirate or

	followed by increasingly severe coughing spells. Fever, if present, is usually mild. The clinical course is divided into three stages: **Catarrhal Stage:** Characterized by insidious onset of coryza (runny nose), sneezing, low-grade fever, and a mild, occasional cough, similar to the common cold. The cough gradually becomes more severe, and after 1-2 weeks, the second or paroxysmal stage, begins. Patients with pertussis are most infectious from the beginning of the catarrhal stage through the 3rd week after the onset of paroxysms. **Paroxysmal Stage:** Characterized by bursts, or paroxysms of numerous, rapid coughs, apparently due to difficulty expelling thick	"whoop"; or • Post-tussive vomiting AND • Absence of laboratory confirmation • No epidemiologic linkage to a laboratory confirmed case of pertussis.	least one of the following symptoms: • Paroxysms of coughing; or • Inspiratory "whoop"; or • Post-tussive vomiting AND • Polymerase chain reaction (PCR) positive for pertussis; Illness lasting >2 weeks, with at least one of the following symptoms: • Paroxysms of coughing; or • Inspiratory "whoop"; or • Post-tussive vomiting AND • Contact with a laboratory confirmed case of pertussis.	swab obtained for culture from the posterior nasopharynx.

	mucous from tracheobronchial tree. At the end of the paroxysm, a long inspiratory effort is usually accompanied by a characteristic high-pitched whoop. During such an attack, the patient may become cyanotic (turn blue). Vomiting and exhaustion commonly follow the episode. The patient usually appears normal between attacks. The paroxysms can occur more frequently at night. **Convalescent Stage:** Characterized by gradual recovery. The cough becomes less paroxysmal and disappears over 2-3 weeks. However paroxysms often recur with subsequent viral respiratory infections for many months after the onset of pertussis. Older persons (i.e., adolescents and			

	adults), and those partially protected by the vaccine, may become infected with *B. pertussis*, but usually have milder disease. Pertussis in these persons may present as a persistent (<7 days) cough, and may be indistinguishable from other upper respiratory infections.			

| rabies, Human | The incidence of animal bites is considerably higher among children, particularly those five to nine years of age 4-6. Incidence decreases as age increases. Injuries inflicted by dogs are most common (80-90%), with cats being the next most common species involved3, 4. Doberman pinschers, German shepherds, and pit bull terriers are the most common purebred canines implicated in fatal attacks.

Rabies is an acute encephalomyelitis that almost always progresses to coma or death within 10 days after the first symptom. Rabies virus belongs to the order mononegavirales, viruses with non-segmented, negative- | *Human Exposure* A bite or scratch from a vector species or the introduction of saliva or central nervous system (CNS) tissue from a vector species into an open, fresh wound or mucous membrane (eye, mouth, or nose) of a human being.

Vector Species Species include bats or terrestrial mammals, especially carnivores. *Wild species* known to be reservoirs of rabies include, but are not limited to, raccoons, skunks, foxes, coyotes, bobcats, wolves, or any hybrids between these wild species and domestic dogs and cats. *Domestic species* include, but are not limited to, dogs, cats, and ferrets. | A clinically confirmed case that is laboratory confirmed by testing at a state or federal public health laboratory. | • Detection of lyssavirus antigens in a clinical specimen (preferably the brain or the nerves surrounding hair follicles in the nape of the neck) by direct fluorescent antibody test, or
• Isolation (in cell culture or in laboratory animal) of a lyssavirus from saliva or CNS tissue; or
• Identification of lyssavirus specific antibody (i.e. by indirect fluorescent antibody (IFA) test or complete rabies virus neutralization at 1:5 dilution) in the serum of an unvaccinated person; or
• Detection of |
|---|---|---|---|---|

	stranded RNA genomes. Within this group, viruses with a distinct "bullet" shape are classified in the *rhabdoviridae* family; which includes at least three genera of animal viruses, *lyssavirus*, *ephemerovirus*, and *vesiculovirus*. The genus *lyssavirus* includes the rabies virus10.			lyssavirus viral RNA (using reverse transcriptase-polymerase chain reaction [RT-PCR} in saliva, CSF, or tissue.
rubella	Rubella is a viral illness caused by a togavirus of the genus *rubivirus* and is characterized by a mild, maculopapular rash. The rubella rash occurs in 50%–80% of rubella-infected persons and is sometimes misdiagnosed as measles or scarlet fever. Children usually develop few or no constitutional symptoms, but adults may experience a 1–5-day prodrome of low-grade fever, headache, malaise, mild coryza, and	In the absence of a more likely diagnosis, an illness characterized by all of the following: • Acute onset of generalized maculopapular rash; and • Temp. > 99.0^{0}F or 37.2^{0}C; and • Arthralgia, arthritis, lymphadenopathy, or conjunctivitis; and • Lack of epidemiologic linkage to a laboratory-confirmed case of rubella; and • Noncontributory or no serologic or	A case with or without symptoms who has laboratory evidence of rubella infection confirmed by one or more of the following laboratory tests: • Isolation of rubella virus; or • Detection of rubella-virus specific nucleic acid by polymerase chain reaction; or • Significant rise between acute- and convalescent-phase titers in serum rubella	Rubella virus can be detected from nasal, throat, urine, blood, and cerebrospinal fluid specimens from persons with rubella. The best results come from throat swabs. Cerebrospinal fluid specimens should be reserved for persons with suspected rubella encephalitis. Efforts should be made to obtain clinical specimens for virus detection from all case-patients at the time of the

	conjunctivitis. Postauricular, occipital and posterior cervical lymphadenopathy is characteristic and precedes the rash by 5–10 days. Arthralgia or arthritis may occur in up to 70% of adult women with rubella. Rare complications include thrombocytopenic purpura and encephalitis. Rubella is transmitted through direct or droplet contact from nasopharyngeal secretions and has an average incubation period of 17 days (range: 12–23 days). Persons with rubella are most infectious when rash is erupting, but they can shed viruses from 7 days before to 7 days after rash onset. When rubella infection occurs during pregnancy, especially during	virology testing.	immunoglobulin G antibody level by any standard serologic assay; or • Positive serologic test for rubella immunoglobulin M (IgM) antibody; OR An illness characterized by all of the following: • Acute onset of generalized maculopapular rash; and • Temp. > 99.0^{0}F or 37.2^{0}C; and • Arthralgia, arthritis, lymphadenopathy, or conjunctivitis; and • epidemiologic linkage to a laboratory-confirmed case of rubella	initial investigation. Virus may be detected from 1 week before to 2 weeks after rash onset. However, maximum viral shedding occurs up to day 4 after rash onset. Real-time RT-PCR and RT-PCR can be used to detect rubella virus and has been extensively evaluated for its usefulness in detecting rubella virus in clinical specimens. Clinical specimens obtained for virus detection and sent to CDC are routinely screened by these techniques. Molecular typing is recommended because it provides important epidemiologic information to track the epidemiology of rubella in the United States now that

	the first trimester, serious consequences can result. These include miscarriages, fetal deaths/stillbirths, and a constellation of severe birth defects known as congenital rubella syndrome (CRS). The most common congenital defects are cataracts, heart defects and hearing impairment.			rubella virus no longer continuously circulates in this country. By comparing virus sequences obtained from new case-patients with other virus sequences, the origin of particular virus types in this country can be tracked. Furthermore, this information may help in documenting the maintenance of the elimination of endemic transmission. In addition, genotyping methods are available to distinguish wild-type rubella virus from vaccine virus.

Definitions

  Case Definition: *A case definition is set of uniform criteria used to define a disease for public health surveillance. Case definitions enable public health to classify and count cases consistently across reporting jurisdictions, and should not be used by healthcare providers to determine how to meet an individual patient's health needs. (CDC, 2013)*

  Communication: A process in which participants create and share information with one another in order to reach a mutual understanding. Diffusion is a particular type of communication in which the message content that is exchanged is concerned with a new idea. (Rogers, 2003, p. 18)

  Communication channel: The means by which messages get from one individual to another. (Rogers, 2003, p. 18)

  Completeness or data quality: Data quality reflects the completeness and validity of the data recorded in the public health surveillance system. Examining the percentage of blank "required" responses to items on surveillance forms is a straightforward and easy measure of data quality. (CDC, 2011, p. 407)

  Diffusion: The process in which an innovation is communicated through certain channels over time among the members of a social system. (Rogers, 2003, p. 11)

Diffusion of Innovation Theory: The diffusion model is a conceptual paradigm with relevance for many disciplines. The multidisciplinary nature of diffusion research cuts across various scientific fields. A diffusion approach provides a common conceptual ground that bridges these divergent disciplines and methodologies. (Rogers, 2003, p. 103-104)

Dissemination: Diffusion that is directed and managed. (Rogers, 2003, p. 7)

Innovation: An idea, practice, or object perceived as new by an individual or other unit of adoption. (Rogers, 2003, p. 12)

Positive Predictive Value (PPV): The proportion of persons identified as having cases that actually do have the condition under surveillance. (CDC, 2011, p. 407)

Sensitivity: The sensitivity of a surveillance system can be considered on two levels. First, at the level of case reporting, sensitivity refers to the proportion of cases of a disease (or other health-related event) detected by the surveillance system (43). Second, sensitivity can refer to the ability to detect outbreaks, including the ability to monitor changes in the number of cases over time. *(CDC, 2011, p. 407)*

Social Change: The process by which alteration occurs in the structure and function of a social system. (Rogers, 2003, p. 6)

Technology: A design for instrumental action that reduces the uncertainty in the cause-effect relationships involved in achieving a desired outcome. (Rogers, 2003, p. 13)

Time: Time is involved in diffusion in (1) the innovation-diffusion process, (2) innovativeness, and (3) an innovation's rate of adoption. (Rogers, 2003, p. 37)

Timeliness: Timeliness reflects the speed between steps in a public health surveillance system (CDC, 2011, p. 407)

Uncertainty: The degree to which a number of alternatives are perceived with respect to the occurrence of an event and the relative probability of these alternatives (Rogers, 2003, p. 6).

Assumptions

The major assumption was that all data had been reported accurately for both surveillance systems within the times specified, WVEDSS (2007-2010) and WVEDSS-NEDSS (March 2012-March 2014).

Scope and Delimitations

The West Virginia state epidemiology office was contacted for permission to evaluate all Category II infectious disease data reported within the specified time frame. Category II infectious diseases were included in the study and not Category I, III, IV, or V infectious diseases. I worked with the West Virginia state epidemiology office to determine which cases of Category II infectious diseases in West Virginia to examine to achieve more power for the analysis. The system attributes of timeliness and completeness were covered, but not sensitivity and positive predictive value.

The sample size, which included over 1000 cases of infectious disease from the entire state, increased the reliability of the sample. Lee and Baskerville (2003) explained that to increase the reliability of a random sample the size of the sample must be increased. Increasing the sample size reaffirms what has been uncovered in the sample but does not allow the sample findings to be generalized to the population. Increasing the

sample size does increase the level of statistical significance and the generalizability of the sample to other samples, but not to the population being studied or to the rejection or acceptance of the null hypothesis. This sampling procedure does reduce the likelihood of a Level I error. The only scientifically acceptable way to generalize a theory in a new setting is for the theory to persist in an experiential test in that setting.

Limitations

The entire state is required to submit their reportable cases to their local health departments. The limitation for this study is that secondary data will be collected from the past from two different time periods. Creswell (2009) stated that limitations in data not collected for research purposes or data collected in the past are that it can be incomplete, inaccurate, have selection bias, and many other variables that are unknown to the researcher. Limitations from using data from two different time periods can be that cases are not randomized, pre- and post- groups may not have the same characteristics, others factors may indicate confounding bias (Creswell, 2009). According to Harris, Bradham, Baumgarten, Zuckerman, Fink, and Perencevich (2004) the nonrandom nature of a quasi-experimental design is its major weakness. The data in this study will selected by convenience and will include all data entered for the time periods specified.

Other weaknesses in the study design were regression to the mean and maturation effects. Regressions to the mean and maturation effects were both threats to internal validity in this study. Regression to the mean was a possible threat because the intervention may or may not have been the reason for an improvement in surveillance.

Maturation effects were a possible threat in concluding that the intervention caused an improvement in reporting.

A major weakness in regard to the variables was the reporting behavior of the patients and in identifying where in the reporting process this behavior occurs. The reporting behavior of the patients is only attributable to the date of disease onset. Since timeliness was measured from diagnosis date to report date this clears the patients reporting behavior as a limitation to the study. This clearly indicates an opportunity for public health officials to develop education and awareness programs.

Social Change Implications

The results of this study may provide health departments with the information and tools to address the fundamental factors that help public health officials assess the population's health. Integration of the EHR with WVEDSS-NBS affords health professionals instant access to the most recent health data and thus allows local health departments to effect social change. Positive social change begins with reducing morbidity and mortality of infectious diseases within the population and this study identified issues related to timeliness and the completeness of intake forms. Colbert and Harrison (2011) stated that to accomplish these objectives and to understand the complex matrix of health disparities, more complete epidemiological and surveillance data must be acquired. An evaluation of surveillance system data was done on West Virginia to identify the incidence of Category II infectious diseases and to assess the effectiveness of the state health department by examining, comparing, and evaluating the old WVEDSS and the newly developed WVEDSS-NBS for the system attributes of timeliness and

completeness. I used the diffusion of innovation theory to examine the environment in which the surveillance systems operated in order to identify areas for improvement and sustain social change.

Significance

Health practitioners in West Virginia could use the results of this research to improve the time from reporting of the infectious disease to recording them in the database. With accurate and timely reporting, public health officials have the necessary data to plan, organize, and implement public health interventions and policies to prevent and control infectious disease outbreaks in West Virginia.

1. Improve the timeliness of reporting the Category II infectious diseases in West Virginia by establishing evidence-based evaluation criteria to identify differences in mean reporting time.

2. Identify sources of reporting delay from the 24-hour standard within Category II infectious diseases in West Virginia.

3. Improve the completeness of required fields for both data sets of Category II infectious diseases of the West Virginia by examining identifier, dob, gender, state, county, identifier for reporting facility, program area, jurisdiction, date received by public health, specimen source, date specimen collected, resulted test, organism, and add test result button.

Summary and Transition

The current WVEDSS-NBS was active as of March 2012 and further implementation of the system continued throughout 2014. Data from the old system,

WVEDSS, was not used in the current system because only new data was uploaded. The goal of the current WVEDSS-NBS is to implement and incorporate infectious disease data across multiple states surrounding West Virginia and integrate the IDSS with the electronic health record (EHR). The goal of this study was to compare the system attributes of timeliness and completeness of the previous WVEDSS to the current WVEDSS-NBS to ensure the accuracy of surveillance system data.

Chapter 2 will connect the variables of the two data sets to the system attributes of timeliness and completeness. This study specifically focused on the valuation of reporting the Category II infectious diseases (Table 1) before and after the Web-based server was employed in March 2012. Key variables and their relation to the system attributes were discussed to further the analysis of the two data sets.

Chapter 3 will discuss the research method, a quasi-experimental interrupted time-series design comparing two data sets before and after a technological intervention. The evaluation of data is an integral part of surveillance systems access and usage. Chapter 4 will discuss the time frame for data collection, discrepancies in data collection from the Chapter 3 plan, baseline descriptive and demographic characteristics of the sample, challenges to implementation as described in Chapter 3, statistical assumptions, and results.   Chapter 5 will discuss the interpretations, limitations, recommendations, and implications of these findings.

Chapter 2: Literature Review

Introduction

Despite technological advances in pubic health informatics, the evaluation of infectious disease surveillance systems data remains incomplete.. Sickbert-Bennett, Weber, Poole, MacDonald, and Maillard (2011) stated that the evaluation of infectious disease surveillance system data is not complete and further measures need to be undertaken to ensure the reliability of these statistics. According to Baker, Easther, and Wilson (2010), potential gaps exist within surveillance system data and existing data is not integrated with the electronic health record. Chriqui, O'Connor, and Chalaoupka (2011) agreed with Baker et al., writing that there was a need for a consistent review of surveillance systems, especially in regard to the development of policy and interventions. Baker et al. (2010) suggested the use of WHO and IHR standards to assess variances in surveillance system data, to identify improvements at the local level, and to examine all relevant surveillance system stages across an area of disease burden. Sahal, Reintjes, and Aro (2009) illustrated the point, writing that the main issue is in the completeness of reporting surveillance system data. Routine evaluations of surveillance systems are imperative for infectious disease detection and for ensuring that accurate feedback is provided to health professionals. Therefore, the purpose of this study was to identify key sections within the two data sets, (WVEDSS and WVEDSS-NBS), where data may be absent or lacking so that corrections could be made to the system. This chapter provides an in-depth examination of issues related to public health surveillance.

Literature Search Strategy

To identify prospective, peer-reviewed articles and books, the following databases—PubMed and Medline—were searched for the years 2008 to the present using the following keywords (with Boolean operators to maximize the results): *surveillance systems, electronic surveillance systems, infectious disease surveillance, WVEDSS, WVEDSS-NBS, timeliness of surveillance systems, completeness of surveillance systems, diffusion of innovation theory, sensitivity of surveillance systems, positive predictive value of surveillance systems*. The CDC website was also valuable.

While the review focused on current peer-reviewed articles, it included an extensive review of theories and seminal literature related to surveillance system policy and government interactions. The literature review was organized by themes found in the literature: the problem statement, the diffusion of innovation theory, the quantitative method for surveillance systems, system attributes of timeliness and completeness, and a summary.

Theoretical Foundation: Diffusion of Innovation

Source of the Theory

Rogers developed the theory, diffusion of innovation, in 1995 and wrote five books about the theory over the next 8 years. Rogers (2003) stated that diffusion is more of a social progression than a mechanical issue. This paper will utilize his first book and his most recent work of the same title written in 2003 with updates that have occurred in research and innovations since his first publication. Greenhalgh et al. (2008) illustrated that the more complex the technology behind an innovation the greater the chances of

failure of the innovation. Rogers (2003) emphasized that the diffusion of innovation describes social change as an essential aspect of human development. According to Greenhalgh et al. (2008), the aspect of diffusion of innovation that deals with the integration of the social and technological aspects is defined as the socio-technical aspect of change (p. 9). Healthcare surveillance systems are multifaceted structures that embody more than the social and technological aspects of surveillance systems. They incorporate outbreak information, social, technological, managerial, privacy, and security aspects and all of these must be processed, adapted, and mastered by individuals and groups within the system.

Major Theoretical Propositions

A technological innovation requires more information to be exchanged within the system and if done correctly reduces uncertainty among the stakeholders embracing the innovation. According to Rogers (2003) diffusion of innovation is the progression of communication exchange throughout a social system that initiates social change within the system. The organization undergoes alterations in the configuration and purpose of their social system through the integration of new philosophies and technologies by change agents. Rogers stated, "the main elements of the diffusion of innovation theory are innovation, communication, time, and the social system" (p. 861). These elements can be identified in all studies and programs revolving around the theory.

Technology is a blueprint for implementing a change to reduce the uncertainty about the advantages and disadvantages of achieving a certain outcome. Two basic aspects of technology include the hardware (the tool) and the software used as the

knowledge center for the tool. Rogers (2003) stated that the decision making process uses information gathering and information reasoning as another means to overcome user doubts. According to Rogers (2003) researchers need to evaluate all the existing technologies within a surveillance system as a technology cluster because they are intimately related. He defined a technology cluster as one or more elements of technology that are symbiotic and diffuse at the same time in a system (p. 383). Past research focused on each new technological development as an isolated innovation. Rogers (2003) identified "rate of adoption (relative advantage and compatibility), complexity, trialability, and observability as the perceived attributes of innovations" (p. 1346). Greenhalgh et al. (2004) emphasized these attributes in their work and they can be identified as diffusion, dissemination, implementation, and sustainability (p. 582). These attributes have been identified through past research as the most important aspects in explaining adoption rate.

Literature and Research-Based Analysis

Prior research on the diffusion of innovation theory used specific criteria to examine the overall evidence supporting their conclusions and discussed thirteen research areas supporting the theory in health service organizations. Greenhalgh et al. (2004) traced the chronological growth of the perceptions, the model, and the approaches in diffusion of innovation by examining the literature and evaluating experts in different fields, and quantifying this data as narrative. They designed an information-mining tool to abstract the key aspects of the theory to compare in their narrative using the World Health Organization Health Evidence Network (WHO-HEN) criteria. Earlier research on

diffusion of innovation theory was classified under four categories: rural sociology, medical sociology, communications studies, and marketing studies.

Opinion leaders and change agents influence interventions and communication within the organization or system. Rogers (2003) developed the area of rural sociology and he defined innovations as new concepts to farmers and defined diffusion as the spread of individual ideas mostly by imitation (p. 591). Rogers (2003) illustrated the importance of social networks specifically how individuals became adopters and how they make the decision to adopt or reject a technology. The medical sociology model followed Rogers's model but applied to doctors, particularly their behaviors when prescribing new antibiotics. These early studies set a precedent, as their focus was to define individuals who used social networks as cultured and sophisticated consumers marking them as the first to embrace new inventions.

Rogers (1995) developed his fundamental concept of diffusion of innovations through the rural sociological approach using communication studies that focused on innovations as 'news' or information that was spread through the news network of television, newspapers, or by individuals. Rogers and Kincaid (1981) focused their communication research in this area focusing on how fast the message was transmitted, where the message was transmitted, and how the changing critical variables influenced diffusion. The marketing category studied innovations as if they were products and developed mathematical models to forecast adoption behavior (Bass, 1969; Boehner & Gold, 2012). Potvin, Haddad, and Frohlich (2001) identified the qualities and demands of

innovations, the personalities and behaviors of adopters, and the effect of the magnitude of media campaigns on adopter's decisions.

As a result of the limitations identified in the conceptual models several new research areas were created including: development studies, health promotion, evidence-based medicine, and several areas in the organization and management literature. These earlier studies had many faulty theoretical suppositions: the individual was all that mattered, that accepting the new idea was the only decision; adoption can be predicted by examining the character of the adopters, and that diffusion research is universal (Greenhalgh et al., 2004). Studies found in the organizational management literature include research done on structural climate and culture (Damanpour, 1991, 1992, 1996); studies conducted on the interaction between groups (Abrahamson, 1991; Abrahamson & Fairchild, 1999); information based approaches to innovations in organizations (Nonaka & Takeuchi, 1995; Zahra & George, 2002); and organizational psychology (UK Department of Health, 2001).

The research focusing on innovation covered the structural climate and culture intertwined with the conventional transformation organization literature. Studies focusing on organizational process, context, and culture dealt with three main areas of research: acceptance, integration, and predictable nature of an innovation (Greenhalgh et al., 2004). This area of research used qualitative methods, mainly ethnographic, focusing on the human aspect including the overall social environment of the organization emphasizing culture, power, leadership, and risk taking attitudes (Greenhalgh et al., 2004). Inter-organizational studies dealt with the organization innovativeness compared to other

organizations on concepts that were essential to forming a social network. Studies that illustrated the connections between organizations focused on networking as a distinct form of communication within the organizations. The last area of research covered related to this study was organizational psychology where leadership skills such as pioneering, evaluation, and working effectively with employees contributed to the adoption of the innovation.

Rationale for the Diffusion of Innovation Theory

The definition and measurement of the diffusion of innovation theory provided a framework for the review of the literature in a systematic and methodic fashion. Greenhalgh et al. (2004) performed a meta-analysis of the literature using a new technique to answer the following question, how can we spread and sustain innovations in health service delivery and organization (p. 583)? Greenhalgh et al. (2004) defined innovation in health care as an innovative set of actions, customs, and operations that focus on perfecting health outcomes, managerial competence, and budgeting efficiency through proper planning and synchronized activities. Bunduchi, Weisshaar, and Smart (2011) stated that the major portion of costs occur in the early stages of a technological innovation with development, capital, ethical, and implementation costs prevailing. Greenhalgh et al. (2008) stated that identifying important aspects of the direction, vision, relationships, and the team in implementing a complex technological innovation begins with defining the theory of diffusion in innovation. Bunduchi et al. (2011) agreed that the technological aspect of the innovation is a significant factor and influences the outcomes

of the entire innovation. Integrating the technological aspect of the surveillance system into the daily routine of the organization is essential to its success.

Diffusion of innovation theory establishes a predefined framework for the researcher to build on as the innovation is integrated into the organization. The purpose was to illustrate the diffusion of innovation theory so that later innovations can be done more efficiently through the understanding and the development of diffusion and dissemination. In Bauman et al. (2006) stated that the main focus was to define dissemination and to reinforce evidence-based practices in public health. Dissemination was defined as describing the communication method utilized along certain paths by varying means in order to reach targeted stakeholders (Bauman et al., 2006). Greenhalgh et al. (2004) described diffusion as a passive process and dissemination as the active integration of the innovation into the organization. Diffusion occurs through personal encounters and is more informal and unstructured where dissemination is a formal planned implementation process that has a predetermined structure and uses social networks to create awareness and spread a message.

The process of diffusion is first identified as an informal planning process that is followed by a formal structured procedure driven by social networking within the organization. Formal dissemination programs are accountable for understanding the varying viewpoints of adopters, weighing the positive and negatives, identifying subdivisions of the whole, categorizing their characteristics, clearly constructing a mission, using the appropriate communication networks; and auditing and appraising objectives and targets (Greenhalgh et al., 2004). Researchers contesting the paradigms of

diffusion research have illustrated that those new technologies previously integrated using only simple diffusion should have gone through a more formal dissemination process (Greenhalgh et al., 2004). For instance, Rogers (2003) suggested using the technology cluster model for technological innovations that include more than one technology within the system. In this way the stakeholders consider all aspects of the innovation and a coordinated strategy is created for implementation.

How the Diffusion of Innovation Theory Relates to the Present Study

Public health researchers and professionals have campaigned for greater coordination in traditional public health surveillance actions pursuits. According to Fedorowicz and Gogan (2010) several surveillance systems have been used to track infectious diseases using different data collection methods and procedures leading to an abundance of irreconcilable databases and applications. The uniformity of the theory developed by Rogers (2003) is needed to examine this technological cluster as a whole, as the innovation is implemented within local and national networks (Fedorowicz et al., 2010). The theory has been utilized by Dearing (2009) to potentiate the spread of evidence-based practice to invoke social change. Bauman et al. (2006) stated that to create a solid foundation for dissemination efforts more research on diffusion in healthcare and public health is needed. A standard needs to be established for evaluating data and communicating it to stakeholders in the system.

Public health officials need to establish methods to follow to integrate data and results obtained from surveillance systems to the other stakeholders in the system. Bauman et al. (2006) provided further evidence for diffusion and adaption efforts to be

focused at the local level. Green, Ottoson, Garcia, and Hiatt (2009) clearly stated that the research is not reaching public health decision makers and healthcare professionals. Greenhalgh et al. (2008) explored the launch of a shared electronic patient record (SCR) in England and the implementation and diffusion of the SCR within the entire healthcare system. They emphasized using the diffusion of innovation theory because the SCR and other technologies are not simple innovations their very nature is complex and the implementation of such technological clusters involves developing communication networks and time management strategies among users within the entire social system.

The Institute of Medicine (IOM, 2010) recommended updates and changes for overhauling the National Center for Health Statistics (NCHS). The IOM stated that improving data collection and measurement, establishing a set of health indicators, and transforming the healthcare system would have a tremendous effect on the health of local populations. A superior method of collaboration is needed between innovation, public health, and medical care **(**Rust, Satcher, Fryer, Levine, & Blumenthal, 2010**).** The Affordable Care Act of 2010 (IOM, 2010) was established to alter the existing heath care system but innovations in public health, social, and environmental factors will need to be improved as well. Reijn, Swann, Kretzschmar, and Steenbergen (2011) found that each infectious disease has its own particular characteristics that must be examined. This data must then be compared for every stage in the surveillance process in order to uncover errors and interruptions within the system so that corrections can be made.

Adoption of the innovation. The interconnectedness of the innovation, the initial adopters, and the rate at which the innovation is adopted are essential to adoption.

Greenhalgh et al. (2004) stated that the standard of diffusion is to be used as a memory aid for implementing complex innovations in diverse situations among numerous interactions. The empirical findings associated loosely with their model include the innovation, adoption by individuals, assimilation by the system, and diffusion and dissemination. Greenhalgh et al. (2004) stated that these factors themselves are not enough for the innovation to be adopted. Rogers (2003) compares adoption as a process versus adopter categories. People are not submissive when it comes to the adoption of innovations they engage and interact on all levels through conversations, feelings, and evaluations.

The adopter is a principle player and team member in the adoption and innovation process interacting with other adopters and other teams. The four aspects of adopters from Greenhalgh et al. (2004) and Rogers (1995) include: personal perceptions, perceptions related to the technology, what the innovation means to them, and their adoption decision process. According to Greenhalgh et al. (2004) prior research done on the diffusion of innovations has mainly been based on specific, modest, and commodity-based innovations where diffusion occurred from the impressions made by innovators in the field. One must not be misled by this literature and over simplify the diffusion process for complex technological based innovations. The successful innovator will understand that the distribution of adoption in the target market needs to be determined by observation and experiment (Rogers, 2003, p. 560). At this level, adoption is referred to as team assimilation to develop structures within organizations to incorporate the innovation.

Rejection of the innovation. Complex innovations in service organizations are process-based innovations and assimilations by teams, departments, and organizations that require changes in the essence of the working environment. Greenhalgh et al. (2004) compared the characteristics of developing simple innovations to complex innovations and described the processes involved in each method. Most of the research on innovations has focused on individual or simple innovations, which are developed through simple imitation (Rogers, 1995). In order to accomplish such a multifaceted mission, a formal decision making process must be formulated, evaluation phases must be established, and implementation must be planned, and effort sustained throughout the process.

All elements and procedures of initiating the innovation must be incorporated into the planning stage. Gladwin, Dixon, and Wilson (2002) stated that it is essential to include all information in the plan for an innovation whether simple or complex. Omitting steps or procedures because they are common sense can be a serious error and lead to rejection of the innovation. Gladwin et al. stated that implications for technology innovations, such as a upgrading a surveillance system from paper to electronic, are basically changes in the organizational structure and should be reviewed and implemented in this fashion. All components and elements that need to be changed or motivated must be included to ensure compliance and integration of the innovation.

Implementing the innovation. The organization's willingness to accept the innovation comprises their apprehension for transformation, the ability of the innovation to incorporate into the existing scheme, and evaluation of the consequences of the

innovation. Greenhalgh et al. (2004) stated that innovation includes system antecedents and the systems willingness for the innovation. System antecedents are composed of the structural components, absorptive capacity for new information, and the organizations receptive ability for transformation. Greenhalgh et al. (2004) stated that operational and socializing components of the organization affect the probability that the innovation will be integrated into the organization. Provisions and promotions, devoted periods and supplies, and the competence to appraise the innovation are the key components of evaluating the consequences of the innovation.

The literature supports analyzing the system precursors as an aggregate because they are multifarious, collaborative, and changeable. According to Greenhalgh et al. (2004) a significant aspect of system integration identified by the literature is that a system's preliminary structural dimensions, absorptive capacity, and receptiveness should be examined as a whole and not dissected into parts. With that in mind the individual precursors for the structural components, absorptive capacity, and receptiveness will be discussed. Organizational structural prerequisites that are sizeable, segregated, developed, and focused increase compliance with integration.

Dopson, Fitzgerald, Ferlie, Gabbay, & Locock (2002) stated a significant aspect from the healthcare literature that was mentioned extensively was the value of the function of investigative evidence in the application of technologies (p.607). Greenhalgh, et al. (2004) identified allocation of "slack resources" (p. 604) as an essential component of the structural precursors, which make up only 15% of the difference between organizations in the literature. Absorptive capacity precursors include the organization's

proficiencies and talent base, established associated technologies, a knowledgeable and understanding culture, and upbeat governance dedicated to establishing communication networks. This evidence must be digested by the existing healthcare culture, established within their communication and social networks, and incorporated into their daily working environment.

An organization may be prepared for innovation overall but still unequipped for a specific innovation especially a technologically based innovation. As the organization prepares for the innovation they acquire a state of system eloquence from which they accept or reject the innovation (Rogers, 1995). A prospective innovation that is successfully embraced into the organization will have the following attributes: apprehension for transformation, the ability of the innovation to incorporate into the existing scheme, and evaluation of the consequences of the innovation. The organization must be prepared at all respective levels in order for the innovation to be successfully incorporated and maintained.

Process. The organization must respect the difference between the research and the application of the finding in the real world. The diffusion of innovation process includes "innovation development and testing, innovation dissemination, its adoption by a population, implementation into that population, and maintenance or sustainability of the innovation*"* (Bauman et al., 2006, p. 58). The article by Bauman et al. (2006) described the fundamentals for the propagation of any public health issue. Bauman et al. (2006) illustrated the need for identification of key policymakers, as an essential step throughout the process by meeting their information needs first to cement cooperation

throughout the process. This begins the process of developing engaging partnerships that will help implement the innovation across disciplines and boundaries. The dissemination process is optimized when role models and leaders can be established and encouraged to see the project through to smooth operation.

How Research Questions Relate to the Theory

This process works much better when those who will utilize the system have apart in the initial plan to implement. In order to establish a more organized assessment and evaluation to guide public health practitioners in their transition from paper based surveillance systems to more elaborate electronic infectious disease surveillance systems improvements must occur at the micro, meso, and macro level. Electronic disease surveillance systems are complex innovations that must be accepted, adopted, and integrated into the daily workload of all participants in the organization. Greenhalgh, et al. (2008) stated that at the micro level these complex innovations include the basic structure of the technology and current surveillance system, the outlook and apprehensions of the people involved, and the current social environment. The organizations past experiences with innovation, their willingness to participate in the innovation, and the current working components of the innovation compose the meso level. The CDC, NIH, and APHA and other governing bodies make up the macro level of the organizational structure, which includes the utilitarian and sociopolitical forces affecting the innovation.

To address innovation in the surveillance system at the micro level several essential components of WVEDSS-NBS structure will be examined and evaluated.

According to the literature this data should be used to establish baselines to assess

WVEDSS-NBS's timeliness and completeness. Therefore, the current WVEDSS-NBS

will be evaluated on its timeliness and completeness by comparing it to the previous

WVEDSS. The first step is to calculate, review, and compare the infectious disease

surveillance systems timeliness or the mean reporting time of infectious diseases under

Category II of the West Virginia reportable infectious diseases of the previous WVEDSS

to the current WVEDSS-NBS.

Public health surveillance goes beyond the mere gathering, analysis, and

explanation of data for public health practices it must report this information to the

correct individuals in a time frame that allows them to take action if needed. Fedorowicz

and Gogan (2010) stated that conventional surveillance systems were designed to validate

a particular disease involved in an outbreak, stress precision and completeness while

ignoring the value of timeliness. Jajosky and Groseclose (2004) stated that timeliness is a

quantitative indicator of the surveillance systems reliability and validity and is used to

determine any time delays between operational phases. The calculation of timeliness for

this study includes how the data is to be used, the communicability of disease, and the

nature of the condition under surveillance. The second focus is on infectious disease

reporting completeness of intake forms from the previous WVEDSS and the current

WVEDSS-NBS. Doyle et al. stated in their study on notifiable infectious disease cases

reported electronically to the local health department that using the electronic system

resulted in a "2.3 fold increase in case reports" (2002, p. 866).

Summary of Diffusion of Innovation Theory

From the first thoughts of Rogers in 1995, the diffusion of innovation theory has developed into addressing innovation in surveillance systems in 2014. A socio-technological innovation within infectious disease surveillance systems requires a change of the social system or culture where the technology will be applied. The diffusion of innovation theory represents a foundational and measurable framework to guide the researcher on implementing innovative electronic surveillance systems around the world. Public health officials can use the research on the theory to integrate and understand the vast amount of electronic data obtained from electronic surveillance systems. Adopters of an innovation go through a process of adoption in which they either accept or reject the innovation. Adoption and subsequent implementation of the innovation require extensive planning, stakeholder involvement, and dissemination of the innovation across the organization.

Literature Related to Timeliness and Completeness

This study focused on improving the assessment of infectious disease data retrieved from surveillance systems. In order to improve surveillance system evaluations this study identified areas within the WVEDSS-NBS where more complete epidemiology and surveillance system data may be missing or where improvements can be made to the system. The WVEDSS-NBS, which is being integrated with EHR, will be compared to the old WVEDSS and evaluated on system attributes of timeliness and completeness. Since the WVEDSS-NBS is now linked to NEDSS, the national system, and therefore the WHO, the international system, they are obligated to follow the IHR (2005). The WHO

(2008) stated that the IHR (2005) is a binding international law that went into effect on June 15, 2007 and it governs the criteria for reporting epidemiological data to the WHO, the WHO's response, and requires the strengthening of member countries surveillance systems and response to public health risks.

Evaluation of Epidemiology Surveillance and Response

Several countries have performed evaluations of epidemiology surveillance efforts. The components discussed will focus on methods for epidemiology surveillance and response, public health laboratory services, and the public health educational infrastructure. Nsubuga et al. (2010) evaluated four countries in Africa to recognize accomplishments and miscalculations using the Integrated Disease Surveillance and Response (IDSR) strategy. The Africa Regional Office (AFRO) and the WHO developed the IDSR in 1998. This knowledge was used to build a guide to address the IDSR key components for evaluating integrated surveillance systems. Taboy, Chapman, Albetkova, Kennedy, and Rayfield (2010) investigated the integration of surveillance using the IHR (2005) to create a set of tools to address the challenges of the action theme to create a sustainable world health network for international collaboration. Takian, Petrakaki, Cornford, Sheikh, Barber, and NHS CRS Team (2012) assessed England's implementation of a national EHR because all WHO member States and partners are undertaking these challenges. Case-by-case evaluations were used for comparison of system attributes between surveillance systems and to verify compliance with IHR recommendations.

The evaluation and comparison of case studies allowed the researcher to pinpoint unique aspects of the surveillance system to begin a discerning discussion about collective themes and unique encounters. According to Takian et al., and National Health Service Care Records Service (NHS CRS) Team (2012) integrated case study evaluations can address multiple levels of the surveillance system and identify the social, technical, and cultural environments. Takian et al. used a case-study design and interpretive approach to evaluate the implementation of England's NHS CRS over a 30-month period from September 2008 to March 2011. The investigation of case studies is critical in establishing the sensitivity of the surveillance system (Watkins, Martin, Kelly, Madin, & Watson (2009). Amirfar, Taverna, Anane, and Singer (2011) described the creation of quantitative quality of life measures to be integrated with a new EHR, the clinical decision support system, for New York Cities' outpatient population. Amirfar et al. analyzed the creation of the CDSS as they went through the planning, developing, and implementing stages to improve population health.

Amirfar et al. (2011) took advantage of existing innovations in technology and EHR to improve the quality of patient care in New York City using established quantitative data: 10 TCNY measures. Many researchers (Wamala et al., 2010; Nsusbuga et al., 2010; Takian et al., 2012; & Taboy et al., 2010) have approached the problem (incomplete evaluation of surveillance systems and data quality) by evaluating their systems using the IHR (2005) and IDSR tools developed by the World Health Organization. Wamala et al. (2010) stated that their evaluation of Uganda for compliance with the IHR (2005) included five core capacities: infectious, chemical, zoonosis, food-

safety, and radio-nuclear. Using the technical guidelines outlined by the IDSR they identified strengths and weaknesses in WHO's approach to improving the evaluation, implementation, and collection of data within surveillance systems. The major strength of their study was it identified gaps in applying the IHR (2005) and uncovered worldwide security issues. Africa needs to address these issues at the national level and the WHO at the international level because no established legal framework is in place to support and enable the required procedures to comply with the IHR (2005). Applying the strategies outlined in the IDSR allowed them to reexamine their existing goals, objectives, and interventions in an organized and structured way.

Reviewing these constructs provided them with ammunition to develop new objectives in line with WHO's IHR (2005). Nsubuga et al. (2010) also focused on the implementation of the IDSR in Africa but broadened their research to include four countries. One major weakness of the IDSR, their tool for evaluation, is that it is still evolving and the data they obtained was mostly qualitative. Taboy et al. (2010) used the Integrated Disease Investigations and Surveillance (IDIS) tools developed by the Laboratory Systems Branch of the CDC and the U.S. Defense Threat Reduction Agency's Cooperative Biological Engagement Program (CBEP) to focus on a systems approach for outlining effective implementation approaches.

The IDIS tools enabled evaluators to combine their ideas, thoughts, and critiques of the system to identify proficiencies and encourage dialogue on sustainable local, state, national, and international communication networks. Lack of sufficient technology and methods to interlink the CDC and CBEP may have had detrimental effects in other areas

of the public health system. Takian et al., and NHS CRS Team (2012) stated that their longitudinal approach to the social and technological assessment of England's NHS CRS occurred simultaneously with the implementation process. The ability to change focus from end point evaluation of surveillance data to analyzing changes as they take place within the system is one of their major strengths. Thus, it was also a weakness because it could show only a limited part of implementation, the predicted research plans were inaccurate, and the length of the study was short.

Attributes of Surveillance Systems

To accomplish a thorough review of the surveillance system the diffusion of innovation theory was utilized to connect the system attributes examined. According to Watkins et al. (2009) system attributes for measuring the sensitivity of a surveillance system should include timeliness, completeness, and the geographic and demographic data of the population. Williams, Vally, Fielding, and Cowie (2011) followed the recommendations of the CDC to establish disease registries to improve the completeness of intake forms fields and allow the user to incorporate additional public health information. The authors also identified under reporting of communicable disease as a cause for concern regarding the completeness of data. The IDIS tools developed by the CDC and CBEP developed pathogen specific templates that were used to compare completeness of intake forms from the old system to the new system **(**Taboy et al., 2010**)**. Nsubuga et al. (2010) stated that the integration of existing surveillance systems with the electronic health record (EHR) increased the efficiency of the system. In order to ensure timeliness and completeness across the whole health system an all-inclusive approach is

required because of the complex nature and multiple interrelated factors surrounding technological innovations.

Timeliness

In this study, the timeliness or the reporting time of infectious diseases under Category II of the West Virginia reportable infectious diseases of the previous WVEDSS was compared to the current WVEDSS-NBS. Timeliness was evaluated by compliance with Category II guidelines that notifiable infectious diseases are reported within the recommended time period, average time lags, and the cumulative time lag between each step in the surveillance process **(**Yoo et al., 2009)**.** The WHO (2008) outlined guidelines on timeliness that are assessed by measuring the time taken for each step from disease onset to International reporting. Jajosky and Groseclose (2004) stated that timeliness is a quantitative indicator of the surveillance systems reliability and validity and is used to determine any time delays between operational phases. Timeliness is a key element and should be used as a consistent evaluation and measurement tool of surveillance systems (Yoo et al., 2009). Perhaps the major error that has been made in the past in the measuring of timeliness is that it has been assessed as a single process.

Definition. In the literature timeliness has been measured as the speed between steps in the surveillance process, the time between disease onset and reporting to local, state, national, and international agencies, and as the time between proxy values established for disease onset and disease reporting. According to Reijn et al. (2011) no standard quantitative measure for timeliness in surveillance systems has been established. I will evaluate timeliness on two factors: mean reporting time and within 24 hours of

disease onset, the standard for Category II infectious diseases. Yoo et al. (2009) stated

that timely reporting is effected most by the interval from disease inception to diagnosis.

Yoo et al. (2009) stated that previous research has indicated that the surveillance steps of

infectious disease reporting vary from system to system and from one infectious disease

to another. Category II infectious diseases of WV will be considered reliable if they are

reported within 24 hours to the LHD.

The most important aspect in evaluating the timeliness of a surveillance system is

to establish a standard definition and establish a quantifiable factor to measure it.

Timeliness was defined in terms of mean reporting time and the 24-hour standard.

Jajosky and Groseclose (2004) collected data on the National Notifiable Disease

Surveillance System (NNDSS) and suggested using the earliest known date of disease

onset as the starting point for the measurement of timeliness, varying by disease. The

comparison of timeliness across surveillance systems and from paper to a Web-based

server illustrated key factors causing delays in the timely reporting of infectious diseases.

Results of Previous Studies. Reijn et al. (2011) stated that study methods for

timeliness varied from comparing paper to electronic systems and timeliness measures

across boundaries. In their evaluation of the Dutch Municipal Health Services (MHS) on

timeliness they identified two key intervals for timeliness as the time period between the

onset of symptoms and MHS notification, and between laboratory diagnosis and MHS

notification. They used distribution of means as their statistical test to evaluate timeliness.

Vogt, Spittle, Cronquist, and Patnaik (2006) illustrated how a LHD could evaluate the

Colorado Electronic Disease Reporting System (CEDRS) for timeliness and

completeness. Timeliness was defined as the time period between "specimen collection date" and "report date" for each patient and they compared them through distribution of mean. Records were said to be complete if all required fields were filled. Most fields were found to be complete except for the "diagnosis date" field but a new field was created "test result date" to substitute for the date of diagnosis. Their results prompted training of disease investigators to fill out intake forms completely with the hope that future evaluations will yield improved timeliness and more complete data. I measured timeliness from the date of diagnosis to the reporting date to the state health department and evaluated each disease on the distribution from the mean.

In order to reduce the spread of infectious diseases continual efforts need to be applied to improve the timeliness of surveillance systems. Reijn et al. (2011) stated that infectious disease surveillance systems (IDSS) should be regularly evaluated for each step in the system for each disease within the system. Reijn et al. found that the proportion of infectious diseases reported to the LHD varied by disease, 0.4% for shigellosis and 90.3% for HAV infection. They compared the median incubation period of each infectious disease to the median time it took to report the disease to the health department. They used incubation period as their standard measure and reliability marker. Some of the most common reasons for delayed reporting are patient's recognition of symptoms, communication issues, missing data, incorrect data, disease specific incubation periods, and laboratory-related delays. Reijn et al. (2011) illustrated that electronic laboratory reporting (ELR) has improved the timeliness in some nations and concluded that an international standardization method for measuring timeliness be

supported. The WVEDSS-NBS has not implemented ELR within its system however a delay in diagnosis was found to be a common disruption of timeliness in the next study even though they used data from an ELR system.

The evaluation of data from surveillance systems being assessed for timeliness varies because each study examines different diseases and measures of timeliness. Yoo et al. **(**2009**)** evaluated over 40,000 infectious disease records from an electronic system that collected data in 2000. They found that the greatest time delay stemmed from the delay in diagnosis from the clinical side and from the excess time spent on lengthy laboratory tests. They found that the total time from disease onset to reporting to the local health department ranged from six to twenty days and varied from one disease to another**.** Nicolay et al. (2010) evaluated the timeliness of different species of Salmonella and found that timeliness varied even among the different species. They found that notification from physicians was faster than laboratory reporting the opposite effect of what was uncovered by Yoo et al. (2009)**.**

However, most studies found that electronic reporting resulted in an improvement in all system attributes especially timeliness. Effler, Ching-Lee, Bogard, Ieong, Nekomoto, and Jernigan (1999) compared an electronic reporting system to the previous conventional system and found a 2.3 fold increase in infectious disease reporting with the new system. The CDC (2005) stated that in New Jersey, which has a Web-based server like WVEDSS-NBS implemented in 2001, the number of cases reported from 2002 to 2004 doubled and that the average days for case reporting dropped from 28 days in 2002 to 3-4 days in 2004. In Massachusetts the implementation of several interventions,

including Web-based infectious disease surveillance system, improved timeliness by decreasing median reporting times from 454 days in 2004 to 26 days in 2008. Lazarus, et al. (2009) stated that despite all of the improvements made in surveillance systems across the country some important internal mechanisms still depend on people. Even though we have come a long way and improved several qualitative and quantitative aspects of infectious disease reporting training and integrating primary stakeholders within the system remains essential.

Past Problems. Electronic reporting, electronic health records, and electronic laboratory reporting have the potential to improve all system attributes. Wurtz and Cameron (2005) illustrated that despite these obvious improvements in infectious disease surveillance the physician must still do their part in submitting a comprehensive and well-timed case report. Lazarus et al. (2009) quantified that electronic laboratory reporting is held in high regard by experts in the field but without integration with the electronic health record the ELR is deficient in essential information for case detection and the condition of the disease. Even though most states have adapted to national guidelines by using the NEDSS equivalent software to upgrade their paper based systems to electronic or Web-based servers many problems still exist in establishing standards for information exchange. Nicolay et al. (2010) stated that research has proven that implementation of electronic reporting will decrease timeliness and increase the completeness of surveillance statistics.

The CDC (2005) stated that establishing secure channels and standards for the exchange of infectious disease, ELR, and EHR data between public health officials and

clinicians remains a challenge. Heisey-Grove, Church, Haney, and Demaria (2011)

suggested that direct integration of data from the EHR would decrease the timeliness of

reporting infectious disease outbreaks. As the interface between clinicians and public

health officials improve the data becomes more streamlined and universal. In the past

health data was faxed, mailed, or emailed to the local or regional epidemiologist to be

entered into the state system. The epidemiologist entered this data into the system

sometimes weeks after the information had been received or the notifiable condition had

transpired. The CDC (2005) reported that many (10-85%) of these cases never made it to

the national level and previously states used over 100 different systems to send reports to

the CDC. A review of the literature has revealed that many definitions and standards of

measurement for timeliness have been used in the past. Madoff, Fisman, and Kass-Hout

(2011) concluded that incorporating the Internet into surveillance reporting would

improve timeliness, sensitivity, and completeness of surveillance system data. I followed

the CDC's recommendations for assessing timeliness in order to establish a baseline for

timeliness comparison by disease category for future research. According to the CDC

(MMWR, 2001) improved timeliness allows for adequate and accurate development of

policies and interventions. Computerized technology allows for the assessment of

timeliness to be completed routinely on each step in the public health surveillance

system.

Timeliness of Electronic Data Systems. Electronic disease reporting has

become the standard by which all other reporting is to be compared. According to several

researchers (Reijn et al., 2011; Yoo et al., 2009; Nicolay et al., 2010; Doyle et al., 2002)

electronic disease reporting has improved the timeliness of infectious disease outbreak notification. In addition these authors and the CDC (2005) recommend that states integrate ELR into their existing systems to improve timeliness because laboratory tests are used to confirm most infectious diseases, labs are important members of the system, and laboratories can be used for other aspects of public health surveillance. Evaluating infectious diseases by integrating the above systems improves timeliness and supports more complete evaluations since infectious diseases must be assessed individually because of critical diagnostic criteria. Nicolay et al. **(**2010) stated that research has proven that implementation of electronic reporting will decrease timeliness and increase the completeness of surveillance statistics. Electronic data and evaluation methods at the local, state, national, and international level allows for more complete assessment of infectious diseases and their spread around the globe.

Completeness

Completeness was measured by the ratio of incomplete fields to complete fields of required data items on the WVEDSS-NBS intake form that has been filled. Lazarus et al. (2009) stated that completeness could be measured as the percentage of the essential statistics required identifying a particular infectious disease. According to Doyle et al. (2002) infectious disease reporting completeness identifies those notifiable cases that have been reported to the local health department. The completeness of intake forms is crucial to the proper accounting of cases of infectious disease within a population. Without this vital information to guide epidemiologist and other public health officials in the diagnosis of notifiable infectious diseases, outbreaks may be missed and epidemics

may occur. I evaluated completeness in this study by the ratio of incomplete fields to complete fields.

Definition. Lazarus et al. (2009) stated that the main issue with using data fields on intake forms to measure completeness is the agreement of what is required for each form. I assumed in this study that all fields are required for a particular case or that each data field within a section is entered correctly. I also assumed that a data field is complete if there is an entry for that field.

Results of other studies. Lazarus et al. (2009) found in their study on completeness that failing to report an individual case with a notifiable condition, false positive, was worse than reporting case that later turned out to be negative, false positive. The false positive case wasted valuable time but the false negative case actually decreased the efficacy of public health interventions. Comprehensive, itemized case information is needed for public health prevention programs that are usually not available from conventional manual forms. In a study performed by Effler et al. (1999) they found using capture/recapture methods that out of 21 data fields common to both electronic and paper intake forms, electronic forms were considerably more complete; thus identifying that the electronic format to be far superior to the conventional paper or manual format.

This leads to the evaluation of the intake forms submitted electronically and the intake forms submitted by the conventional method. Heisey-Grove et al. (2011) stated that they began using the optical character recognition (OCR) form in 2004 for Hepatitis C and from 2005 to 2008 the amount of intake forms received increased dramatically and the percentage complete intake forms increased by three percent. They used the case

ascertainment method to analyze completeness of intake forms. Doyle et al. (2002)

reviewed published articles in the U.S. from 1970 to 1999 that evaluated disease

completeness quantitatively by comparing the number of forms received by comparing

this number to the number received by another collection method. The degree of

completeness in these studies ranged from 9% to 99% and was intensely related to the

disease studied. According to Sickbert-Bennett et al. (2011) disease completeness varied

not only by disease in their retrospective cohort study but also by healthcare system.

Their results showed that disease specific completeness varied from 0% to 82% and

completeness overall was quite low for all diseases. These results are important because

they identify several factors essential to the evaluation of infectious disease completeness

data.

It is important to evaluate infectious disease completeness by each disease under a

specific Category and to examine each reporting source independently to uncover

reporting patterns. Jajosky and Groseclose (2004) stated that mandatory infectious

disease reporting in the United States varies from 9–99% and that active surveillance

completeness was much better than passive disease surveillance systems completeness.

They also indicated that the timeliness of active and passive were relatively the same.

This information is important because it links the system attributes of timeliness and

completeness and emphasizes the significance of evaluating them simultaneously before

drawing any conclusions about the nature of the system. I evaluated disease completeness

by assessing the ratio of incomplete to complete fields on both datasets intake forms.

Past Problems. Evaluating a system based on one attribute will highlight key aspects of the system related to that attribute only and will not address other key attributes of the system. The NEDSS has outlined standards for the evaluation of surveillance systems to improve the accuracy, completeness, and timeliness of infectious disease reporting in the United States. The CDC along with health departments across the nation is working to improve the public health infrastructure by integrating infectious disease surveillance systems with clinical information systems. In essence they are rebuilding the medical and public health infrastructure as one united system. Heisey-Grove et al. (2011) stated that for this to take place more education is needed to inform the clinical professionals about the importance of submitting this data and why it is important to collect it. Training on electronic medical records and other electronic health information systems does not occur in medical school and needs to be on the job training.

Manually submitted data from clinicians has been a source of partial, inaccurate, and untimely information movement in the past. Clinicians outreach programs are essential according to Lazarus et al. (2009) because despite considerable progress in electronic reporting many significant surveillance procedures still rely on practitioner's manual entry and submission of data. The evidence has demonstrated that the timeliness, completeness, and efficiency of data have been greatly affected by data originating from clinicians. Comprehensive, specific infectious disease case information, which goes beyond the standard intake form, is needed for public health integration, policies, and intervention planning and implementation.

In the past public health infectious surveillance system data was sent to the CDC using multiple methods (fax, email, and paper) compiled by hundreds of different surveillance programs (WV DHHR, 2014). According to Jajosky and Groseclose (2004) the United States public health system and the CDC have created a plan to improve the public health infrastructure and implementation in America. The NEDSS was developed to help states across the country to integrate their surveillance systems (like WVEDSS in WV) with the national system (WVEDSS-NBS) and the electronic health record. The NEDSS promises to improve the timeliness and completeness of infectious disease surveillance information exchange.

Previously measuring the completeness of disease reporting was a difficult task but necessary to correctly elucidate infectious disease incidence or to make infectious disease comparisons across national and international boundaries. Doyle et al. (2002) explained reasons from the literature for incomplete infectious disease reporting in the past. The reasons included safety and privacy issues, misinterpretation of the law regarding notifiable conditions, ignorance of required infectious disease to report, clueless about where and to whom to report, and inadequate punishment for not reporting. According to Sickbert-Bennett et al. (2011), the evaluation of the NEDSS in the United States is inadequate and previous studies differ on their assessment of reporting completeness. This variability in the measurement of reporting completeness makes the relationship and combination of assessment data difficult to evaluate.

Completeness of electronic data systems. Automated reporting may be the future of electronic disease surveillance systems. Effler et al. (1999) stated that laboratory

staffs are active participants in infectious disease reporting; electronic laboratory

reporting (ELR) could improve the timeliness and completeness of infectious disease

reporting. In the conventional system clinicians and other health professionals are passive

participants in infectious disease reporting. The estimated completeness of the

conventional system evaluated by Effler et al. (1999) was 38% (95% CI [37%-39%])

compared to the electronic system, which was 80% (95% CI [77%-82%]). Heisey-Grove

et al. (2011) agreed that the conventional system was always incomplete especially in the

area of vital risk prevention data fields. Doyle et al. (2002) stated that active surveillance

has proven to have a more complete case record than passive surveillance. The ELR is a

useful and timely tool in infectious disease surveillance.

Although electronic laboratory reporting (ELR) may be timely it still lacks vital

clinical information essential in determining and localizing infectious disease outbreaks.

Lazarus et al. (2009) stated that ELR may be the gold standard for disease reporting but

the clinical data found in the EHR is crucial for reporting completeness. Doyle et al.

(2002) illustrated that the complete integration of all systems as one automated systems is

the future of surveillance systems, ELR, and the EHR. Much like the NEDSS and the

CDC are doing in the U.S. restructuring the clinical system and public health systems into

one complete health system.

Summary

According to Taboy et al. (2010) the International Health Regulations (IHR,

2005) were created as a set of tools to address the challenges of the action theme to create

a sustainable world health network for international collaboration. Additionally they were

established to identify standard definitions or procedures for system attributes: timeliness and completeness. Several studies have suggested that the quality of surveillance system data is unknown because the assessment protocol for surveillance has yet to be established. The IHR (2005) took effect in 2007 and complete implementation was supposed to occur by the end of 2012 in WHO member states. This study filled the gaps in the literature by providing the most common definition and measures for timeliness and providing the meaning and a standard measure of completeness. A quantitative study design was implemented to examine the existing measures used in WVEDSS-NBS with the old system WVEDSS to establish baseline data, definitions for system attributes and the overall effect of the integration with the EHR.

The research method that is discussed in more depth in Chapter 3 will be a quasi-experimental interrupted time-series design comparing two data sets before and after a technological intervention. The evaluation of data is an integral part of surveillance systems access and usage.

Chapter 3: Research Method

In spite of the improvements to surveillance systems the assessment of the reporting of infectious disease data is imperfect and incomplete. The purpose of this study was to identify areas where more complete epidemiology and surveillance system data is missing or where improvements can be made to the system. The system attributes (timeliness and completeness) of WVEDSS-NBS were compared with the previous system, WVEDSS. All research is based on some basic principle or worldview; the post-positivist view was used in this study.

This chapter discusses the research design and rationale, connection of research design and variables to the research questions, time and resource constraints, research questions, methodology, threats to validity, and a summary. This study used the quasi-experimental, interrupted time-series design, which was analyzed using quantitative methods. To address the goals of this study, the diffusion of innovation theory was used to incorporate the multifaceted components of technological innovation with archival infectious disease surveillance data.

Research Design and Rationale

Research Variables

The key variables in this study were the cases/reports, timeliness, and completeness. The key independent variables were the system attributes of timeliness and completeness. The key dependent variables were the cases/reports of Category II infectious diseases. In order to accomplish these goals, the current WVEDSS-NBS was evaluated on its timeliness and completeness by comparing it to the previous WVEDSS.

Research Design and Connection to the Research Questions

This study used the quasi-experimental, interrupted time-series design along with the diffusion of innovation theory in order to evaluate WVEDSS and to compare it to WVEDSS-NBS on a case-by-case basis. The case study comparison was used to identify factors that may contribute to disruptions within the surveillance system. According to Harris, McGregor, Perencevich, Furuno, Zhu, Peterson, and Finkelstein (2006) and Harris et al. (2004), nonrandomized, quasi-experimental designs are frequently used when randomized control trials are not appropirate or practical. In medical informatic studies, the quasi-experimental design is intended to evaluate nonrandomized interventions before and after their implementation; which the before and after interventions are then compared to nonrandomized control groups. Harris et al. (2006) and Ho, Peterson, and Masoudi (2008) explained that interuppted time-series designs are the strongest among the quasi-experimantal designs for establishing causality. In interuppted time-series designs, a series of observations are evaluated before an intervention (the interruption) then a series of observations are evaluated after the intervention.

Time and Resource Constraints

The only time and resource constraints were in acquiring the data sets from the state epidemiologist for Category II infectious disease from the WVEDSS, the archived data, and the WVEDSS-NBS, live data. The regional epidemiologist and the state of West Virginia provided data from the current and previous version of the WVEDSS database. Other sources of information on infectious disease surveillance came from the

following websites: WHO, CDC, Ohio County Public Health Department, and West Virginia State Department of Health and Human Resources.

Research Questions

This study examined the following three research questions.

4. Is there a difference in mean reporting time of Category II reportable infectious diseases between the two data systems (WVEDSS & WVEDSS-NBS) in West Virginia?

   $H_0{}^1$ - There is no difference in mean reporting time of Category II infectious diseases between WVEDSS and WVEDSS-NBS.

   $H_a{}^1$ - There is a difference in mean reporting time of Category II infectious diseases between WVEDSS and WVEDSS-NBS.

5. Is there a difference from the 24-hour standard (time delay) of the infectious diseases under Category II of the West Virginia reportable infectious diseases for both data sources?

   $H_0{}^2$ - There is no difference from the 24-hour standard for one or both data sources.

   $H_a{}^2$ - There is a difference from the 24-hour standard for one or both data sources.

6. Are the required fields (Identifier, DOB, Current Sex, State, County, Reporting Facility Identifier, Program Area, Jurisdiction, Date Received by Public Health, Specimen Source, Date Specimen Collected, Resulted Test, Organism, Add Test Result Button) complete for both data sources?

$H_0 3$ - There is no difference in completeness of the required fields for one or both data sets.

$H_a 3$ - There is a difference in completeness of the required fields for one or both data sets.

Methodology

The scope of this paper included the evaluation and comparison of the WVEDSS and WVEDSS-NBS to improve reporting times, prevention, and interventions for Category II infectious diseases in West Virginia. Category II reportable infectious diseases were chosen because they must be reported to the LHD within 24 hours and it includes any unusual or emerging infectious disease. The diffusion of innovation theory was used to understand the scope, objectives, and system attributes (identified as timeliness and completeness). This data was used to assess the effectiveness of the local health department's policies and prevention strategies, intervention, and control measures for disease outbreaks to create more complete surveillance system data.

Population

The target population was the regions of West Virginia. This census data has been compiled over a period of four years from 2007-2010. The total population in West Virginia under surveillance in 2010 according to the U.S. Census was 1,852,994 and estimated to be 1,855,413 for 2012.

Sampling and Sampling Procedures

Sampling was non-random by convenience of data submitted for WVEDSS and WVEDSS-NBS for Category II infectious diseases in WV. I obtained permission for all

state data for Category II infectious diseases. Category II infectious diseases were chosen

for this study because they include emerging infectious diseases and any other unusual

conditions. According to Sahal, Reintjes, and Aro (2009), it is beneficial to study many

different diseases within a surveillance system to get a larger representation of how the

entire population is affected. All data reported for the above infectious diseases from

WVEDSS (2007-2010) and WVEDSS-NBS (March, 2012- March, 2014) for Category II

infectious diseases (Table 2) was included in the sample.

Power analysis to ensure appropriate sample size. Power analysis was

conducted to ensure that the sample size from available secondary data would meet a

minimum level of 95%. They following parameters were included in G*Power 3.1.7

(Faul, Erdfelder, Lang, & Buchner, 2007 and Faul, Erdfelder, Buchner, & Lang, 2009):

Test family (Exact), Statistical test (Inequality, two independent groups (Fisher's exact

test), Type of power analysis (A priori: Compute required sample size), two tails,

proportions dataset 1 (WVEDSS) = x1, proportion dataset 2 (WVEDSS-NBS) = x2, α =

0.05, Power (1- β err problem) = 0.95, and allocation ratio (N1/N2) = 2. The proportion

sizes (x1, x2) were determined from the West Virginia DHHR website on infectious

disease surveillance cases from 2007-2014. The following outputs were determined:

sample size haemophilus influenza invasive 1 = 12, group 2 = 24, total sample size = 36;

sample size hepatitis type A acute group 1 = 417, group 2 = 834, total sample size =

1251; sample size hepatitis type B group 1 = 495, group 2 = 990, total sample size =

1485; sample size pertussis group 1 = 7, group 2 = 14, total sample size = 21; sample size

rabies human group 1 = 11, group 2 = 11, total sample size = 22; sample size rubella

group 6= 100, and total sample size = 150. As there were thousands of cases available for analysis among the WVEDSS and WVEDSS-NBS datasets, there was no issue with obtaining minimum sample size.

Archival Data

The WV State Infectious Disease Epidemiologists were contacted to receive permission to work with archival data within the WVEDSS (2007-2010) and WVEDSS-NBS (March, 2012- March, 2014). Authorized users manually enter data into disease reporting forms (specific for each disease) on the Web-based server WVEDSS-NBS. Permission was obtained from the state's IRB committee and Walden's IRB committee approved a data use agreement. The state epidemiologist blinded the data and a HIPPA and consent form to use the data for research purposes was signed before data was released to the student. The data were stored on a separate hard drive after being blinded by state officials.

Operationalization of Constructs

The WVEDSS-NBS outlined the procedures for preparing a disease report for notifiable infectious diseases on the West Virginia Department of Health & Human Resources (WVDHHR) website. They provided a quick reference guide for reporting infectious diseases into WVEDSS and other resources to guide users on submitting complete and up to date information. The epidemiologist review all reportable cases and investigates each case individually to confirm the infectious disease responsible. Each disease under Category II in West Virginia has a separate intake form that was available for entry online. Once the health professional entered the initial intake information into

WVEDSS, the epidemiologist then is able to check the information and send that confirmed infectious disease to the state office, which sends it to the CDC.

Data Analysis

All data was stored in Microsoft Excel and imported into *SPSS* for statistical analysis. The two datasets were entered into an excel document and this data was reviewed to address issues in reliability, credibility, validity, and practicality of information. I assessed the dataset's reliability and credibility by evaluating the level of bias and confidence intervals, validity of collection method and practicality of the datasets was assessed using triangulation when possible and verified by the source's dependability (The Assessment Capacities Project, 2014). According to Harris, et al. (2006) statistical analysis of quasi-experimental design using interrupted time-series data can detect variations in mean and in the slope or intercept as an effect of the intervention. Descriptive statistics was performed to get an understanding of the data.

Research questions evaluated differences in mean reporting time, the 24-hour standard, and complete fields (DOB, gender, etc.) of the two data sets using independent samples *t* test. The *t* test was chosen because it was appropriate for comparison of means. The assumptions of the *t* test are bivariate independent variables, continuous dependent variable, each observation of the dependent variable was independent of the other observations of the dependent variable, and the dependent variable has a normal distribution, with the same variance, σ^2, in each group (Weaver, 2004). If some variables are not normally distributed the non-parametric test, Wilcoxon Mann-Whitney was used.

The timeliness of Category II infectious diseases was evaluated by comparing the mean reporting times and the difference from the 24-hour standard. Completeness was measured by examining the number of fields completed on the intake forms for each form submitted under Category II. A field was counted as complete if there was an entry for that field on the intake form. I counted the number of incomplete fields per form and compared that to the number of required complete fields (#incomplete/#complete). Table 3 outlined how each research question and variables were evaluated using statistics.

Table 3

Research Questions and Statistical Test

Research Question	Variables	Statistical Test
Is there a difference in mean reporting time of Category II reportable infectious diseases between the two data systems (WVEDSS & WVEDSS-NBS) in West Virginia?	Mean reporting time = time reported – time of diagnosis	t test – comparison of mean difference.
Is there a difference from the 24-hour standard (time of diagnosis to reporting to LHD) of the infectious diseases under Category II of the West Virginia reportable infectious diseases for both data sources?	The data collected from the Category II diseases (Table 2) will be coded by Group (1-5) and case number (e.g. Group 1-1 (H. influenza - case 1), Group 2-2 (hepatitis A – case 2) and the time associated in reporting will be assigned to each case. (e.g. Group 1-1 $\leq$ 1) Group 3 = hepatitis B Group 4 = pertussis Group 5 = rabies Group 6 = rubella (Report Date – Diagnosis Date $\leq$ 1 day)	t test – comparison of means.

| Are the required fields complete for both data sources? | The Required Fields will be coded alphabetically:

dentifier = A,
DOB = B,

Gender = C,
State = D,
County = E,
Reporting Facility Identifier = F,
Program Area = G,
Jurisdiction = H,
Date Received by Public Health = I,
Specimen Source = J,
Date Specimen Collected = K,
Resulted Test = L,
Organism =M,
Add Test Result Button = N
The number of incomplete fields will be compared to number of incomplete fields.

Ratio = #Incomplete fields/#Complete fields | t test – comparison of means. |

Threats to Validity

Threats to External Validity

There are four basic threats to external validity: Selection bias; constructs, methods, and confounding; the real world versus experimental world; and history effects maturation (Steckler & McLeroy, 2008). Selection bias was overcome because the two groups being compared will include all cases in West Virginia. This information was applied across the entire state by comparing the different regions within the state. To ensure the validity of constructs such as timeliness the step from disease diagnosis to disease reporting was measured and compared between the two groups. If the steps in

reporting have changed from one group to another then this was noted and an explanation provided in the literature. Maturation was discussed as a threat to internal validity.

Threats to Internal Validity

Maturation of individuals within the surveillance system does happen over time but new members of society are born and growing up within the system. The researcher was careful to make generalizations regarding snap shots in time versus over time. Quasi-experimental experimental designs have several threats to internal validity including nonrandomization, confounding variables, and regression to the mean (Harris, 2006). Other weaknesses or limitations in the study design are controlling for maturation effects and regression to the mean. Regression to the mean and maturation are both threats to internal validity and possibilities in this study. Regression to the mean was a possible threat because the intervention may or not be the reason for an improvement in surveillance. Maturation effects were a possible threat in concluding that the intervention caused an improvement in reporting. In interuppted time-series designs there are a series of observations which are interrupted by the intervention (WVEDSS-NBS) then a series of observations after the intervention. With the series of observations before and after the intervention it is easier to address and control for maturation effects and regression to the mean.

<div align="center">

Ethical Procedures

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I obtained permission from the Walden University IRB committee. A signed agreement was made with the state infectious disease office to gain access to the appropriate blinded data. All ethical concerns were addressed by receiving data that was

void names and other identifying characteristics of participants. Data were be protected

again by its anonymous nature and only included pertinent information needed to

evaluate and compare across surveillance systems. Data were stored in a separate

portable hard drive that only I had access to and will be stored for 5 years after

dissertation is complete and then destroyed. If there is a breach of confidentiality the

Walden IRB committee and this committee members will be notified immediately.

Summary

In spite of the improvements to surveillance systems the assessment of the

reporting of infectious disease data is imperfect and incomplete. In order to fulfill the

purpose of this study a quasi-experimental design was used. The WVEDSS and

WVEDSS-NBS were evaluated on a case by case basis and then compared through

system attributes. This study recognized significant differences between WVEDSS

(2007-2010) and WVEDSS-NBS (March 2012 to March 2014) to identify factors that

contributed to disruptions within the surveillance systems. Chapter 4 will discuss data

collection, descriptive statistics of the sample, results, and a summary.

Chapter 4: Results

Introduction

The purpose of this study was to identify key areas in the process from disease diagnosis to disease prevention to improve the WVEDSS-NBS. The essential elements of the Category II VPID reported within the time frame chosen were identified; they were then examined quantitatively using the quasi-experimental, interrupted time-series design along with the diffusion of innovation theory. The difference between mean reporting times and the 24-hour standard between the two data sets was evaluated for timeliness. The required fields were assessed for completeness. Secondary data were used to evaluate the following research questions and hypotheses.

1. Is there a difference in mean reporting time of Category II reportable infectious diseases between the two data systems (WVEDSS and WVEDSS-NBS) in West Virginia?

2. Is there a difference from the 24-hour standard (time delay) of the infectious diseases under Category II of the West Virginia reportable infectious diseases for both data sources?

3. Are the required fields complete for both data sources?

Chapter 4 will discuss the time frame for data collection, discrepancies in data collection from the Chapter 3 plan, baseline descriptive and demographic characteristics of the sample, challenges to implementation as described in Chapter 3, statistical assumptions, and results.

Data Collection

Data collection did not proceed as planned in Chapter 3. The time frame for data collection was 6 months from preliminary Walden IRB approval, October 28, 2014 to final approval on February 28, 2015. The time frame was extended because the West Virginia state epidemiology office made changes to the data request based on their access to the data in question. After the Walden IRB processed these changes and requests, data was made available.

The Chapter 3 plan included the following Category II Infectious Diseases: H. influenza, hepatitis A, hepatitis B, pertussis, rabies, and rubella. However, while working with the West Virginia state epidemiology office, the Category II infectious diseases they chose were vaccine preventable infectious diseases because this was the most complete data available. Therefore, the following vaccine preventable infectious diseases were obtained for data analysis: diphtheria; haemophilus influenza invasive (note: only Type B is vaccine preventable); meningococcal disease, invasive; mumps; pertussis, and poliomyelitis. There was no data on diphtheria and poliomyelitis. I used haemophilus influenza, invasive meningococcal disease, mumps, and pertussis as Category II Infectious Diseases.

Originally, the required fields for Research Question 3 were chosen from the WVEDSS user guide. However, the WV state epidemiology office changed the required fields to the following based on their required fields: patient unique identifier, date of diagnosis (and date of laboratory report), date of report to public health (also known as PHC add time), date of birth, gender, county, state, date of symptom onset, vaccination

history (which can mean number of doses or date of vaccination), specimen source (if specimen submission is required), and the date of specimen collection (if specimen submission is required). The data was cleaned by the WV state epidemiology office and summarized by the researcher before leaving the WV state epidemiology office. Power analysis was performed for meningococcal disease and mumps to ensure sufficient sample size was obtained (p. 107).

Descriptive Statistics of the Sample

The sample included all individuals within both data sets for the entire population of West Virginia. The sample was representative of all counties and regions of West Virginia. Therefore the sample was representative of the population of the state of West Virginia.

Table 4 details the frequency of cases by vaccine preventable infectious disease (VPID), including valid cases and missing or invalid cases for WVEDSS (2009-2011) and WVEDSS-NBS (2012-2013). The majority of cases were pertusis, followed by H. influenza, meningococcal disease, and mumps.

Table 4

Frequency of cases by vaccine preventable disease (n = *714)*

	RQ1 & RQ2				RQ3	
Vaccine Preventable Infectious Diseases	Valid cases 2009-2011	Missing or invalid cases 2009-2011	Valid cases 2012-2013	Missing or invalid cases 2012-2013	All available cases 2009-2011	All available cases 2012-2013
H. influenza	101	21	92	0	122	92

meningococcal disease	20	3	9	0	23	9
mumps	8	0	6	0	8	6
pertussis	288	45	116	5	333	121
Total cases	417	69	223	5	486	228

Table 5 details the geographic description of cases by vaccine preventable

infectious disease (VPID), including cases by Region for WVEDSS (2009-2011) and

WVEDSS-NBS (2012-2013). The state is divided up into regions geographically and

each region is assigned to a Regional Epidemiologist who oversees these areas. The

majority of cases were in Region 2, 3, 5 and 7.

Table 5

*Geographic description of cases by region (*n = 905)

	Regions							
Vaccine Preventable Infectious Diseases	1	2	3	4	5	6	7	8
H. influenza								
2009-2011	21	27	22	11	13	9	7	12
2012-2013	12	15	28	10	6	5	7	6
meningococcal disease								
2009-2011	1	3	2	5	4	2	5	1
2012-2013	0	0	4	0	1	1	1	2
mumps								
2009-2011	0	2	3	0	0	2	1	0
2012-2013	1	1	0	0	0	2	2	0
pertussis								
2009-2011	29	17	41	35	126	12	46	27
2012-2103	32	14	29	14	14	3	5	6
Total Cases	96	178	147	75	164	54	128	63

Results

Research Question 1

An independent-samples, *t* test was run to determine if there were differences in mean reporting times between 101 H. influenza WVEDSS cases and 92 WVEDSS-NBS H. Influenza cases. The mean reporting times (days) were shorter for WVEDSS H. Influenza cases (M = 5.19, *S.D.* = 5.72) than for WVEDSS-NBS H. Influenza cases (*M* = 17.22, *S.D.* = 19.43). The assumption of homogeneity of variances was violated, as assessed by Levene's test for equality of variances (p < .001). Equal variances were not assumed and there was a statistically significant difference in mean reporting times for H. influenza between WVEDSS and WVEDSS-NBS, *t* (105.338) = 5.716, p < .05. Therefore, we can reject the null hypothesis and accept the alternative hypothesis.

An independent-samples, *t* test was run to determine if there were differences in mean reporting times between 20 meningococcal disease WVEDSS cases and 9 WVEDSS-NBS meningococcal disease cases. The mean reporting times were shorter for WVEDSS meningococcal disease cases (*M* = 1.55, *S.D.* = 2.44) than for WVEDSS-NBS meningococcal disease cases (*M* = 8.00, *S.D.* = 6.97). The assumption of homogeneity of variances was violated, as assessed by Levene's test for equality of variances (p < .001). Equal variances were not assumed and there was a statistically significant difference in mean reporting times for meningococcal disease between WVEDSS and WVEDSS-NBS, *t* (8.895) = 2.705, p = .024. Therefore, we can reject the null hypothesis and accept the alternative hypothesis.

An independent-samples, *t* test was run to determine if there were differences in mean reporting times between 8 mumps WVEDSS cases and 6 WVEDSS-NBS mumps cases. The mean reporting times were shorter for WVEDSS mumps cases (*M* = 3.88, *S.D.* = 2.90) than for WVEDSS-NBS mumps cases (*M* = 3.83, *S.D.* = 4.92). There was homogeneity of variances for mean reporting times for WVEDSS and WVEDSS-NBS, as assessed by Levene's test for equality of variances (p = .077). Equal variances were assumed and there was not a statistically significant difference in mean reporting times for mumps between WVEDSS and WVEDSS-NBS, *t* (12) = 0.020, p = 0.99. Therefore, we can reject the alternative hypothesis and fail to reject the null hypothesis.

An independent-samples, *t* test was run to determine if there were differences in mean reporting times between 289 pertussis WVEDSS cases and 116 WVEDSS-NBS pertussis cases. The mean reporting times were shorter for WVEDSS pertussis cases (*M* = 5.01, *S.D.* = 22.05) than for WVEDSS-NBS pertussis cases (*M* = 26.01, *S.D.* = 37.44). The assumption of homogeneity of variances was violated, as assessed by Levene's test for equality of variances (p < .001). Equal variances were not assumed and there was a statistically significant difference in mean reporting times for pertussis between WVEDSS and WVEDSS-NBS, *t* (148.096) = 5.659, p < .05. Therefore, we can reject the null hypothesis and accept the alternative hypothesis.

Table 6 details the mean reporting time (MRT) of cases by vaccine preventable infectious disease (VPID), including the number of cases before and after the intervention, *t* value, dF, and the P values for WVEDSS (2009-2011) and WVEDSS-NBS (2012-2013). The majority of MRT for WVEDSS cases were shorter then MRT for

WVEDSS-NBS cases. Meaning that timeliness was better before the intervention of the

Web-based server.

Table 6

*Cases by mean reporting time (*n *= 713)*

RQ 1							
Vaccine Preventable Infectious Diseases	WVEDSS Cases 2009-2011	WVEDSS-NBS Cases 2012-2013	MRT WVEDSS 09-11	MRT WVEDSS-NBS 12-13	*t* value	dF	P value
H. influenza	101	92	M=5.19, S.D.=5.72	M=17.22, S.D.=19.43	5.716	105.338	< .05
meningococcal disease	20	9	M=1.55, S.D.=2.44	M=8.00, S.D.=6.97	2.705	8.895	.024
mumps	8	6	M=3.88, S.D.=2.90	M=3.83, S.D.=4.92	0.020	12	0.99
pertussis	289	116	M=5.01, S.D.=22.05	M=26.01, S.D.=37.44	5.659	148.096	< .05

Research Question 2

An independent-samples, *t* test was run to determine if there were differences in

24-hour standard reporting times between 101 H. influenza WVEDSS cases and 92

WVEDSS-NBS H. influenza cases. The 24-hour standard reporting times were shorter

for WVEDSS H. influenza cases (*M* = 1.65, *S.D.* = 0.48) than for WVEDSS-NBS H.

influenza cases (*M* = 1.96, *S.D.* = 0.21). The assumption of homogeneity of variances

was violated, as assessed by Levene's test for equality of variances (p < .001). Equal

variances were not assumed and there was a statistically significant difference in mean

reporting times for H. influenza between WVEDSS and WVEDSS-NBS, *t* (138.249) =

5.809, p < .05. Therefore, we can reject the null hypothesis and accept the alternative

hypothesis.

Independent-samples, *t* test was run to determine if there were differences in 24-hour standard reporting times between 20 meningococcal disease WVEDSS cases and 9 WVEDSS-NBS meningococcal disease cases. The 24-hour standard reporting times were shorter for WVEDSS meningococcal disease cases (*M* = 1.35, *S.D.* = 0.48) than for WVEDSS-NBS meningococcal disease cases (*M* = 2.00, *S.D.* = 0). The assumption of homogeneity of variances was violated, as assessed by Levene's test for equality of variances (p < .001). Equal variances were not assumed and there was a statistically significant difference in the 24-hour standard reporting times for meningococcal disease between WVEDSS and WVEDSS-NBS, *t* (19.000) = 5.940, p < .05. Therefore, we can reject the null hypothesis and accept the alternative hypothesis.

Independent-samples, *t* test was run to determine if there were differences in 24-hour standard reporting times between 8 mumps WVEDSS cases and 6 WVEDSS-NBS mumps cases. The 24-hour standard reporting times were shorter for WVEDSS mumps cases (*M* = 1.88, *S.D.* = 0.35) than for WVEDSS-NBS mumps cases (*M* =1.50, *S.D.* = 0.55). The assumption of homogeneity of variances was violated, as assessed by Levene's test for equality of variances (p = .024). Equal variances were not assumed and there was a statistically significant difference in the 24-hour standard reporting times for mumps between WVEDSS and WVEDSS-NBS, *t* (8.052) = 1.464, p = .181. Therefore, we can reject the null hypothesis and accept the alternative hypothesis.

Independent-samples, *t* test was run to determine if there were differences in 24-hour standard reporting times between 288 pertussis WVEDSS cases and 116 WVEDSS-NBS pertussis cases. The 24-hour standard reporting times were shorter for WVEDSS

pertussis cases (M = 1.52, $S.D.$ = 0.50) than for WVEDSS-NBS pertussis cases (M =

1.88, $S.D.$ = 0.33). The assumption of homogeneity of variances was violated, as assessed

by Levene's test for equality of variances ($p < .001$). Equal variances were not assumed

and there was a statistically significant difference in the 24-hour standard reporting times

for pertussis between WVEDSS and WVEDSS-NBS, t (319.902) = 8.387, $p < .05$.

Therefore, we can reject the null hypothesis and accept the alternative hypothesis.

Table 7 details the 24-hour standard reporting time of cases by vaccine

preventable infectious disease (VPID), including the number of cases before and after the

intervention, t value, dF, and the P values for WVEDSS (2009-2011) and WVEDSS-NBS

(2012-2013). None of the cases before or after the intervention meet the 24-hour standard

reporting times for Category II Infectious Diseases. In fact, the times actually increased

after the intervention of the Web-based server.

Table 7

*Cases by 24-hour standard reporting time (*n = 712)

RQ 2							
Vaccine Preventable Infectious Diseases	WVEDSS Cases 2009-2011	WVEDSS-NBS Cases 2012-2013	24-hour standard WVEDSS 09-11	24-hour standard WVEDSS-NBS 12-13	t value	dF	P value
H. influenza	101	92	M=1.65, S.D.=0.48	M=1.96, S.D.=0.21	5.809	138.249	< .05
meningococcal disease	20	9	M=1.35, S.D.=0.48	M=2.00, S.D.=0.00	5.940	19.000	< .05
mumps	8	6	M=1.88, S.D.=0.35	M=1.50, S.D.=0.55	1.464	8.052	.181
pertussis	288	116	M=1.52, S.D.=0.50	M=1.88, S.D.=0.33	8.387	319.902	< .05

Research Question 3

An independent-samples, t test was run to determine if there were differences in Incomplete Fields/Complete Fields Ratio between 122 H. influenza WVEDSS cases and 92 WVEDSS-NBS H. influenza cases. The Incomplete/Complete Ratio was less complete for WVEDSS H. influenza cases ($M = 0.32$, $S.D. = 0.24$) than for WVEDSS-NBS H. influenza cases ($M = 0.07$, $S.D. = 0.07$). The assumption of homogeneity of variances was violated, as assessed by Levene's test for equality of variances ($p < .001$). Equal variances were not assumed and there was a statistically significant difference in the Incomplete to Complete Ratio for H. influenza between WVEDSS and WVEDSS-NBS, t (147.088) = 11.221, p < .05. Therefore, we can reject the null hypothesis and accept the alternative hypothesis.

Independent-samples, t test was run to determine if there were differences in Incomplete Fields/Complete Fields Ratio between 20 meningococcal disease WVEDSS cases and 9 WVEDSS-NBS meningococcal disease cases. The Incomplete/Complete Ratio was less complete for WVEDSS meningococcal disease cases ($M = 0.22$, $S.D. = 0.05$) than for WVEDSS-NBS meningococcal disease cases ($M = 0.02$, $S.D. = 0.07$). There was homogeneity of variances for the 24-hour standard reporting time for WVEDSS and WVEDSS-NBS, as assessed by Levene's test for equality of variances (p = .228). Equal variances were assumed and there was not a statistically significant difference in the Incomplete to Complete Ratio for meningococcal disease between WVEDSS and WVEDSS-NBS, t (30) = 8.668, p > .05. Therefore, we can reject the alternative hypothesis and fail to reject the null hypothesis.

Independent-samples, *t* test was run to determine if there were differences in Incomplete Fields/Complete Fields Ratio between 8 mumps WVEDSS cases and 6 WVEDSS-NBS mumps cases. The Incomplete/Complete Ratio is less complete for WVEDSS mumps cases (*M* = 0.13, *S.D.* = 0.57) than for WVEDSS-NBS mumps cases (*M* = 0.10, *S.D.* = 0.00). The assumption of homogeneity of variances was violated, as assessed by Levene's test for equality of variances (p = .002). Equal variances were not assumed and there was a statistically significant difference in the Incomplete to Complete Ratio for mumps between WVEDSS and WVEDSS-NBS, *t* (7.000) = 1.528, p = .170. Therefore, we can reject the null hypothesis and accept the alternative hypothesis.

Independent-samples, *t* test was run to determine if there were differences in Incomplete Fields/Complete Fields Ratio between 333 pertussis WVEDSS cases and 121 WVEDSS-NBS pertussis cases. The Incomplete/Complete Ratio was less complete for WVEDSS pertussis cases (*M* = 0.26. *S.D.* = 0.11) than for WVEDSS-NBS pertussis cases (*M* = 0.03, *S.D.* = 0.08). The assumption of homogeneity of variances was violated, as assessed by Levene's test for equality of variances (p = .001). Equal variances were not assumed and there was a statistically significant difference in the Incomplete to Complete Ratio for pertussis between WVEDSS and WVEDSS-NBS, *t* (284.892) = 24.544, p < .05. Therefore, we can reject the null hypothesis and accept the alternative hypothesis.

Table 8 details the completeness (incomplete/complete) of cases by vaccine preventable infectious disease (VPID), including the number of cases before and after the intervention, *t* value, dF, and the P values for WVEDSS (2009-2011) and WVEDSS-NBS

(2012-2013). All WVEDSS-NBS cases were less complete after the intervention of the

Web-based server.

Table 8

*Cases by completeness ratio (*n *= 712)*

RQ 3							
Vaccine Preventable Infectious Diseases	WVEDSS Cases 2009-2011	WVEDSS-NBS Cases 2012-2013	24-hour standard WVEDSS 09-11	24-hour standard WVEDSS-NBS 12-13	*t* value	dF	P value
H. influenza	122	92	M=0.32, S.D.=0.24	M=0.07, S.D.=0.07	11.221	147.088	< .05
meningococcal disease	20	9	M=0.22, S.D.=0.05	M=0.02, S.D.=0.07	8.668	30	<
mumps	8	6	M=0.13, S.D.=0.57	M=0.10, S.D.=0.00	1.528	7.000	.05
pertussis	333	121	M=0.26, S.D.=0.11	M=0.03, S.D.=0.08	24.544	284.892	.170 < .05

Summary

There was a statistically significant difference between means (p < .05) for all

research questions and vaccine preventable infectious diseases except for mumps mean

reporting time for Research Question 1. For this question, there was not a statistically

significant difference between means (p > .05), and therefore, we fail to reject the null

hypothesis. For research question 1, all the vaccine preventable diseases mean reporting

times were longer after the intervention. There was a statistically significant difference

between means (p < .05) for all research questions and vaccine preventable infectious

diseases except for mumps mean reporting time for Research Question 2. For research

question 2, three vaccine preventable infectious diseases were longer after the

intervention and mumps were longer before the intervention. There was a statistically significant difference between means ($p < .05$) for all research questions and vaccine preventable infectious diseases except for meningococcal disease for Research Question 3. Therefore, for meningococcal disease we can reject the alternative hypothesis and fail to reject the null hypothesis. All the vaccine preventable diseases for Research Question 3 were less complete after intervention.

1. Is there a difference in mean reporting time of Category II reportable infectious diseases between the two data systems (WVEDSS and WVEDSS-NBS) in West Virginia?

    a. H. influenza

    There was a statistically significant difference between means ($p < .05$), and therefore, we can reject the null hypothesis and accept the alternative hypothesis.

    b. meningococcal disease

    There was a statistically significant difference between means ($p < .05$), and therefore, we can reject the null hypothesis and accept the alternative hypothesis.

    c. mumps

    There was not a statistically significant difference between means ($p > .05$), and therefore, we can reject the alternative hypothesis and fail to reject the null hypothesis.

    d. pertussis

There was a statistically significant difference between means ($p < .05$), and therefore, we can reject the null hypothesis and accept the alternative hypothesis.

2. Is there a difference from the 24-hour standard (time delay) of the infectious diseases under Category II of the West Virginia reportable infectious diseases for both data sources?

    a. H. influenza

There was a statistically significant difference between means ($p < .05$), and therefore, we can reject the null hypothesis and accept the alternative hypothesis.

    b. meningococcal disease

There was a statistically significant difference between means ($p < .05$), and therefore, we can reject the null hypothesis and accept the alternative hypothesis.

    c. mumps

There was a statistically significant difference between means ($p < .05$), and therefore, we can reject the null hypothesis and accept the alternative hypothesis.

    d. pertussis

There was a statistically significant difference between means ($p < .05$), and therefore, we can reject the null hypothesis and accept the alternative hypothesis.

3. Are the required fields (identifier, dob, gender, state, county, reporting facility identifier, program area, jurisdiction, date received by public health, specimen source, date specimen collected, resulted test, organism, add test result button) complete for both data sources?

    a. H. influenza

    There was a statistically significant difference between means ($p < .05$), and therefore, we can reject the null hypothesis and accept the alternative hypothesis.

    b. meningococcal disease

    There was not a statistically significant difference between means ($p > .05$), and therefore, we can reject the alternative hypothesis and fail to reject the null hypothesis.

    c. mumps

    There was a statistically significant difference between means ($p < .05$), and therefore, we can reject the null hypothesis and accept the alternative hypothesis.

    d. pertussis

    There was a statistically significant difference between means ($p < .05$), and therefore, we can reject the null hypothesis and accept the alternative hypothesis.

Chapter 5 will discuss the interpretations, limitations, recommendations, and implications of these findings.

Chapter 5: Discussion, Conclusions, and Recommendations

Introduction

The purpose of this study was to pinpoint crucial steps in the surveillance process from disease diagnosis to disease prevention (regional epidemiologists report to state epidemiology office) to improve the evaluation of the timeliness and completeness of the surveillance system. A quasi-experimental, interrupted time-series design, with non-random assignment of groups was used to compare the infectious disease cases that were manually entered into WVEDSS between 2009 and 2012 and those that were entered into the newly developed WVEDSS-NBS, which was established on Web-based server in March 2012. In this study, data were collected from March 2012 through December 2013. Timeliness was assessed by the difference in mean reporting times (Report date – Diagnosis Date) and the 24-hour standard reporting time (Report date – Diagnosis date $\leq$ 1), using the two independent samples t test. The required fields (patient unique identifier, date of diagnosis, and date of laboratory report), date of report to public health (also known as PHC add time), date of birth, gender, county, state, date of symptom onset, vaccination history (which can mean number of doses or date of vaccination), specimen source (if specimen submission is required), and the date of specimen collection (if specimen submission is required) were evaluated for completeness by comparing the incomplete fields/complete fields ratio using the two independent samples t test. Four Vaccine-Preventable Category II Infectious Diseases were used: H. influenza, meningococcal disease, mumps, and pertussis.

Summary of Key Findings

There was a statistically significant difference (p < 0.5) between mean reporting times of Category II vaccine-preventable infectious diseases between the two data systems (WVEDSS and WVEDSS-NBS) in West Virginia. The study rejected the null hypothesis and accepted the alternative hypothesis for H. influenza, meningococcal disease, and pertussis. For mumps we failed to reject the null hypothesis. There was a difference from the 24-hour standard of the vaccine preventable infectious diseases under Category II VPID of the West Virginia reportable infectious diseases for both data sources. We rejected the null hypothesis and accepted the alternative hypothesis for H. Influenza, meningococcal disease, mumps, and pertussis. The required fields were complete for both data sources. We rejected the null hypothesis and accepted the alternative hypothesis for H. influenza, mumps, and pertussis. The study failed to reject the null hypothesis for meningococcal disease.

Interpretation of the Findings

The findings disconfirm that timeliness of reporting to the public health department would improve after the intervention. The mean reporting time for all infectious diseases increased after the intervention and in some cases the mean reporting times doubled and tripled. The majority of cases from both datasets did not meet the 24-hour standard for reporting Category II infectious diseases. This indicates that the cases from before and after the intervention were not timely.

These findings confirm that the ratio of incomplete to complete fields improved after the intervention of a Web-based server. All fields were found to be less complete

after the intervention. This means that the completeness improved after switching to the Web-based server, WVEDSS-NBS, in March of 2012.

This data extends knowledge in the discipline. which is illustrated by comparing the data with what was found in the peer-reviewed literature described in Chapter 2. Heisey-Grove et al. (2011) agreed that the conventional system was always incomplete especially in the area of vital risk prevention data fields. Doyle et al.(2002) stated that active surveillance has proven to have a more complete case record than passive surveillance. According to Sickbert-Bennett et al. (2011) disease completeness varied not only by disease in their retrospective cohort study but also by healthcare system. In a study performed by Effler et al. (1999) they found the electronic format to be far superior to the conventional paper or manual format. However, the results of this study indicate that both data systems had complete reporting with data being more complete after the intervention.

Timeliness is a key element and should be used as a consistent evaluation and measurement tool of surveillance systems (Yoo et al., 2009). Jajosky and Groseclose (2004) stated that timeliness is a quantitative indicator of the surveillance systems reliability and validity and is used to determine any time delays between operational phases. Reijn et al. (2011) stated that infectious disease surveillance systems (IDSS) should be regularly evaluated for each step in the system for each disease within the system. The WV state epidemiology office can use the data from this study on timeliness to evaluate where the time lag exists in the process from disease diagnosis to disease reporting.

Reijn et al. found that the proportion of infectious diseases reported to the LHD varied by disease. Lazarus et al. (2009) stated that despite all of the improvements made in surveillance systems across the country some important internal mechanisms still depend on people. Even though we have come a long way and improved several qualitative and quantitative aspects of infectious disease reporting training and integrating primary stakeholders within the system remains essential. Nicolay et al. (2010) stated that research has proven that implementation of electronic reporting will decrease timeliness and increase the completeness of surveillance statistics. The literature and the results of this study indicate that implementing electronic reporting may not be the reason that the reporting for vaccine preventable infectious diseases was not timely. An error may be occurring on the human side of the reporting process.

Incorporating an electronic evaluation system for WVEDSS-NBS can help epidemiologists' evaluate the system for timeliness. Madoff, Fisman, and Kass-Hout (2011) concluded that incorporating the Internet into surveillance reporting would improve timeliness, sensitivity, and completeness of surveillance system data. Computerized technology allows for the assessment of timeliness to be completed routinely on each step in the public health surveillance system. Although completeness improved in this study timeliness of the system for Category II VPID was longer after the intervention.

Electronic reporting, electronic health records, and electronic laboratory reporting have the potential to improve all system attributes. Wurtz and Cameron (2005) illustrated that despite these obvious improvements in infectious disease surveillance, physicians

must still do their part in submitting a comprehensive and well-timed case report. When analyzing the data it was discovered that although the completeness of incomplete/complete fields improved after the intervention timeliness actually increased. One reason for this may have been that the actually intervention, going to a Web-based server, may not have been communicated to the stakeholders. The physicians and other health professionals that diagnose patients and record the diagnosis date may not have been aware that a change was taken place in reporting. A qualitative study surveying this group of stakeholders could be done in the future to examine this line of reasoning.

On the other side, the WV state epidemiologist office assigns epidemiologists to specific regions in the state. The response of these individuals on a questionnaire for report date fields may shed some light on the increased timeliness for infectious diseases in Category II. These regional epidemiologists are the leading innovators and adopters in their field. The process of diffusion is first identified as an informal planning process that is followed by a formal structured procedure driven by social networking within the organization.

It may be that during the implementation of the WVEDSS-NBS the technological difficulties surpassed the epidemiologist's ability to report cases to the state office in a timely manner. Perhaps a more formal process of dissemination should have been implemented so that essential stakeholders were prepared for implementing data on time. Researchers contesting the paradigms of diffusion research have illustrated that those new technologies previously integrated using only simple diffusion should have gone through a more formal dissemination process (Greenhalgh et al., 2004). For instance,

Rogers (2003) suggested using the technology cluster model for technological

innovations that include more than one technology within the system. The WV state

epidemiology office will need to consider all aspects of the innovation and coordinate a

strategy for implementation that includes all the stakeholders in the system.

One area that was not covered in this study was the time from disease onset to

diagnosis. Yoo et al. **(**2009) stated that timely reporting is effected most by the interval

from disease inception to diagnosis. As electronic disease reporting improves the

evaluation of this step in the surveillance process can be incorporated into the

surveillance process. Yoo et al. (2009) stated that previous research has indicated that the

surveillance steps of infectious disease reporting vary from system to system and from

one infectious disease to another. In this study all Category II VPID were measured for

timeliness in the same manner.

The most important aspect in evaluating the timeliness of a surveillance system is

to establish a standard definition. Timeliness was defined in terms of mean reporting time

and the 24-hour standard. Jajosky and Groseclose (2004) collected data on the National

Notifiable Disease Surveillance System (NNDSS) and suggested using the earliest known

date of disease onset as the starting point for the measurement of timeliness, varying by

disease. The comparison of timeliness from paper to a Web-based server illustrated key

factors causing delays in the timely reporting of infectious diseases. These key factors

may assist epidemiologists in improving the timeliness of the WVEDSS-NBS.

Results of the Colorado Electronic Disease Reporting System (CEDRS) prompted

training of disease investigators to fill out intake forms completely with the hope that

future evaluations will yield improved timeliness and more complete data. Vogt, Spittle,

Cronquist, and Patnaik (2006) illustrated how a LHD could evaluate the CEDRS for

timeliness and completeness. Timeliness was defined as the time period between

"specimen collection date" and "report date" for each patient and they compared them

through distribution of means. In this study I did not have a problem with the

completeness of the "diagnosis date" or "report date". However, when the WV State

Epidemiologist Office may run into problems here when they evaluate the entire

surveillance system to establish their baseline.

Some of the most common reasons for delayed reporting are patient's recognition

of symptoms, communication issues, missing data, incorrect data, disease specific

incubation periods, and laboratory-related delays. Reijn et al. (2011) illustrated that

electronic laboratory reporting (ELR) has improved the timeliness in some nations and

concluded that an international standardization method for measuring timeliness be

supported. The WVEDSS-NBS has not implemented ELR within its system. The results

indicated that some fields had incorrect data and missing data, which may be resolved by

instilling a warning message within the data entry feature.

The evaluation of data from surveillance systems for timeliness varies because

each study examines different diseases and measures of timeliness**.** Yoo et al. **(**2009)

evaluated over 40,000 infectious disease records from an electronic system that collected

data in 2000. They found that the greatest time delay stemmed from the delay in

diagnosis from the clinical side and from the excess time spent on lengthy laboratory

tests. They found that the total time from disease onset to reporting to the local health

department ranged from six to twenty days and varied from one disease to another. In this study the total time from disease onset to reporting to the state health department ranged from one to 366 days.

Most studies found that electronic reporting resulted in an improvement in all system attributes especially timeliness. Effler et al. (1999) compared an electronic reporting system to the previous conventional system and found a 2.3 fold increase in infectious disease reporting with the new system. The CDC (2005) stated that in New Jersey, which has a Web-based server like WVEDSS-NBS that they implemented in 2001, the number of cases reported from 2002 to 2004 doubled and that the average days for case reporting dropped from 28 days in 2002 to 3-4 days in 2004. In this study the mean reporting times increased after the switch to a Web-based server and the 24-hour standard reporting times were not met.

Even though most states have adapted to national guidelines by using the NEDSS equivalent software to upgrade their paper based systems to electronic or Web-based servers many problems still exist in establishing standards for information exchange. As the interface between clinicians and public health officials improve the data becomes more streamlined and universal. In the past health data was faxed, mailed, or emailed to the local or regional epidemiologist to be entered into the state system. The epidemiologist entered this data into the system sometimes weeks after the information had been received or the notifiable condition had transpired. The CDC (2005) reported that many (10-85%) of these cases never made it to the national level and previously states used over 100 different systems to send reports to the CDC. A review of the

literature has revealed that many definitions and standards of measurement for timeliness have been used in the past. I used the CDC's recommendations for the measurement for timeliness and the incomplete/complete ratio for the completeness to prepare a foundation for future measurements on WVEDSS-NBS. West Virginia may find that they need to implement ELR to improve the timeliness of WVEDSS-NBS.

Electronic disease reporting has become the standard by which all other reporting is to be compared. According to several researchers (Reijn et al., 2011; Yoo et al., 2009; Nicolay et al., 2010; Doyle et al., 2002) electronic disease reporting has improved the timeliness of infectious disease outbreak notification. In addition these authors and the CDC (2005) recommend that states integrate ELR into their existing systems to improve timeliness because laboratory tests are used to confirm most infectious diseases, labs are important members of the system, and laboratories can be used for other aspects of public health surveillance.

As West Virginia learns more about electronic disease reporting process and builds the state surveillance infrastructure to comply with national standards, the evaluation process will improve. Nicolay et al. (2010) stated that research has proven that implementation of electronic reporting will decrease timeliness and increase the completeness of surveillance statistics. Electronic data and evaluation methods at the local, state, national, and international level allows for more complete assessment of infectious diseases and their spread around the globe.

Completeness was measured by the ratio of incomplete fields to complete fields of data items required by the West Virginia state epidemiology office. According to

Doyle et al. (2002) infectious disease reporting completeness identifies those notifiable cases that have been reported to the local health department. The completeness of intake forms is crucial to the proper accounting of cases of infectious disease within a population. Without this vital information to guide the epidemiologist and other public health officials in the diagnosis of notifiable infectious diseases, outbreaks may be missed and epidemics may occur. Although this study indicated an improvement in completeness overall there is room for WVEDSS-NBS completeness to improve.

It is important to evaluate infectious disease completeness by each disease under a specific Category. Jajosky and Groseclose (2004) stated that mandatory infectious disease reporting in the U.S. varies from 9% to 99% and that active surveillance completeness was much better than passive disease surveillance systems completeness. The NEDSS has outlined standards for the evaluation of surveillance systems to improve the accuracy, completeness, and timeliness of infectious disease reporting in the United States. I evaluated disease completeness by assessing the ratio of incomplete to complete fields by each infectious disease under a specific Category on both datasets intake forms.

The NEDSS recommends that each state follow guidelines for submitting infectious disease data. Clinicians in West Virginia may need training on the new format of infectious disease reporting in order to improve timeliness and completeness. Clinicians outreach programs are essential according to Lazarus et al. (2009) because despite considerable progress in electronic reporting many significant surveillance procedures still rely on practitioner's manual entry and submission of data. Training

health professionals on WVEDSS-NBS and other aspects of electronic disease reporting can improve the timeliness and completeness of the system.

In the past the measurement and evaluation of disease completeness was a difficult task. Doyle et al. (2002) explained reasons from the literature for incomplete infectious disease reporting in the past. The reasons included safety and privacy issues, misinterpretation of the law regarding notifiable conditions, ignorance of required infectious disease to report, clueless about where and to whom to report, and inadequate punishment for not reporting. Even at the national level the evaluation of the NEDSS is incomplete. According to Sickbert-Bennett et al. (2011) the evaluation of the NEDSS in the United States is inadequate and previous studies differ on their assessment of reporting completeness. I evaluated disease completeness in this study using the incomplete/complete data fields across diseases in Category II VPID. Doyle et al. (2002) illustrated that the complete integration of all systems as one automated systems is the future of surveillance systems, ELR, and the EHR. The NEDSS and the CDC are restructuring the clinical system and public health systems into one complete health system in the United States. West Virginia has begun infrastructure building and that type of work does not happen over night.

Limitations of the Study

Permission was obtained to use all the cases under Category II Vaccine Preventable Infectious Diseases from the state of West Virginia epidemiology office. This eliminated the limitation from using data from two different time periods, sample data and reduced selection bias, statistical analysis and Levene's test also helped in

controlling for bias, maturation effects, and regression to the mean. Regression to the

mean and maturation are both threats to internal validity and possibilities in this study.

Regression to the mean is a possible threat because the intervention may or not be the

reason for an improvement in surveillance. Maturation effects are a possible threat in

concluding that the intervention caused an improvement in reporting.

Power analysis was conducted to ensure that the sample size from available

secondary data met a minimum level of 95%. The following parameters were included in

G*Power 3.1.7 (Faul, Erdfelder, Lang, & Buchner, 2007; Faul, Erdfelder, Buchner, &

Lang, 2009): Test family (Exact), Statistical test (Inequality, two independent groups

(Fisher's exact test), Type of power analysis (A priori: Compute required sample size),

two tails, proportions dataset 1 (WVEDSS) = x1, proportion dataset 2 (WVEDSS-NBS)

= x2, α = 0.05, Power (1- β err problem) = 0.95, and allocation ratio (N1/N2) = 2. The

proportion sizes (x1, x2) were determined from the West Virginia DHHR website on

infectious disease surveillance cases from 2007-2014. The following outputs were

determined: sample size haemophilus influenza invasive 1 = 12, group 2 = 24, total

sample size = 36; sample size meningococcal disease group 1 = 1, group 2 = 3, total

sample size = 4; sample size mumps group 1 = 3, group 2 = 5, total sample size = 8;

sample size pertussis group 1 = 21, group 2 = 41, total sample size = 62. Based on these

calculations from G*Power 3.1.7 the sample size was efficient for all VPID.

Recommendations

Recommendations for further research are grounded in the strengths and

limitations of the current study as well as the literature reviewed in chapter 2.

Recommendations for further research are based on the results of this study. A formal process for including stakeholders and healthcare professionals should be implemented to ensure proper adherence to infectious disease reporting. A survey of these individuals and the regional epidemiologists may shed light into why the timeliness of vaccine preventable infectious diseases actually increased after the intervention.

Recommendations for action are based on the results of this study and the literature. An evaluation of all infectious diseases in all categories should be performed to better understand the timeliness and completeness of the intervention. Electronic reminders should be sent to regional epidemiologists and healthcare professionals to reinforce timely reporting according to categories. A plan for action may include updating the WVEDSS-NBS to the next level, the National Electronic Disease Surveillance System (NEDSS) To do so, the WV Department of Health and Human Services would need to incorporate ELR into its current surveillance system. Another plan of action is to introduce community awareness programs that will engage the health professionals in the system.

Areas identified for improvement in regard to the diffusion of innovation theory were identified at the macro level of organization. At the micro level the WV state epidemiology office's level of communication and social networking were well organized. However, areas in dissemination at the macro level to public health officials and healthcare professionals throughout the state needs to be refined and reworked. Areas they need to address are stakeholder communication, social networking, and implementation of Rogers (2003) technology cluster model for technology innovations.

A SWOT analysis (Attaway, Jacobsen, Falconer, Manca, & Waters, 2014) of the tasks

needed for a macro level dissemination would identify their current strengths,

weaknesses, opportunities, and threats (SWOT) and all potential improvements that need

to be made. Furthermore, incorporating Geographical Information Systems (GIS)

(Busgeeth, 2004 & Ruiz, Tedesco, & McTighe, 2004) into outbreak management would

allow visualization of the data to aid in policy creation and outbreak preparedness.

Implications

The results of this study provide health departments with the information and

tools to address the fundamental factors that help public health officials assess the

population's health. Integration of the EHR with WVEDSS-NBS allows health

professionals to have instant access to the most recent health data allowing local health

departments to effect social change. We want to reduce morbidity/mortality and one way

to do that is through improving reporting times so that we can better control disease

outbreaks. Therefore we need timely and complete forms to work appropriately. Colbert

and Harrison (2011) stated that to accomplish these tasks more complete epidemiological

and surveillance data must be acquired to understand the complex matrix of health

disparities. A more complete evaluation of surveillance system data needs done by West

Virginia to identify the incidence of Category II infectious diseases and assess the

effectiveness of the LHD by examining, comparing, and evaluating the old WVEDSS and

the newly developed WVEDSS-NBS for these system attributes (identified as timeliness

and completeness). I examined the environment in which the surveillance systems

operated (by utilizing the diffusion of innovation theory) in order to identify areas for improvement and sustain social change.

Implications for social change begin at the individual level when one adopter understands that their actions can bring about the changes needed. It takes one epidemiologist to see that decreasing the timeliness of WVEDSS-NBS can save money and improved reporting can reduce the length of outbreaks. The decreased spread of infectious diseases in the state will reduce mortality and morbidity from disease outbreaks. Community awareness programs and academic research in the area of timely reporting can influence policies to improve the timeliness of reporting. The medical culture and society in West Virginia would be enriched by a more reliable and valid approach to infectious disease reporting in the state.

Conclusion

The results of the study indicate that the timeliness was quite poor with Category II VPID. However, the completeness improved after the introduction of the Web-based server. When implementing an electronic intervention, like a Web-based server, it is essential to build a communication network to support electronic disease surveillance. According to Watkins et al. (2009) system attributes for measuring the sensitivity of a surveillance system should include timeliness, completeness, and the geographic and demographic data of the population. On going evaluation methods will need to be implemented by the State of West Virginia to ensure that timeliness and completeness of surveillance system data improves over time. Healthcare professionals in the state can utilize the results of this research to improve the system attributes of timeliness and

completeness. Implications for positive social change included improved access to public

health data to better understand health disparities, which could reduce morbidity and

mortality within the population.

References

2012 Case Definitions: Nationally Notifiable Conditions Infectious and Non-Infectious

Case. (2012). Atlanta, GA: Centers for Disease Control and Prevention.

Abrahamson, E. (1991). Managerial fads and fashions: The diffusion and rejection of

innovations. *The Academy of Management Review, 16* (3), 586-612.

Abrahamson, E. & Fairchild, G. (1999). Management fashion: Lifecycles, triggers, and

collective learning processes. *Administrative Science Quarterly, 44*(4)*,* 708-740.

Amirfar, S., Taverna, J., Anane, S., & Singer, J. (2011). Developing public health clinical

decision support systems (CDSS) for the outpatient community in New York

City: our experience. *BMC Public Health, 11,* 753-761.

Assessment of ESSENCE performance for influenza-like illness surveillance after an

influenza outbreak-U.S. Air Force Academy, Colorado, 2009. (2011, April 8).

MMWR: Morbidity Mortality Weekly Report, 60(13)*,* 406-409. Retrieved from:

http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6013a3.htm

Attaway, D.F., Jacobsen, K.H., Falconer, A., Manca, G., & Waters, N.M. (2014).

Assessing the methods needed for improved dengue mapping: a SWOT analysis.

PanAfrican Medical Journal, 17, 289-296.

Averhoff, F., Zucker, J., Vellozzi, C., Redd, S., Woodfill, C., Waterman, S., …& Reef,

S.E. (2006). Adequacy of surveillance to detect endemic rubella transmission in

the United States. *Clinical Infectious Disease, 43*, 151-157.

Baker, M.G., Easther, S., and Wilson, N. (2010). A surveillance sector review applied to

infectious diseases at a country level. *BioMed Central Public Health*, 1-16.

Bandura, A. (1998). Health promotion from the perspective of social cognitive theory. *Psychology and Health*, *13*, 623-649.

Bass, F. M. (1969). A new product growth model for consumer durables. *Management Science, 15*(5), 215-227.

Bauman, A.E., Nelson, D.E., Pratt, M., Matsudo, V., & Schoeppe, S. (2006, October). Dissemination of physical activity evidence, programs, policies, and surveillance in the international public health arena. *American Journal of Preventive Medicine*, *31*(4S), 57-65.

Baxter, R., Rubin, R., Steinberg, C., Carroll, C., Shapiro, J., & Yang, A. (2000). Assessing core capacity for infectious diseases surveillance. The Lewin Group, Inc. Retrieved from: http://www.lewin.com/publications/publication/46/"

Boehner, R. & Gold, S. (2012). Modeling the impact of marketing mix on the diffusion of innovation in the generalized bass model of firm demand. *Developments in Business Simulation and Experiential Learning, 39,* 75-92.

Bolvin, G., Hardy, I., Tellier, G., & Maziade, J. (2000). Predicting influenza infections during epidemics with use of a clinical case definition. *Clinical Infectious Diseases*, *31*(5), 1166-1169.

Brenner, H. (Jan., 1995). Use and limitations of the capture-recapture method in disease monitoring with two dependent sources. *Epidemiology, 6*(1)*,* 42-48.

Buczak, A.L., Babin, S., & Moniz, L. (2010). Data-driven approach for creating synthetic electronic medical records. *BMC Medical Informatics and Decision Making, 10*, 1-28.

Bunduchi, R., Weisshaar, C., & Smart, A.U. (2011). Mapping the benefits and costs associated with process innovation: The case of RFID adoption. *Technovation, 31*(9), 505-521.

Busgeeth, K, Rivett, U. (2204). The use of spatial information system in the management of HIV/AIDS in South Africa. *International Journal of Health Geographics, 3*(1), 13-21.

Cabrera, D. & Trochim, W.M. (2006). A theory of systems evaluation. Systems evaluation and evaluation systems whitepaper series. Ithaca, NY: Cornell University Dspace Open Access Repository. National Science Foundation Systems Evaluation Grant No. EREC-0535492.

Centers for Disease Control and Prevention. (2012). National notifiable diseases surveillance system (NNDSS). Retrieved from: http://wwwn.cdc.gov/nndss/

Centers for Disease Control and Prevention. (2013). Case Definitions. http://wwwn.cdc.gov/nndss/

Chriqui, J.F., O'Connor, J.C., and Chaloupka, F.J. (2011). What gets measured, gets changed: Evaluating law and policy for maximum impact. *Journal of Law, Medicine, & Ethics*, 21-26.

Colbert, S.J. and Harrison, K.M. (2011). Reflections from the CDC 2010 health equity symposium. *Public Health Reports, 126*(3), 38-40.

Creswell, J.W. (2009). *Research design: qualitative, quantitative, and mixed methods approaches.* Thousand Oaks, CA: Sage Publications.

Damanpour, F. (1991). Organizational innovation: A meta-analysis of effects of

determinants and moderators. *Academy of Management, 34*(3), 555-590.

Damanpour, F. (1992). Organizational size and innovation. *Organizational Studies, 13*(3), 375-402.

Damanpour, F. (1996). Organizational complexity and innovation: Developing and testing multiple contingency models. *Management Science, 42,* 693-716.

Dean, H.D., and Fenton, K.A. (2010). Addressing the social determinants of health in the prevention and control of HIV/AIDS, viral hepatitis, sexually transmitted infections, and tuberculosis. *Public Health Reports*, *125*(4), 1-5.

Dearing, J.W. (2009, September). Applying diffusion of innovation theory to intervention development. *Res Social Work Practice*, *19(5),* 1-18.

Department of Health and Human Resources. (DHHR, 2011). West Virginia Electronic Disease Surveillance System (WVEDSS). Office of Epidemiology & Prevention Services. Retrieved from:

http://www.dhhr.wv.gov/oeps/Pages/SpecialProjects.aspx

Dopson, S., Fitzgerald, L., Ferlie, E., Gabbay, J., & Locock, L. (2002). No magic targets. Changing clinical practice to become more evidence based. *Health Care Management Review, 37,* 35-47.

Doyle, T.J., Glynn, M.K., & Groseclose, S.L. (2002). Completeness of notifiable infectious disease reporting in the United States: An analytical literature review. *American Journal of Epidemiology, 155*(9)*,* 866-874.

Effler, P., Ching-Lee, M., Bogard, A., Ieong, M., Nekomoto, T., & Jernigan, D. (1999). Statewide system of electronic notifiable disease reporting from clinical

laboratories comparing automated reporting with conventional methods. *JAMA, 282*(19), 1845-1850.

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, *41*, 1149-1160.

Faul, F., Erdfelder, E., Lang, A.G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*, 175-191.

Fedorowicz, J. & Gogan, J.L. (2010). Reinvention of interorganizational systems: A case analysis of the diffusion of a bio-terror surveillance system. *Information Systems Frontiers, 12(1),* 81-95.

Framework for evaluating public health surveillance systems for early detection of outbreaks. (2004, May 7). *MMWR: Morbidity Mortality Weekly Report, 53*(RR-5), 1 -16. Retrieved from: http://www.cdc.gov/mmwr

Framework for program evaluation in public health. (1999, September 17). MMWR: *Morbidity Mortality Weekly Report, 48*(RR11), 1-40. Retrieved from: http://www.cdc.gov/mmwr/

Gladwin, J., Dixon, R.A., & Wilson, T.D. (2002). Rejection of an innovation: Health information management training materials in East Africa. *Health Policy & Planning, 17,* 354-361.

Green, L.W., Ottoson, J.M., Garcia, C., & Hiatt, R.A. (2009). Diffusion theory and knowledge dissemination, utilization, and integration in public health. *The*

Annual Review of Public Health, *30*, 151-174.

Greenhalgh, T., Robert, G., Macfarlane, F., Bate, P., & Kyriakidou, O. (2004). Diffusion of innovations in service organizations: Systematic review and recommendations. *The Milbank Quarterly*, *82(4),* 581-629.

Greenhalgh, T., Stramer, K., Bratan, T., Byrne, E., Mohammad, Y., & Russell, J. (2008). Introduction of shared electronic records: multi-site case study using diffusion of innovation theory. *British Medical Journal, 337,* 1-10.

Harris, A.D., Bradhan, D.D., Baumgarten, M., Zuckerman, I.H., Fink, J.C., & Perencevich, E.N. (2004). The use and interpretation of quasi-experimental studies in infectious diseases. *Clinical Infectious Disease, 38,* 1586-1591.

Harris, A.D., McGregor, J.C., Perencevich, E.N., Furuno, J.P., Zhu, J., Peterson, D.E., & Finkelstein, J. (2006). The use and interpretation of quasi-experimental studies in medical informatics. *Journal of American Medical Informatics Association, 13,* 16-23.

Heisey-Grove, D.M., Church, D.R., Haney, G.A., & Demaria, A. (2011). Enhancing surveillance for hepatitis C through public health informatics. *Public Health Reports, 126*(1), 13-18.

Ho, P.M., Peterson, P.N. & Masoudi, F.A. (2008). Evaluating the evidence: Is there a rigid hierarchy? *Circulation, 118,* 1675-1684.

Institute of Medicine. (2010, December). *For the public's health: The role of measurement in action and accountability. National Academies Press, Washington, D.C.* Retrieved from: www.iom.edu/measuringhealth

Jajosky, R.A., & Groseclose, S.L. (2004). Evaluation of reporting timeliness of public health surveillance systems and infectious disease. *BMC Public Health, 4*(29),1471-2458.

Kasper, M.R., Wierzba, T.F., Sovann, L., Blair, P.J., & Putnam, S.D. (2010). Evaluation of an influenza-like illness case definition in the diagnosis of influenza among patients with acute febrile illness in Cambodia. *BioMed Central Infectious Diseases,10,* 320-325.

Katz, R., May, L., Baker, J., & Test, E. (2011). Redefining syndromic surveillance. *Journal of Epidemiology and Global Health, 1,* 21-31.

Klevens, R.M., Fleming, P.L., Li, J., Gaines, C.G., Gallagher, K., Schwarcz, S.,…& Ward, J.W. (2001, October). The completeness, validity, and timeliness of AIDS surveillance data. *Annals of Epidemiology, 11*(7), 443-449.

Krause, G., Brodhun, B., Altmann, D., Claus, H., & Benzler, J. (2006). Reliability of case definitions for public health surveillance assessed by Round-Robin test methodology. *BMC Public Health*, *10*(6), 129-135.

Lazarus, R., Klompas, M., Campion, F.X., McNabb, S.J., Hou, X., Daniel, J., …& Platt, R. (2009). Electronic support for public health: Validated case finding and reporting for notifiable disease using electronic medical data. *Journal of American Medical Informatics Association, 16,* 18-24.

Lee, A.S. & Baskersville, R.L. (2003). Generalizing generalizability in information systems research. *Information Systems Research, 14*(3), 221-243.

Lopman, B.A., Reacher, M.H., van Duijnhoven, Y., Hanon, F., Brown, D., & Koopmans,

M. (2003). Viral gastroenteritis outbreaks in Europe, 1995-2000. E*merging Infectious Diseases*, *9*(1)*,* 90-96.

Madoff, L.C., Fisman, D.N., & Kass-Hout, T. (2011). A new approach to monitoring Dengue Fever. *Plos Neglected Tropical Diseases, 5*(5), 1215-1220.

Mandatory reporting of infectious diseases by clinicians. (1990, June 22). MMWR: *Morbidity and Mortality Weekly Report*, *39*(RR-9), 1-17. Retrieved from: http://www.cdc.gov/mmwr

Mokdad, A.H. (2009). The behavioral risk factors surveillance system: Past, present, and future. *Annual Review Public Health*, *30*, 43-54.

National surveillance for asthma --- United States, 1980-2004. (2007, October 19). *MMWR: Morbidity and Mortality Weekly Report Surveillance Summary, 56(*SS08); 1-14;18-54.

Nicolay, N., Garvey, P., Delappe, N., Cormican, M., & McKeown, P. (2010). Completeness and timeliness of Salmonella notifications in Ireland in 2008: a cross sectional study. *BioMed Central Public Health*, *10,* 1-10.

Nonaka, I., & Takeuchi, H. (1995). *The knowledge creation company: How Japanese companies create dynamics in innovation.* New York: Oxford University Press.

Nsubuga, P., Brown, W.G., Groseclose, S.L., Ahadzie, L., Talisuna, A.O., Mmbuji, P., …& White, M. (2010). Implementing integrated disease surveillance and response: Four African countries' experience, 1998-2005. *Global Public Health, 5(4),* 364-380.

Papoz, L., Balkau, B., & Lellouch, J. (1996). Case counting in epidemiology: Limitations

of methods based on multiple data sources. *International Journal of Epidemiology*, *25*(3), 474-478.

Perry, H.N., McDonnell, S.M., Alemu, W., Nsubuga, P., Chungong, S., Otten, M.W…& Thacker, S.B. (2007). Planning an integrated disease surveillance and response system: a matrix of skills and activities. *BioMed Central Medicine*, *5*(24), 1-8.

Pillaye, J., & Clarke, A. (2003). An evaluation of completeness of tuberculosis notification in the United Kingdom. *BioMed Central Public Health*, *3*(31)*,* 1-5.

Potvin, L., Haddad, S., & Frohlich. K.L. (2001). Beyond process and outcome evaluation: A comprehensive approach for evaluating health promotion programmes. *WHO Regional Publications, European Series, 92,* 45-62.

Public health surveillance workforce of the future. (2012, July 27). *MMWR: Morbidity and Mortality Weekly Report, 61,* 25-29. Retrieved from: http://www.cdc.gov/mmwr

Reijn, E., Swaan, C.M., Kretzschmar, M.E., & van Steenbergen, J.E. (2011). Analysis of timeliness of infectious disease reporting in the Netherlands. *BioMed Central Public Health*, *11*, 1- 9.

Reintjes, R., Termorshuizen, F., & van de Laar, M.J. (1998). Assessing the sensitivity of STD surveillance in the Netherlands: an application of the capture-recapture method. *Epidemiology Infectious Diseases*, *122,* 97-102.

Reintjes, R., Thelan, M., Reiche, R., & Csohan, A. (2007). Benchmarking national surveillance systems: a new tool for the comparison of communicable disease surveillance and control in Europe. *European Journal of Public Health*,*17*(4),

375-380.

Rogers, E. M. (1995). *Diffusion of innovations* (4th ed.). New York: Free Press.

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). New York: Free Press.

Rogers, E.M. & Kincaid, D.L. (1981). *Communication networks: Toward a new*

paradigm for research. New York: Free Press.

Rolka, H., Walker, D.W., English, R., Katzoff, M.J., Scogin, G., & Neuhaus, E. (2012).

Analytical challenges for emerging public health surveillance. *Morbidity*

Mortality Weekly Report, 61, 35-39.

Roush, S., Birkhead, G., Koo, D., Cobb, A., & Fleming, D. (1999). Mandatory reporting

of diseases and conditions by health care professionals and laboratories. *Journal*

of American Medical Association, 281(2*),* 164-170.

Ruiz, M.O., Tedesco, C., McTighe, T.J., Austin, C., & Kitron, U. (2004). Environmental

and social determinants of human risk during a West Nile virus outbreak in the

greater Chicago area, 2002. *International Journal of Health Geographics, 3*(1)*,* 8-

19. doi:10.1186/1476-072X-3-8

Rust, G., Satcher, D., Fryer, G.E., Levine, R., & Blumenthal, D.S. (2010). Triangulating

on success: Innovation, public health, medical care, and cause-specific U.S.

mortality rates over a half-century (1950-2000). American Journal of Public

Health, *100*(S1), 95-104.

Sahal, N., Reintjes, R., & Aro, A.R. (2009). Communicable diseases surveillance lessons

learned from developed and developing countries: Literature review.

Scandinavian Journal of Public Health, 37, 187-200.

Saint Louis, M. (2012). Global health surveillance. *Morbidity Mortality Weekly Report, 61,* 15-19.

Saval, T.G. & Foldy, S. (2012). The role of public health informatics in enhancing public health surveillance. *Morbidity Mortality Weekly Report, 61,* 20-24.

Sickbert-Bennett, E.E., Weber, D.J., Poole, C., MacDonald, P.D.M., & Maillard, J. (2011). Completeness of communicable disease reporting, North Carolina, USA, 1995-1997 and 2000-2006. *Emerging Infectious Diseases, 17*(1), 23-29.

Steckler, A. & McLeroy, K.R. (2008). The importance of external validity. *American Journal of Public Health, 98*(1), *9-10.*

Straetemans, M., Altmann, D., Eckmanns, T., & Krause, G. (2008). Automatic outbreak detection algorithm versus electronic reporting system. *Emerging Infectious Diseases*, *14*(10), 1610-1612.

Suzuki, J. (2011). Ecological model and systems theory. Retrieved from: www.hawaii.edu/dyson/Ecological%20model%20and20systems%

Taboy, C.H., Chapman, W., Albetkova, A., Kennedy, S., & Rayfield, M.A. (2010). Integrated disease investigations and surveillance planning: a systems approach to strengthening national surveillance and detection of events of public health importance in support of the international health regulations. *BioMed Central Public Health*, *10*(1), 1-6.

Takian, A., Petrakaki, D., Cornford, T., Sheikh, A., Barber, N., & On behalf of the National Care Records Service Evaluation (NHS CRS) Team. (2012). Building a house on shifting sand: methodological considerations when evaluating the

implementation and adoption of national electronic health record systems.
BioMed Central Health Services Research, *12* (105), 1-11.

Thacker, S.B., Berkelman, R.L., & Stroup, D.F. (1989). The science of public health surveillance. *Journal of Public Health Policy, 10*(2), 187-203.

Thacker, S.B., Qualters, J.R., & Lee, L.M. (2012). Public health surveillance in the United States: Evolution and Challenges. *Morbidity Mortality Weekly Report, 61,* 3-9.

Tilling, K. (2001). Capture-recapture methods- useful or misleading? International Journal of *Epidemiology*, *30,* 12-14.

Travers, D., Barnett, C., Ising, A., & Waller, A. (2006). Timeliness of emergency department diagnosis for syndromic surveillance. AMIA 2006 Symposium Proceedings, 769.

United Kingdom Department of Health. (2001). Health Services and Delivery Research (HS&DR) Programme. Retrieved from: http://www.nets.nihr.ac.uk/programmes/hsdr

United States Census. (2011). West Virginia State and County Quick Facts. Retrieved from: http://quickfacts.census.gov/qfd/states/54000.html

Updated guidelines for evaluating public health surveillance systems. (2001, July 27). MMWR: Morbidity Mortality Weekly Report, *50*(RR13), 1 -35. Retrieved from: http://www.cdc.gov/mmwr

Vogt, R.L., Spittle, R., Cronquist, A., & Patnik, J.L. (2006). Evaluation of timeliness and completeness of web-based notifiable disease reporting system by a local

health department. *Journal of Public Health Management Practice, 12*(6), 540-544.

Wamala, J.F., Okot, C., Makumbi, I., Natseri, N., Kisakye, A., Nanyunja, M., …& Chungong, S. (2010). Assessment of core capacities for the International Health Regulations (IHR[2005]) – Uganda, 2009. *BioMed Central Public Health, 10*(1), 1-10.

Watkins, R.E., Martin, P.A., Kelly, H., Madin, B., & Watson, C. (2009). An evaluation of the sensitivity of acute flaccid paralysis surveillance for poliovirus infection in Australia. *Bulletin of Sociologic Methodology Infectious Diseases, 9*(162), 1-13.

Weaver, B. (2004). Assumptions of *t*-tests: Exact and Approximate Tests. Retrieved from: www.angelfire.com/wv/bwhomedir/notes/t_test_assumptions.pdf

West Virginia Department of Human and Health Resources. (2013). WVEDSS. Retrieved from http://www.dhhr.wv.gov/oeps/disease/WVEDSS/Pages/default.aspx

West Virginia State Legislature. (2011). Series 7, reportable disease, events and conditions. Title 64, Legislative Rule, Bureau for Public Health, Department of Health and Human Resources, 1-28. Retrieved from: http://www.dhhr.wv.gov/oeps/disease/Law/Pages/default.aspx

Williams, S., Vally, H., Fielding, J., & Cowie, B. (2010). Chronic hepatitis B surveillance in Victoria, 1998-2008: instituting a 21st Century approach to an old disease. *Australian and New Zealand Journal of Public Health, 35*(1), 16-21.

World Health Organization. (2006). Communicable disease surveillance and response

systems. A guide to planning. Retrieved from:

www.who.int/csr/resources/publications/surveillance//WHO_CDS_EPR_LYO_20

06_1.pdf

World Health Organization. (2010, December). Protocol for assessing national

surveillance and response capacities for the International Health Regulations

(2005). *International Health Regulations Coordination,* 1- 145.

World Health Organization. (2012). Information to States parties regarding determination

of fulfillment of the IHR core capacity requirements for 2012 and potential

extensions. *International Health Regulations Coordination,* 1- 34.

Wuhib, T., Chorba, T.L., Davidiants, V., MacKenzie, W.R., & McNabb, S.J.N. (2002).

Assessment of the infectious disease surveillance system of the Republic of

Armenia: an example of surveillance in the Republics of the former Soviet Union.

BioMed Central Public Health, 2, 1-8.

Wurtz, R. & Cameron, B.J. (2005). Electronic laboratory reporting for the infectious

diseases physician and clinical microbiologist. *Clinical Infectious Diseases, 40,*

1638-1643.

Yoo, H., Park, O., Park, H., Lee, E., Jeong, E., Lee, J., & Cho, S. (2009). Timeliness of

national notifiable diseases surveillance system in Korea: a cross-sectional study.

BioMed Central Public Health, *9,* 1-8.

Zahra, A.S. & George, G. (2002). Absorptive capacity: A review, reconceptualization,

and extension. *Academy of Management Review, 27*(2), 185-203.

Zeldenrust, M.E., Rahamat-Langendoen, J.C., Postma, M.J., & van Vliet, J.A. (2008).

The value of ProMED-mail for the Early Warning Committee in the Netherlands:

more specific approach recommended. *Euro Surveillance, 13*(6), 1-4.

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Appendix A: Checklist for Evaluating Public Health Surveillance Systems

Appendix A.

Checklist for Evaluating Public Health Surveillance Systems

Tasks for evaluating a surveillance system*	Page(s) in this report
☐ Task A. Engage the stakeholders in the evaluation	4
☐ Task B. Describe the surveillance system to be evaluated	4–11
☐ 1. Describe the public health importance of the health-related event under surveillance	4– 5
☐ a. Indices of frequency	
☐ b. Indices of severity	
☐ c. Disparities or inequities associated with the health-related event	
☐ d. Costs associated with the health-related event	
☐ e. Preventability	
☐ f. Potential future clinical course in the absence of an intervention	
☐ g. Public interest	
☐ 2. Describe the purpose and operation of the surveillance system	5–10
☐ a. Purpose and objectives of the system	
☐ b. Planned uses of the data from the system	
☐ c. Health-related event under surveillance, including case definition	
☐ d. Legal authority for data collection	
☐ e. The system resides where in organization(s)	
☐ f. Level of integration with other systems, if appropriate	
☐ g. Flow chart of system	
☐ h. Components of system	
☐ 1) Population under surveillance	
☐ 2) Period of time of data collection	
☐ 3) Data collection	
☐ 4) Reporting sources of data	
☐ 5) Data management	
☐ 6) Data analysis and dissemination	
☐ 7) Patient privacy, data confidentiality, and system security	
☐ 8) Records management program	
☐ 3. Describe the resources used to operate the surveillance system	10–11
☐ a. Funding source(s)	
☐ b. Personnel requirements	
☐ c. Other resources	
☐ Task C. Focus the evaluation design	11–12
☐ 1. Determine the specific purpose of the evaluation	
☐ 2. Identify stakeholders who will receive the findings and recommendations of the evaluation	
☐ 3. Consider what will be done with the information generated from the evaluation	
☐ 4. Specify the questions that will be answered by the evaluation	
☐ 5. Determine standards for assessing the performance of the system	
☐ Task D. Gather credible evidence regarding the performance of the surveillance system	13–24
☐ 1. Indicate the level of usefulness	13–14
☐ 2. Describe each system attribute	14–24
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☐ b. Flexibility	
☐ c. Data quality	
☐ d. Acceptability	
☐ e. Sensitivity	
☐ f. Predictive value positive	
☐ g. Representativeness	
☐ h. Timeliness	
☐ i. Stability	
☐ Task E. Justify and state conclusions, and make recommendations	24
☐ Task F. Ensure use of evaluation findings and share lessons learned	25

* Adapted from *Framework for Program Evaluation in Public Health* [CDC. Framework for program evaluation in public health. MMWR 1999;48(RR-11)] and the original guidelines [CDC. Guidelines for evaluating surveillance systems. MMWR 1988;37(No. S-5)].

Appendix B: Cross-Reference of Tasks and Relevant Standards for Evaluating a

Surveillance System

Appendix B.

Cross-reference of Tasks and Relevant Standards

Tasks for evaluating a surveillance system*	Relevant standards[†]
Task A. Engage the stakeholders in the evaluation.	**Stakeholder identification.** Persons involved in or affected by the evaluation should be identified so that their needs can be addressed. **Evaluator credibility.** The persons conducting the evaluation should be trustworthy and competent in performing the evaluation to ensure that findings from the evaluation achieve maximum credibility and acceptance. **Formal agreements.** If applicable, all principal parties involved in an evaluation should agree in writing to their obligations (i.e., what is to be done, how, by whom, and when) so that each party must adhere to the conditions of the agreement or renegotiate them. **Rights of human subjects.** The evaluation should be designed and conducted in a manner that respects and protects the rights and welfare of human subjects. **Human interactions.** Evaluators should interact respectfully with other persons associated with an evaluation so that participants are not threatened or harmed. **Conflict of interest.** Conflict of interest should be handled openly and honestly so that the evaluation processes and results are not compromised. **Metaevaluation.** The evaluation should be formatively and summatively evaluated against these and other pertinent standards to guide its conduct appropriately and, on completion, to enable close examination of its strengths and weaknesses by stakeholders.
Task B. Describe the surveillance system to be evaluated.	**Complete and fair assessment.** The evaluation should be complete and fair in its examination and recording of strengths and weaknesses of the system so that strengths can be enhanced and problem areas addressed. **System documentation.** The system being evaluated should be documented clearly and accurately. **Context analysis.** The context in which the system exists should be examined in enough detail to identify probable influences on the system. **Metaevaluation.** The evaluation should be formatively and summatively evaluated against these and other pertinent standards to guide its conduct appropriately and, on completion, to enable close examination of its strengths and weaknesses by stakeholders.
Task C. Focus the evaluation design.	**Evaluation impact.** Evaluations should be planned, conducted, and reported in ways that encourage follow-through by stakeholders to increase the likelihood of the evaluation being used.

Appendix B. — Continued

Cross-reference of Tasks and Relevant Standards

Tasks for evaluating a surveillance system*	Relevant standards†
Task C. (*Continued*) Focus the evaluation design.	***Practical procedures.*** Evaluation procedures should be practical while needed information is being obtained to keep disruptions to a minimum. ***Political viability.*** During the planning and conducting of the evaluation, consideration should be given to the varied positions of interest groups so that their cooperation can be obtained and possible attempts by any group to curtail evaluation operations or to bias or misapply the results can be averted or counteracted. ***Cost-effectiveness.*** The evaluation should be efficient and produce valuable information to justify expended resources. ***Service orientation.*** The evaluation should be designed to assist organizations in addressing and serving effectively the needs of the targeted participants. ***Complete and fair assessment.*** The evaluation should be complete and fair in its examination and recording of strengths and weaknesses of the system so that strengths can be enhanced and problem areas addressed. ***Fiscal responsibility.*** The evaluator's allocation and expenditure of resources should reflect sound accountability procedures by being prudent and ethically responsible so that expenditures are accountable and appropriate. ***Described purpose and procedures.*** The purpose and procedures of the evaluation should be monitored and described in enough detail to identify and assess them. The purpose of evaluating a surveillance system is to promote the best use of public health resources by ensuring that only important problems are under surveillance and that surveillance systems operate efficiently. ***Metaevaluation.*** The evaluation should be formatively and summatively evaluated against these and other pertinent standards to guide its conduct appropriately and, on completion, to enable close examination of its strengths and weaknesses by stakeholders.
Task D. Gather credible evidence regarding the performance of the surveillance system.	***Information scope and selection.*** Information collected should address pertinent questions regarding the system and be responsive to the needs and interests of clients and other specified stakeholders. ***Defensible information sources.*** Sources of information used in the system evaluation should be described in enough detail to assess the adequacy of the information.

Appendix B. — Continued

Cross-reference of Tasks and Relevant Standards

| Tasks for evaluating a surveillance system*	Relevant standards[†]
Task D. (*Continued*) Gather credible evidence regarding the performance of the surveillance system.	**Valid information.** Information-gathering procedures should be developed and implemented to ensure a valid interpretation for the intended use.
	Reliable information. Information-gathering procedures should be developed and implemented to ensure sufficiently reliable information for the intended use.
	Systematic information. Information collected, processed, and reported in an evaluation should be systematically reviewed and any errors corrected.
	Metaevaluation. The evaluation should be formatively and summatively evaluated against these and other pertinent standards to guide its conduct appropriately and, on completion, to enable close examination of its strengths and weaknesses by stakeholders.
Task E. Justify and state conclusions, and make recommendations.	**Values identification.** The perspectives, procedures, and rationale used to interpret the findings should be carefully described so that the bases for value judgments are clear.
	Analysis of information. Information should be analyzed appropriately and systematically so that evaluation questions are answered effectively.
	Justified conclusions. Conclusions that are reached should be explicitly justified for stakeholders' assessment.
	Metaevaluation. The evaluation should be formatively and summatively evaluated against these and other pertinent standards to guide its conduct appropriately and, on completion, to enable close examination of its strengths and weaknesses by stakeholders.
Task F. Ensure use of evaluation findings and share lessons learned.	**Evaluator credibility.** The persons conducting the evaluation should be trustworthy and competent in performing the evaluation to ensure that findings from the evaluation achieve maximum credibility and acceptance.
	Report clarity. Evaluation reports should clearly describe the system being evaluated, including its context and the purposes, procedures, and findings of the evaluation so that essential information is provided and easily understood.
	Report timeliness and dissemination. Substantial interim findings and evaluation reports should be disseminated to intended users so that they can be used in a timely fashion.

Appendix B. — Continued

Cross-reference of Tasks and Relevant Standards

Tasks for evaluating a surveillance system*	Relevant standards[†]
Task F. Ensure use of the findings of the evaluation and share lessons learned.	***Evaluation impact.*** Evaluations should be planned, conducted, and reported in ways that encourage follow-through by stakeholders to increase the likelihood of the evaluation being used.
	Disclosure of findings. The principal parties of an evaluation should ensure that the full evaluation findings with pertinent limitations are made accessible to the persons affected by the evaluation and any others with expressed legal rights to receive the results.
	Impartial reporting. Reporting procedures should guard against the distortion caused by personal feelings and biases of any party involved in the evaluation so that the evaluation reflects the findings fairly.
	Metaevaluation. The evaluation should be formatively and summatively evaluated against these and other pertinent standards to guide its conduct appropriately and, on completion, to enable close examination of its strengths and weaknesses by stakeholders.

* Adapted from *Framework for Program Evaluation in Public Health* [CDC. Framework for program evaluation in public health. MMWR 1999;48(RR–11)] and the original guidelines [CDC. Guidelines for evaluating surveillance systems. MMWR 1988;37(No. S-5)].
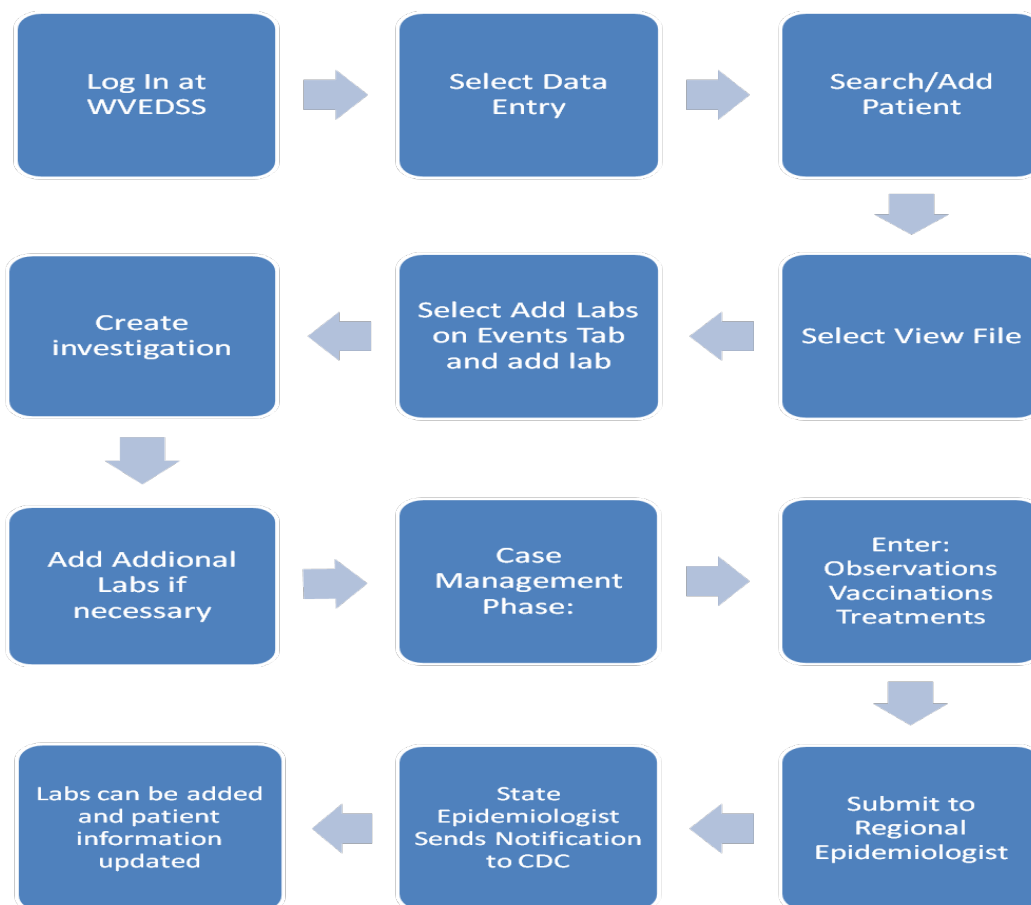
[†] Adapted from *Framework for Program Evaluation in Public Health* [CDC. Framework for program evaluation in public health. MMWR 1999;48(RR-11)].

Appendix C: Health Situation Awareness (Thacker, Qualters, & Lee, 2012)
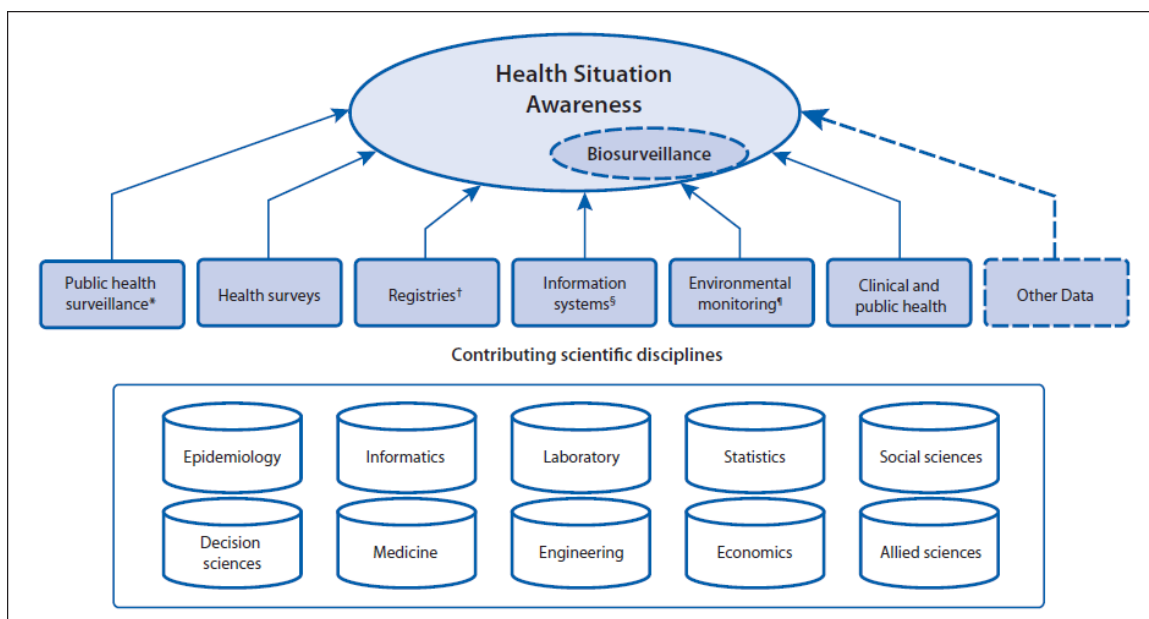
Appendix D: Flowchart for WVEDSS

Appendix E: NNDSS History

National Notifiable Diseases Surveillance System History

Overview: 60 Years of Disease Surveillance

Notifiable diseases are conditions public health authorities voluntarily share with CDC. National Notifiable Diseases Surveillance System (NNDSS) including components like the National Electronic Disease Surveillance System (NEDSS) support surveillance efforts in CDC Programs as well as state, territorial, and local health departments. Prior to 1985, notifiable disease data was sent by the states to CDC by mail and by phone. Since then, CDC has worked closely partners to support state, local, territorial, and tribal health departments by helping them develop integrated and interoperable public health surveillance systems.

1951 • The National Office of Vital Statistics begins receiving summary data from states by phone and by mail.

1961 • Responsibility for collecting and publishing data on nationally notifiable diseases transfers from the National Office of Vital Statistics to CDC.
• CDC begins publishing the MMWR with notifiable diseases data.

1985 • Electronic era of public health surveillance begins with the Electronic Surveillance Project (ESP) at CDC, a national 5-year pilot project for electronically collecting notifiable disease data. ESP pilot states each develop their own version of an electronic health reporting system. In response, CDC develops standards and systems to translate data sent from states.

1990 • NETSS (National Electronic Telecommunications System for Surveillance) launches after positive ESP pilot program assessment. NETSS provided an intuitive, easy to use and understand, and stable system developed to better reconcile national and state records.

1993 • Program for Surveillance of Vaccine Preventable Disease (VPD) expands and a version of NETSS tailored to the VPD program is first deployed. After 2 years, 100% of states use the system, and CDC provides no additional funding to states.

1994 • CDC program participation begins. STD program initiates move to NETSS, followed by meningitis, lyme disease, hepatitis, and VPD programs.

1995 • The Epidemiology Program Office (EPO) proposes updating NETSS from a DOS-based to a Windows-based system.

1998 • Integration project begins among 11 CDC systems to update NETSS by creating data elements CDC programs needed.

1999 • Integration project is suspended. CDC OD's Information Resources Management Office (IRMO) creates NEDSS to promote use of data and information system standards to 1) advance the development of efficient, integrated, and interoperable surveillance systems at federal, state, and local levels and 2) facilitate the electronic transfer of public health surveillance data. At this time, surveillance activities remain in EPO.

2000 • States begin receiving federal funding from CDC through the Epidemiology and Laboratory Capacity (ELC) cooperative agreement to plan and implement integrated electronic systems for disease surveillance.
• CDC develops the NEDSS Base System (NBS), a platform for disease-specific modules, which it supports and provides to states for use in electronic surveillance.

2004 • CDC creates the Public Health Information Network (PHIN) as an outgrowth of NEDSS to embrace broader public health surveillance. EPO moves to CDC's newly established Division of Public Health Informatics.

2005 • 27 state health departments and 2 jurisdictions enter at least some notifiable disease data by using a secure, Internet-based system, and 26 jurisdictions receive lab results through electronic laboratory reporting (ELR).

2008 • CDC and NNDSS receive first HL7 messages for TB and varicella case notifications.

2009 • CDC establishes Office of Surveillance, Epidemiology, and Laboratory Services as part of CDC reorganization.

2011 • Every state uses a NEDSS-compliant disease reporting system, and one third of states use the CDC-created NBS.

http://www.cdc.gov/nndss

Office of Surveillance, Epidemiology, and Laboratory Services
Public Health Surveillance Program Office, Division of Notifiable Diseases and Healthcare Information

CDC