Evaluation and Continuous Improvement of Foodborne Disease Surveillance

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Evan Elliot Henke

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Dedication

This dissertation is dedicated to the memory of Kevin Kowalcyk, the Kowalcyk family, and the Center for Foodborne Illness Research and Prevention. They have provided me inspiration, support, and experience throughout the completion of this thesis and I am eternally grateful to them.

Abstract

The purpose of this thesis is to contribute to the evidence base of public health performance evaluation by applying innovative measurement and improvement methods to a foodborne disease outbreak detection and investigation process. This thesis is the results of investigation into the three following research questions: 1) can foodborne disease outbreak responder training and work experience be measured in an electronic survey, 2) what is the performance of the Minnesota Department of Health in detecting and investigating foodborne disease outbreaks, and 3) can quality improvement and evaluation tools be used to evaluate MDH process stability and capability? Three research studies were developed to address these research questions. In Chapter 1, the development and analysis of an online survey to ascertain foodborne disease outbreak responder training and work experience is described. In Chapter 2, a bacterial foodborne disease surveillance program in a state health department is described and its performance is evaluated. In Chapter 3, four processes that are conducted by a bacterial foodborne disease surveillance program are evaluated for stability and capability over three years using statistical process control charts. I conclude that methods for evaluating predictive factors of public health performance need to be improved, and that quantitative performance evaluation, within context, has great potential for improving evidenced-based public health preparedness, demonstrating changes in departmental performance, and enabling internal public health practice quality improvement.

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Introduction

Public health surveillance has been defined as the "ongoing systematic collection, analysis, and interpretation of data essential to the planning, implementation, and evaluation of public health practice, closely integrated with the timely dissemination of these data to those who need to know" (1). Foodborne disease outbreaks represent recurring public health emergencies requiring public health responses including laboratory testing, epidemiological investigation, environmental evaluation, and regulatory traceback. Foodborne disease surveillance exists to identify novel pathogens, clinical syndromes, and sequelae; describe new reservoirs and vehicles of transmission; evaluate existing prevention strategies; and identify deficiencies in the food safety systems on local, national, and international levels (2).

The systematic evaluation of foodborne disease surveillance systems' design and performance has been identified as both a research and practice priority. The comparison of surveillance systems' context, design, workforce, processes, and performance within the context of the system's goals can identify model factors to improve public health preparedness and response (3-7). Additionally, performance evaluation is a prerequisite for internal quality improvement (QI) activities.

Performance evaluation and QI activities have been successfully applied in public health programs to quantify and improve performance (8). Recent surveys by the National Association of City and County Health Officials estimate that 84% of local health departments have performed formal or informal QI activities (9). There are many potential benefits to continuous performance evaluation. Most importantly, performance

evaluation provides the public health workforce with ownership of performance and facilitates continuous improvement. For this reason, the Public Health Accreditation Board has made the demonstration of performance measurement and improvement activities a requirement for public health accreditation at the department-level (10). Performance summaries and improvement examples may be useful for obtaining future program grants and for justifying continued investment in current programs. Performance evaluations are also a means of communicating normal public health work outputs to public customers and may bolster public support of essential public health preparedness and response programs.

Although several relevant guidance documents exist (10-12, 14), there is no single consensus framework for quantitatively evaluating the performance of infectious disease surveillance systems. The purpose of a quantitative performance evaluation and the unique processes of a surveillance system determine which performance metrics are appropriate to evaluate. There are multiple different banks of potential performance metrics that could be applied to foodborne disease surveillance systems (4, 13). Reports of validated performance metric selection processes within infectious disease surveillance systems also exist (14).

A model of public health agency performance in the detection and investigation of foodborne disease outbreaks as determined by several predictive factors was developed. The model was formed in cooperation with state and local government foodborne disease outbreak responders in Minnesota during a focus group in 2010. Performance can be measured in either frequency of process completions, completeness of processes, and

timeliness of processes. Factors that might predict public health agency performance include the size of the jurisdiction of the agency, the food consumption patterns of the jurisdiction, the population's willingness to be interviewed about their food consumption history, the public health laws within the jurisdiction, state and local public health organizational structure, the program budget, the specific surveillance processes, the number of employees, the training and work experience of the employees, the additional workload the employees must complete other than foodborne disease surveillance, and the technological and office resources of the agency. Widespread reporting of evaluations of surveillance programs considering all predictive factors and performance measurement methods would enable the use of this model, and might help to identify factors that are critical to high-performance outbreak detection and investigation.

Two systematic literature reviews published in 2004 found a lack of timeliness reporting in infectious disease surveillance system evaluations. Jajosky and Groseclose reviewed 8 evaluations of infectious disease surveillance and found a wide range of timeliness measurement methods for a variety of public health processes, and a particular lack of timeliness reporting in state and local surveillance system evaluations (15). Bravata et al. found 72 reports of timeliness metrics for 43 infectious disease surveillance systems and noted a great lack of performance evidence to guide surveillance system administrators (16).

A scoping study was completed to locate and summarize published quality improvement reports and performance evaluations of foodborne disease surveillance systems. Zero quality improvement reports and 8 evaluations were located; 6 (75%)

evaluated the timeliness of foodborne disease reporting (17-22) and 2 (25%) evaluated the quality and frequency of laboratory activities (23, 24). Evaluation methods and metrics varied among the reports, and evaluation tools critical for quality improvement were rarely reported. Five (63%) of the evaluations contained detailed explanations of the context of the surveillance systems, 2 (25%) evaluations contained detailed process maps to describe the process being evaluated, and 6 (75%) evaluations selected metrics that measured the performance of government processes. The frequency of process iterations was evaluated in all 8 reports, the timeliness of processes was evaluated in 7 (88%) reports, the accuracy of laboratory tests was evaluated in 1 report, and the completeness of the processes was evaluated in 1 report. Two (25%) evaluations measured the performance of a process over time with median values or counted disease reports received. None of the 8 evaluations examined the process of obtaining food exposure history from cases. None of the 8 evaluations evaluated the resources, staff, training or work experiences of the surveillance system.

The most comprehensive evaluation of a foodborne disease surveillance system to date may have been performed by Bender et al., who describe in detail the legal context and surveillance processes involved in cluster detection and investigation before summarizing the number of clusters and outbreaks of Salmonellosis identified at the Minnesota Department of Health (25). Rounds et al. evaluated the ability of the Minnesota Department of Health to solve clusters of *Salmonella* Typhimurim and *E. coli* O157:H7, which can be considered a quantitative performance evaluation. Rounds identified descriptive factors about clusters that predict the solving of a cluster at MDH

(26, 27). The evaluation within adds additional context to assess the reported performance of MDH as well as to assess the validity and utility of Round's previous recommendation to investigate Salmonellosis clusters where 3 or more specimens are received within 5 business days.

The CDC, along with the national non-profit Robert Wood Johnson Foundation (RWJF) and Center for Science in the Public's Interest (CSPI), have all separately published reports of state health department capabilities to perform tasks critical to foodborne disease outbreak detection and response (28-30). The CDC's "Public Health Preparedness: Strengthening the Nation's Emergency Response State by State 2010" report summarizes the frequency and completeness of *E. coli* O157:H7 and *Listeria monocytogenes* pulsed field gel electrophoresis (PFGE) processes at public health laboratories in all 50 states. The CDC report is not intended to evaluate the predictors of performance such as the state infectious disease reporting rules and laboratory processes. While these metrics can be considered useful for the ends of the report, additional qualitative evaluation of the laboratory and performance measures may more completely describe the capacity of the state to obtain and process bacterial isolates. The RWJF's "Ready or Not 2010" report also evaluated the completeness of *E. coli* O157:H7 PFGE pattern uploads within 4 business days in all 50 states. The intention of this report was to annually review the broad progress of public health preparedness programs, and while program costs are considered, performance metrics and program contexts are not specific enough to foster comparative effectiveness research, specifically for foodborne disease surveillance systems. Neither the CDC nor the RWJF report evaluated in detail the

process of detecting and investigating clusters of foodborne disease after PFGE patterns had been recovered. CSPI's "All Over the Map" report evaluated the performance of state health departments to investigate foodborne disease outbreaks by measuring the number of outbreaks reported to the CDC over 10 years and the size of outbreaks reported. The three major reports show a gradient of public health agency capability to detect and investigate foodborne disease outbreaks. However, none of the three provide detailed and focused evaluation useful for comparative effectiveness research or quality improvement.

Surveys conducted by the CDC have attempted to longitudinally evaluate self-reported epidemiology capacity in United States health departments for over 10 years. (31-36). These surveys have been effective at tracking the self-perceived capacity of epidemiology units over time. However, the metrics are not results-based and cannot be considered valid measures of performance. A potential exists for comparative effectiveness research to reveal predictors of low-capacity in epidemiology departments in the future, but these publications were not intended to describe any such factors.

While performance metrics, performance measurement, program evaluation, and quality improvement have been discussed in public health for over 20 years, there is still a clear need to increase the application and reporting of said methods and tools.

The purpose of this thesis is to contribute to the evidence base of public health practice by applying innovative measurement and improvement methods to foodborne disease outbreak investigation processes. This work is the product of the investigation of three research questions: 1) Can foodborne disease outbreak responder training and work experience be measured in an electronic survey? 2) What is the performance of the

Minnesota Department of Health (MDH) in detecting foodborne disease outbreaks? Lastly, 3) can quality improvement and evaluation tools be used to evaluate MDH process stability and capability?

Three research projects were developed to address these research questions. In Chapter 1, the development and analysis of an online survey to ascertain foodborne disease outbreak responder training and work experience is described. In Chapter 2, a bacterial foodborne disease surveillance program at MDH is described and its performance is evaluated in detail. In Chapter 3, four processes that are conducted by a bacterial foodborne disease surveillance program (MDH) are evaluated for stability and capability over three years using statistical process control charts. I conclude that methods for evaluating predictive factors of public health performance need to be improved, and that quantitative performance evaluation, within context, has great potential for improving evidenced-based public health preparedness, demonstrating changes in departmental performance, and enabling internal public health practice quality improvement projects.

Chapter 1. Ascertainment of Foodborne Disease Outbreak Responder Training and Outbreak Investigation Activities with an Online Survey

Methods

The University Simulations and Exercises in Effective Education at the University of Minnesota – Twin Cities School of Public Health is a Centers for Disease Control and Prevention Office of Public Health Preparedness and Response-supported Public Health Preparedness and Emergency Response Research Center consisting of 4 sub-projects committed to building the evidence base for effective public health preparedness education and training. Our sub-project conducted focus groups with foodborne disease outbreak responders in Olmsted County, Minnesota in March, 2011. We determined the need for a training survey based on input collected from our focus group using a Delphi method. Experts agreed that in order to build a multivariate model able to link organizational factors to public health response performance, staff education, training, and work experience needed to be quantified.

A survey was developed to quantify the education, training, and work experience of foodborne disease outbreak responders (epidemiologists, environmental health professionals, and laboratory professionals) at the Minnesota Department of Health (MDH), and in local health departments (LHDs) in Minnesota. Responder demographic information, job title, public health agency, education, outbreak investigation training, and outbreak investigation experience data were collected. We ascertained outbreak investigation trainings by asking responders to indicate the completion of several Center

for Disease Control and Prevention (CDC), Council of State and Territorial Epidemiologists (CSTE), and National Environmental Health Association (NEHA) public health fellowships and training courses, as well as the National Incident Management System (NIMS) training series. We asked participants if they had completed student internships in outbreak investigation as undergraduate or graduate students. Previous outbreak investigation experience was ascertained by asking responders to indicate the number of times they had ever completed outbreak investigation tasks as listed in Chapter 5 of the CIFOR Guidelines to Improve Foodborne Outbreak Response, as shown in Table 2 (4). Outbreak Investigation activity questions pertained to two types of outbreaks: Those triggered by a community complaint that involved single events or establishments (complaint-based), and more dispersed bacterial outbreaks detected by pathogen-specific surveillance (pathogen-specific), routinely conducted at MDH. Survey responders were asked to produce an estimated number of times they had participated each type of outbreak and the number of times they had participated in each outbreak task. Responders who indicated that they were department supervisors or managers were asked to estimate the percentage of each type of outbreak response for which their department performed each outbreak investigation activity and to provide barriers to activity completion. The survey was developed and coordinated by the University Of Minnesota Health Survey Research Center (HSRC) and launched in May 2011. The survey was left open for responders to complete for 90 days before closing and analysis.

Public health agencies responsible for investigating foodborne disease outbreak investigations were recruited for the survey at the Minnesota Environmental Health

Association's 2011 Spring Conference. Agency managers reviewed and signed agency consent forms and agreed to forward an electronic link of the survey to employees responsible for foodborne disease outbreak response. Individual responders were recruited for the survey after receiving the email from the agency manager and indicating individual consent online. All responders were asked to send in documentation of training completion to the HSRC to validate training responses. All survey recruitment protocols and questionnaires were exempted from full review by the University of Minnesota IRB.

All data analysis was completed with Microsoft Excel 2007 (Microsoft Corporation, Redmond, WA). Medians and ranges of number of times ever participating in each outbreak investigation activity were calculated and stratified by employee type.

Results

The Minnesota Department of Health and 3 LHDs were enrolled in the survey. MDH is responsible for the epidemiological investigation of outbreaks in the state of Minnesota except for in 4 local jurisdictions, while LHDs are responsible for the environmental evaluation of food service establishments during all outbreak investigations within their jurisdiction. A total of 36 responses were collected, 14 were excluded from analysis due to lack of public health agency and/or job title information. A total of 22 responses were analyzed. Training records for validation were not received from any responders. After exclusion of incomplete responses, we estimated a 43% response rate among relevant employees of recruited health departments based upon the number of responders working in health departments as reported by managers (not all

responders attempted the survey).

Table 1 displays the reported education, training, and outbreak investigation experience of epidemiologists and environmental health professionals in the SHD and 3 LHDs in Minnesota. Epidemiologist job titles were reported only in the SHD. Environmental health professionals responded solely from LHDs.

The SHD is led by an experienced and educated supervisor with specialized training from the CDC's Epidemic Intelligence Service. Epidemiologists working at MDH reported having 0-4 years of experience and participation and leadership in dozens of outbreak investigations. Several epidemiologists also reported being student employees in the foodborne disease surveillance unit prior to becoming an epidemiologist. Student employees in the unit reported 1—3 years of experience and participation, but not leadership, in dozens of outbreak investigations.

LHD supervisors reported a median of 24 years of experience and participation in and direction of dozens of complaint-based outbreaks and up to 15 pathogen-specific outbreaks. Local environmental health professionals reported a median of 6 years of work experience, participation in few complaint-based and pathogen-specific outbreaks, but participation in several complaint-based outbreak investigations.

One state laboratory manager and one state laboratory professional responded to our survey. The state laboratory manager reported extensive experience beyond that of the state laboratory professional.

The number of times outbreak investigation responders had participated in CIFOR activities was recorded, but the number of survey responders completing these questions

was three or less in each category of employee. The distribution of reported activities shows that different tasks for different types of outbreak responses are completed at the state and local levels in Minnesota. All responses are recorded in Table 3. Responses are indicated as "skipped" when a survey respondent did not enter a response but skipped on to the next survey question.

Student employees at MDH reported more experience in several epidemiological activities than local environmental health professionals. Student employee activity estimations approached or exceeded the reported experience of state epidemiologists in some instances. Local environmental health professionals reported more experience than state workers in conducting environmental health tasks during complaint-based outbreak investigations. These results are a function of the division of duties during outbreak investigations in the state of Minnesota.

Supervisor responses are shown in Table 4. Again, two different patterns of outbreak investigation activities are presented at the state and local levels. Many CIFOR outbreak investigation activities are performed by either a state or local health department in any outbreak scenario. CIFOR activities not routinely performed by any health department during complaint-based outbreak investigations included contacting the health-care providers of cases who have sought medical attention or to find additional cases, Obtaining stools from food workers, determining if the setting or food item suggests an agent, obtaining environmental samples, and creating a food flow to determine the point of contamination, evaluating the results of an environmental investigation given the identification of an agent and results of epidemiologic

investigation to identify factors most likely to have contributed to outbreak, modifying menus, or reviewing additional abatement procedures in the presence of ongoing transmission. Managers reported that the tasks were often not an appropriate use of resources, lack of cooperation from foodworkers, and the task being the responsibility of another agency as reasons tasks were not routinely performed.

6 of 14 CIFOR practices were reported as being performed by the SHD in 0-25% of pathogen-specific cluster investigations. These activities included interviewing controls, obtaining shopper card records, analyzing case-control data, alerting healthcare, taking additional control steps, and using a statistical program. That the steps were not appropriate was cited as a reason for 3 steps, while specialized explanations were provided for the other steps (such as lack of an epidemiological hypothesis, an obvious food vehicle, or lack of shopper cards).

9 of 17 CIFOR practices were not routinely performed by LHDs in Minnesota during pathogen-specific outbreak investigations. Contacting establishments to determine food providers and common food products, obtaining food samples, conducting informal tracebacks, contacting food service establishments to ask about complaints, tracing the source of the implicated food item from and through distribution, interviewing food workers, and modifying food preparation practices were performed in 25% or less pathogen-specific outbreak responses. That the activity was not appropriate was cited as the most common explanation as to why the activities were not routinely performed.

Discussion

This survey represents a novel approach to ascertaining workforce factors that may be associated with health department performance with an online survey tool. Despite an unrepresentative sample of foodborne disease outbreak responders in Minnesota, the survey did begin to reveal the distribution of different outbreak investigation activities occurring at state and local health departments in 2011.

We experienced a very low enrollment rate among our target population. We experienced difficulties enrolling a large percentage of the Minnesota environmental health workforce by relying on the pre-approval of LHD supervisors. We did not enroll any environmental health professionals working in MDH. In the lack of an incentive to participate, we were only able to enroll 3 LHDs of over 80 in the state. Valid and reliable information capture from complete workforce populations is key to the effective use of training data in a predictive model of public health performance.

Responders had some negative feedback about the design of the survey. Many responders reported that it was very difficult to remember all training exposures after several years of work experience. Many responders had taken graduate level coursework, but there was no opportunity in our survey to report this. Some responders were confused between complaint-based and pathogen-specific outbreaks. Many responders were worried about the accuracy of their estimations of the number of times they had performed activities, and many stopped the survey during these questions. There were also several complaints collected about the overall length of the survey.

An additional limitation to this report is a lack of evaluation of survey validity and

reliability. We received no formal training documentation from respondents and were unable to calculate the validity and reliability of the training histories. Development of easily accessible and easy-to-update electronic training and development databases could improve the validity and reliability of similar surveys in the future. Further attempts to survey the public health workforce should include validity and reliability evaluations.

Our observation of state and local responder training and experience validates the educational model of "Team Diarrhea", the team of graduate student employees who are concurrently completing Masters of Public Health degrees at the University of Minnesota School of Public Health. When hiring epidemiologists, the unit considers hiring student employees who have completed or are very near the completion of their MPH. These candidates typically report 1-3 years of experience at MDH. Student employees have undergone a unique training and culture-building process within the department that make them ideal candidates for more advanced positions in the unit. Student employees are also intimately familiar with the unique processes of the unit. Our survey has validated an existing assumption that student employees also have extensive experience in investigating outbreaks. We conclude that "Team Diarrhea" is an efficient and effective public health preparedness and response training program that trains highly qualified candidates while accomplishing routine surveillance tasks. Evaluations of similar student employment/internship programs in public health surveillance programs have been published, and we encourage the continued evaluation of such programs to improve the efficiency and effectiveness of epidemiology training (37-39).

Our work experience methods were not effective in collecting representative data

on the distribution of experience among state and local responders. The data do, however, suggest that student employees at the state health department are similarly experienced in many outbreak tasks as the epidemiologists that supervise them, for example in speaking with healthcare professionals and while interviewing outbreak cases and food service workers. An improved method of documenting work experience information that is not so tedious for the survey respondent is needed, as well as a validation of the validity and reliability of the exposure questions.

Our survey was able to distinguish the different activites performed by different levels of governmental public health agencies in Minnesota. These distributions of activities are a function of the legal jurisdictions of the responding LHDs, the requirements of the LHDs from MDH in terms of quality, the unique needs of each outbreak investigation, and the performance of the health department. Several CIFOR activities are performed regularly by state and local health agencies. Those that are not performed usually require exceptional circumstances to be appropriate or are the responsibility of another agency.

Table 1. Foodborne Disease Outbreak Survey Respondent's Training and Work Experience.

Job	n (#)	Yrs Exp.	# Complaint Outbreak Participate Median (Range)	# Complaint Outbreak Direct Median (Range)	# Pathogen Outbreak Participate Median (Range)	# Pathogen Outbreak Direct Median (Range)	# PhD, # MPH /MS	Special Training
State Epi. Supv.	1	12	10	700	20	500	1, 0	CDC EIS
State Epi. Staff	6	2 (0-4)	30 (20-50)	46.5 (18-30)	27.5 (20-60)	23 (6-40)	0, 6	CSTE Epi Fellow, Student Employee
State Student Staff	5	2 (1-3)	16 (15-120)	NA	40.5 (1-80)	NA	0, 0	Student Employee
Local EH Supv.	3	24 (5-28)	32.5 (30-35)	13.5 (12-15)	8.5 (2-15)	1.5 (0-3)	0, 2	Registered Sanitarian
Local EH	5	6 (4-15)	2 (1-15)	50	1 (0-2)	NA	0, 1	Registered Sanitarian
State Lab Supv.	1	9	0	0	2	12	0, 1	None
State Lab Staff	1	1	2	0	3	NA	0, 1	None

Table 1 displays the job descriptions and reported work and training exposures of foodborne disease outbreak responders at MDH and in 3 LHDs. Column 2 shows the number of survey respondents who reported each job description in column 1. Columns 3 and 4 show the number of complaint-based outbreak investigations that respondents reported participating in and directing over their entire public health work history, while columns 5 and 6 show this experience during pathogen-specific outbreak investigations. Colum 7 describes the number of respondents who reported having a PhD/DVM/MD and an MPH/MS degree. Column 8 describes outbreak investigation-related special trainings that survey respondents reported.

Table 2. CIFOR Guidelines to Improve Outbreak Response Chapter 5 Outbreak Investigation Activities.

Code	Outbreak Investigation Activity
CEpi1	Contact health-care providers of cases who have sought medical attention.
CEpi2	Interview cases to characterize symptoms, incubation period, and duration of illness.
CEpi3	Obtain stool from cases.
CEpi4	Establish case definition based on confirmed diagnosis or clinical profile of cases.
CEpi5	Obtain from event organizer a list of persons attending an event, or, if possible, list of persons patronizing the establishment during the outbreak period.
CEpi6	Interview persons who attended event or patronized establishment to determine attack rates, by time.
CEpi7	Contact health-care providers to identify additional persons seeking medical care who meet the case definition.
CEpi8	Interview identified cases and controls or well meal companions about exposure sources. Calculate odds ratios for specific exposures.
CEpi9	Calculate odds ratios for specific exposures without a statistical computation package.
CEpi10	Interview persons with identified exposures to determine attack rates and relative risks for specific exposures.
CEpi11	Combine descriptive and analytical epidemiology to develop a model for the outbreak.
CEpi12	Summarize information to identify confirmed or suspected agent.
CEpi13	Summarize information to identify confirmed or suspected food vehicle.
CEpi14	On the basis of agent, incubation period, and likelihood of secondary spread, create epidemic curve, and evaluate the course of the epidemic to determine whether additional cases may still be occurring.
CEpi15	If outbreak appears to be ongoing, review potential abatement procedures.
CEnv1	Interview management to determine whether it has noticed any ill employees or any circumstances that could be the cause of a foodborne illness.
CEnv2	Interview Foodworkers to determine illness. This activity could also be conducted by nursing/healthcare staff.
CEnv3	Obtain stool from ill or all food workers. This activity could also be conducted by nursing/health-care staff.
CEnv4	Obtain and store samples of implicated and suspected food items and ingredients.
CEnv5	Determine whether setting or food item suggests a likely pathogen.
CEnv6	Obtain lists of reservations for establishment, credit card receipts, receipts for take-out orders, inventory of foods ordered at establishment, or guest lists for events. Where possible, obtain information electronically.
CEnv7	Obtain menu from establishment or event.
CEnv8	Interview food workers to determine food-preparation responsibilities.
CEnv9	Reconstruct food flow for implicated meal or food item.
CEnv10	Identify contributing factors.
CEnv11	Obtain samples of implicated food.
CEnv12	Obtain environmental samples from food contact surfaces or potential environmental reservoirs.
CEnv13	Evaluate food flow for implicated meal or food item to identify contamination event at point of preparation or service.
CEnv14	If no contamination event is identified, trace source of ingredients of implicated food item back through distribution to point where a contamination event can be identified or, if no contamination events can be identified during distribution to source of production.
CEnv15	Evaluate results of environmental investigation, given identification of agent and results of

	epidemiologic investigation, to identify factors most likely to have contributed to outbreak.
CEnv16	Implement control measures to prevent further exposures.
CEnv17a	Verify that all food workers who pose a risk for transmission have been excluded.
CEnv17b	Verify that potentially contaminated foods have been properly disposed.
CEnv17c	Verify that food contact surfaces and potential environmental reservoirs have been adequately cleaned and sanitized.
CEnv17d	Train staff in safe food-handling practices.
CEnv17e	Modify food-production and food-preparation processes.
CEnv17f	Modify menu.
CEnv18	If any of these measures cannot be verified, review additional abatement procedures, or if further exposure appears likely, alert public or close premises.
PEpi1	Interview cases as soon as possible with standardized trawling questionnaire to identify potential common exposures. In some situations, cases are interviewed as soon as they are reported and before an outbreak has been recognized.
PEpi2	Establish case definition on the bases of characteristics of the agent that led to detection of outbreak.
PEpi3	Characterize cases by person, place, and time, and evaluate the descriptive epidemiology to identify pattern potential associated with particular food items or diets.
PEpi4	Compare trawling questionnaire exposure frequencies against known or estimated background exposure rates, such as those found in the FoodNet Atlas of Exposures, to identify suspected food item.
PEpi5	Interview non-ill community controls or non-outbreak associated ill persons to obtain detailed exposure information to be used in a case-comparison analysis of exposures.
PEpi6	Obtain shopper card information to identify and verify grocery purchases.
PEpi7	Document brand names and product code information for prepackaged food items.
PEpi8	Analyze exposure information comparing cases to relevant comparison group (e.g., non-ill controls or cases not associated with outbreak) to implicate food item or nonfood-exposure source.
PEpi9	Alert health-care providers of possible outbreak to identify additional persons seeking medical care, and review laboratory reports and medical charts at hospitals or physician's offices to identify potential cases.
PEpi10	Ask cases if they know others who are similarly ill.
PEpi11	Depending on the nature of the outbreak, take additional steps as warranted. Examples include reviewing employee or school absences, reviewing death certificates, surveying population affected, or directly asking members of the public to contact the health department if they have the illness under investigation.
PEpi12	Combine descriptive and analytical epidemiology results to develop a model for the outbreak using a statistical computation package.
PEpi13	Summarize information to identify confirmed or suspected food vehicle.
PEpi14	Create and evaluate epidemic curve to determine whether additional cases might still be occurring.
PEpi15	If outbreak appears to be ongoing, continue surveillance, and review potential abatement procedures.

Table 2 shows the CIFOR Guidelines to Improve Foodborne Outbreak Response outbreak investigation activities that were inquired about in the survey as well as their code shown in Table 3.

Table 3. Self-Reported Number of Times Ever Participated in Model Foodborne Disease Outbreak Investigation Activities, by State and Local Public Health Employee Level, Minnesota, 2011.

Practice	State Epi	State Student	Local EH
CEpi1	230, 50, 3	100,100	Skipped
Cepi2	500, 50	100, 120, 600	3,4,15
CEpi3	50, 10	5, 20, 24	1
CEpi4	30, 13	32	Skipped
CEpi5	30, 8	32	4
CEpi6	5, 47	100, 120, 32	3,5,2
CEpi7			
CEpi8	200,50	100, 120	3,5
CEpi9	15, skipped	skipped	5
CEpi10	never, 50	100, 120	3
CEpi11	never, 13	10	Skipped
CEpi12	30, 13	skipped	Skipped
CEpi13	30, 13	10	Skipped
CEpi14	15, 8	1	Skipped
CEpi15	15, skipped	skipped	1,2,5
CEnv1	10,4,0	skipped	3, 15
CEnv2	200,15,30	100,40,0	1, 6
CEnv3	15,50,10	5,0	
CEnv4	10, skipped, 5	skipped, skipped,1	2, 4
CEnv5	35,5,80	skipped, skipped	
CEnv6	30,40,80	none	6
CEnv7	30,8,80	never,3	1,7
CEnv8			
CEnv9			
CEnv10	7, skipped,5	skipped, skipped,1	2,2
CEnv11	5, skipped,5	skipped, skipped, skipped	1
CEnv12	200,3,80	100, skipped	6
CEnv13	30, skipped,50	skipped,1	
CEnv14	5, skipped,75	skipped,1	3
CEnv15	5, skipped,3	skipped, skipped	4,3
CEnv16	35,13,80	skipped, skipped	3
CEnv17a	35,8,80	30	1,4
CENV17b	30, skipped,80	skipped, skipped	6
CEnv17c	30, skipped,80	skipped, skipped	1,6
CEnv17d	30, skipped,10	skipped, skipped	3
CEnv17e	Skipped, skipped, skipped	skipped, skipped	2
CEnv17f	1, skipped, skipped	skipped, skipped	Skipped
CEnv18	skipped, skipped, skipped	skipped, skipped	
PEpi1	1000, 100	80	
PEpi2	100,5	skipped	

PEpi3	100,55	skipped	
PEpi4	10,3	skipped	
PEpi5	50,3	3	
PEpi6	10,4	skipped	
PEpi7	100,100	80	
PEpi8	100,35	skipped	
PEpi9	skipped,25	skipped, skipped	
PEpi10	100,100	80	
Pepi11	100,3	skipped, skipped	
PEpi12	100,15	skipped	
PEpi13	100,31	1	
PEpi14	100,9	skipped	
PEpi15	100,3	skipped	

Table 3 shows all estimations of the number of times each outbreak investigation task had ever been completed throughout a responder's work experience collected in our survey. The table shows these responses categorized by three job descriptions, epidemiologists at MDH, student employees at MDH, and environmental health professionals in LHDs in Minnesota.

Table 4. Percentage of Foodborne Disease Outbreak Investigations where Model Practices are Performed, by Level of Government, Minnesota, 2011.

Activity	% of Outbreaks Performed, State	% of Outbreaks Performed, Local
CEpi1	0%-25%	0%-25%
Cepi2	76%+	76%+
CEpi3	76%+	76%+
CEpi4	76%+	76%+
CEpi5	76%+	76%+
CEpi6	76%+	76%+
CEpi7	0%-25%	0%-25%
CEpi8	76%+	76%+
CEpi9	0%-25%	76%+
CEpi10	0%-25%	76%+
CEpi11	0%-25%	76%+
CEpi12	76%+	76%+
CEpi13	76%+	76%+
CEpi14	76%+	76%+
CEpi15	76%+	76%+
CEnv1	0%-25%	76%+
CEnv2	26%-50%	76%+
CEnv3	0%-25%	0%-25%
CEnv4	0%-25%	0%-25%
CEnv5	76%+	76%+
CEnv6	26%-50%	76%+
CEnv7	76%+	76%+
CEnv8	X	X
CEnv9	X	X
CEnv10	0%-25%	0%-25%
CEnv11	0%-25%	0%-25%
CEnv12	26%-50%	76%+
CEnv13	0%-25%	76%+
CEnv14	0%-25%	76%+
CEnv15	0%-25%	0%-25%
CEnv16	76%+	76%+
CEnv17a	51%-75%	76%+
CEnv17b	0%-25%	76%+
CEnv17c	0%-25%	76%+
CEnv17d	0%-25%	76%+
CEnv17e	0%-25%	51%-75%
CEnv17f	0%-25%	0%-25%
CEnv18	0%-25%	0%-25%
PEpi1	76%+	
PEpi2	76%+	
PEpi3	76%+	
PEpi4	76%+	
PEpi5	0%-25%	
PEpi6	0%-25%	

PEpi7	76%+	
PEpi8	0%-25%	
PEpi9	0%-25%	
PEpi10	76%+	
Pepi11	0%-25%	
PEpi12	0%-25%	
PEpi13	76%+	
PEpi14	76%+	
PEpi15	76%+	
PEnv1		0%-25%
PEnv2		0%-25%
Penv3		0%-25%
PEnv4		0%-25%
PEnv5		76%+
PEnv6		0%-25%
PEnv7		0%-25%
PEnv8a		76%+
PEnv8b		76%+
PEnv8c		0%-25%
PEnv8d		0%-25%
PEnv9		76%+
PEnv10		76%+
PEnv11		76%+
PEnv12		76%+
PEnv13		76%+
PEnv14		0%-25%

Table 4 shows the percentage of outbreak investigations where MDH and LHDs performed CIFOR Guidelines to Improve Foodborne Outbreak Response-recommended outbreak investigation activities. Tasks related to complaint-based outbreak investigations precede tasks related to pathogen-specific outbreak investigations in Table 4. For further explanation of each task code, reference Table 3.

Chapter 2. Routine *Salmonella* and *E. coli* O157:H7 Surveillance Processes, Minnesota Health Department, 2009-2011

Methods

The purpose of this evaluation was to quantitatively and qualitatively evaluate the processes performed at the Minnesota Department of Health (MDH) during routine *Salmonella* and *E. coli* O157:H7 surveillance, characterize the processes used to detect and investigate foodborne disease outbreaks, and evaluate the completeness and timeliness of those processes in calendar days where public customers are at risk.

Our lead evaluator (EEH) conducted interviews with key MDH staff and supervisors to qualitatively describe the context and design of the bacterial foodborne pathogen-specific surveillance system. Workforce information was obtained in an electronic survey of surveillance system staff administered by academic partners in 2011 (EEH, CWH). Additional methods and results of the survey are contained in Chapter 1 of this thesis. MDH authors (EEH, CM, KES) contributed to the map of the routine surveillance process and selected appropriate performance metrics for the evaluation purpose in focus groups. Quantitative performance data was abstracted from electronic disease surveillance databases, laboratory databases, and paper copies of case reports and case interviews by our lead evaluator (EEH).

Cases were defined as unique case-person specimens/isolates that under MDH processes warrant an exposure history interview. Carrier case-isolates, secondary, tertiary, and childcare outbreak-associated cases were excluded from analysis. Cases that

were classified as interviewed had a paper interview record that showed consent to initiate the exposure history interview had been obtained and three CDC FoodNet questions (case race, ethnicity, travel history, and date of onset) had been answered. Cases classified as lost to follow-up were unable to be interviewed or refused an interview upon contact.

The Minnesota exposure history questionnaire involves three food exposure history sections: 1) a list of food service establishments patronized; 2) A freely-recalled food exposure history; and 3) an 85 food item-specific consumption and purchase history questions, all within the 7 days prior to the illness onset. Food histories were classified as complete if the food item-specific questions had been thoroughly completed. Additionally, food histories were classified as complete if the case was interviewed as part of a known outbreak and answered targeted outbreak exposure questions, even if no routine food history was obtained, or if the case was an infant on a formula or breast milk diet. Known secondary, tertiary, and daycare-associated cases were not routinely asked about food history and were excluded from analysis.

For a majority of all reported *Salmonella* and *E. coli* O157:H7 cases, the time of isolate or stool specimen receipt at the public health lab represents the instant that MDH is aware of a case and can begin taking action to reveal details about that case that may lead to the detection of a cluster. Two details are usually prerequisite to outbreak detection and investigation: The molecular subtype of the isolate as ascertained by PFGE, and the food exposure history of the case as ascertained in a telephone interview. To support our evaluation goal of describing the performance of routine MDH processes to

detect outbreaks, median days from public health laboratory specimen/isolate receipt to day of pulsed field gel electrophoresis (PFGE)-pattern upload to CDC's PulseNet and day of case interview were calculated from dates in a laboratory database and on paper interview forms. Results were measured in calendar days. These metrics were selected on the basis of evaluating metrics that had potential relevance to MDH customers, primarily, the public. During an outbreak investigation, the public is at risk for foodborne illness for calendar days while they could be eating contaminated foods. We therefore evaluated calendar days to express the timeliness of MDH processes as they relate to the public customers of the health department, as opposed to work days as is often reported to federal agency-customers for quality assurance purposes.

Outbreak definitions were taken from Bender et al.'s evaluation of molecular subtyping performed at MDH (23). An outbreak was defined as two or more cases in separate households with a common epidemiologic exposure. A cluster was defined as two or more cases involving the same subtype, occurring within two weeks of each other, which may or may not have become a confirmed outbreak after epidemiologic, environmental, and regulatory investigation.

All data analysis was performed with Microsoft Excel 2010 (Microsoft Corp., Redmond, WA).

Surveillance Context, Design, and Budget

Salmonella and *E. coli* O157:H7 are reportable foodborne pathogens in the state of Minnesota. Healthcare providers are required to send specimens or isolates of

foodborne pathogens directly to the state public health laboratory within 24 hours of clinical identification under Minnesota state administrative rules. The centralized reporting structure of the system is of note because it creates a surveillance catchment population of considerable scale (~3,000,000) and does not require specimens, isolates, or case reports to be routed through local health authorities before being counted and noticed at the state level. Thus times from stool sample collection to PFGE-pattern upload and case interview may be lower in Minnesota than in other states and nations due to highly centralized reporting laws. The written mission statement of the foodborne disease surveillance unit at MDH is to perform representative and complete surveillance of all cases of foodborne pathogens within the state. This centralized process design supports the written mission of the unit as well as an unwritten but culture-based goal encompassing rapidly and completely identifying, investigating, and responding to foodborne disease outbreaks.

It is notable that not all cases of Salmonella or E. coli O157:H7 are first reported to MDH through the submission of a laboratory specimen to the public health lab. Occasionally, MDH receives an electronic report of a case from an infection control practitioner before the specimen is received at the laboratory, however these instances are relatively rare compared to the number of instances where a specimen is received at the laboratory before the receipt of a case report. It is also notable that not all clusters are detected through the evaluation of PFGE patterns. Some clusters and outbreaks are detected through the use of a telephone/electronic foodborne illness reporting “hotline”, again however, these instances are rare compared to the number of instances where

clusters are detected through the evaluation of PFGE patterns. For this reason, the process of obtaining and analyzing information through the complaint hotline is not described here.

Staff Education and Experience

Table 5 describes the self-reported education and work experiences of foodborne disease surveillance unit staff responsible for the collection of case exposure histories through telephone interviews as well as the detestation outbreaks. MDH is led by an experienced and educated supervisor with specialized training from the CDC's Epidemic Intelligence Service. Epidemiologists working at MDH reported having 0-4 years of experience and participation and leadership in dozens of outbreak investigations. Several epidemiologists also reported being student workers on the foodborne disease surveillance unit prior to becoming an epidemiologist. Student employees in the unit report 1—3 years of experience and participation, but not leadership in dozens of outbreak investigations.

Surveillance Process

Figure 1 describes the MDH process of obtaining PFGE subtypes and case interviews. Process steps within MDH units and handoffs between MDH units are shown. Potential and certain overnight delays are indicated by dashed or solid lines within unit process boxes. Three specific time points are relevant for our timeliness evaluation; 1) the receipt of a specimen or isolate in the public health lab, representing the moment at

which the surveillance system is notified of a disease case; 2) the interview of the case, representing the ascertainment of case exposure history; and 3) the upload of the PFGE subtype to PulseNet, representing the ascertainment of the molecular subtype of the pathogen.

The MDH enteric disease laboratory receives specimens and isolates from healthcare providers Monday through Saturday. The lab reports specimen and isolate receipts to the surveillance unit every business day and processes specimens into isolates for PFGE beginning on Monday through Saturday, over a period of 1-4 days, depending on the specimen type, pathogen, and day of receipt. Upon notification of specimen and isolate receipts, the surveillance unit assesses the receipts for potential temporal clusters and communicates findings to the PFGE lab. Surveillance then immediately contacts the case for interview. Once the enteric lab has prepared isolates for PFGE, the isolates are handed off to the PFGE lab and the process is run overnight. When the PFGE lab has obtained the PFGE results, it analyzes and uploads the results to CDC's PulseNet on the same day. The PFGE lab immediately report results of temporal cluster isolates to the surveillance unit with a telephone call, while all other results are reported on the next business day via laboratory-epidemiology reporting software. Surveillance student paraprofessionals work weekdays, weeknights, and Sunday evenings to contact and interview reported cases, independent of the PFGE process progress in the enteric or PFGE lab.

Experience has taught the surveillance unit that the receipt, interview, or PFGE subtyping of a single new case can trigger the detection a new cluster or solve an existing

cluster, so critical evaluation of spatial and temporal trends in specimen/isolate reporting and exposure histories is conducted throughout the surveillance unit process. Epidemiologists continuously evaluate data sources, looking for clues relevant to spatial and temporal clusters, along with exposure history factors. This provides a theoretical basis for the assumption that epidemiologists with experience investigating hundreds of foodborne disease outbreaks may have an advanced perception of how to examine available data sources for clues that identify the common source of a foodborne disease outbreak.

In addition to PFGE subtyping all Minnesota isolates, the PFGE lab also subtypes isolates of foodborne pathogens for the State of Nebraska. This represents work flow that the PFGE Lab must complete, and that may affect performance metrics.

Performance

From 2009-2011, 1968 unique case-isolates of *Salmonella* and 415 unique case-isolates of *E. coli* O157:H7 were submitted to MDH. Two-hundred and thirty four clusters and 42 confirmed outbreaks of *Salmonella* and 54 clusters and 23 confirmed outbreaks of *Escherichia coli* O157:H7 were recorded. Frequency, completeness, and timeliness of the case interview and PFGE subtyping processes are shown in Table 3. Case interview and food history completion percentages were similar and consistent for both *Salmonella* and *Escherichia coli* O157:H7 in all three study years. Specimen/isolate receipt to case interview timeliness appeared to be faster for *Escherichia coli* O157:H7 than it was for *Salmonella* (median 5 vs. 7), however specimen/isolate receipt to PFGE

upload timeliness appeared to be faster for *Salmonella* than for *Escherichia coli* O157:H7 (Median 3 vs. 4). Some timeliness improvement was evident among all 4 processes evaluated from 2009 to 2011.

Discussion

The process map (Figure 1) described in this report may serve as an effective visual model to describe the routine surveillance processes at MDH. Both investigators and staff noted that the process of creating the map inspired a shared mental model of the surveillance process for MDH staff to reference and teach in the future.

It may be possible in the future to determine optimal staffing levels, governmental labor and public health laws, and other preparedness efforts with comparative effectiveness research across several agencies within similar contexts.

The extent to which the context, program budget, and surveillance processes contribute to the performance of MDH's surveillance program cannot be quantified at this time. The replication and comparison of similar evaluations at other health departments would foster comparative effectiveness research to describe the contributions of these theoretical predictive factors. However, we do not suggest that the evaluation of surveillance systems for the purposes of comparison is practical. We suggest that internally-led evaluations tailored to specific evaluation questions, within the context of the surveillance system and its written mission statement are most practical for surveillance programs hoping to quantify and improve their performance.

Minnesota state professionals involved in the epidemiologic surveillance of

foodborne diseases reported several years of experience in foodborne disease outbreak investigation and substantial experience in responding to foodborne diseases in the past. A closer examination of the education and training of foodborne disease outbreak responders in Minnesota is described in Chapter 1 of this thesis. The extent to which the training and work experiences of foodborne disease responders contribute to program performance cannot be ascertained without the replication of similar evaluations and comparative effectiveness research.

A novel quantitative performance evaluation of foodborne disease surveillance processes has been presented. To our knowledge, this is one of few foodborne disease surveillance system evaluations describing the frequency of, completeness of, and timeliness of specific surveillance processes. We value a holistic approach to surveillance system evaluation and appreciate this balanced-scorecard approach to performance evaluation. It is also important to recognize that this evaluation had a specific purpose: to measure the ability to which MDH was capable of producing informational products that are prerequisite to the detection of almost all pathogen-specific outbreaks in MDH's nearly 20 year experience. A balanced-scorecard approach evaluating the process with the tools used within, and frequency, completeness, and timeliness metrics, was a desirable evaluation strategy to answer our evaluation question. Therefore we stress the importance of the specific evaluation question at hand when performing quantitative performance evaluations in the future.

Figure 1. Minnesota Department of Health Routine *Salmonella* and *E. coli* O157:H7 Surveillance Process.

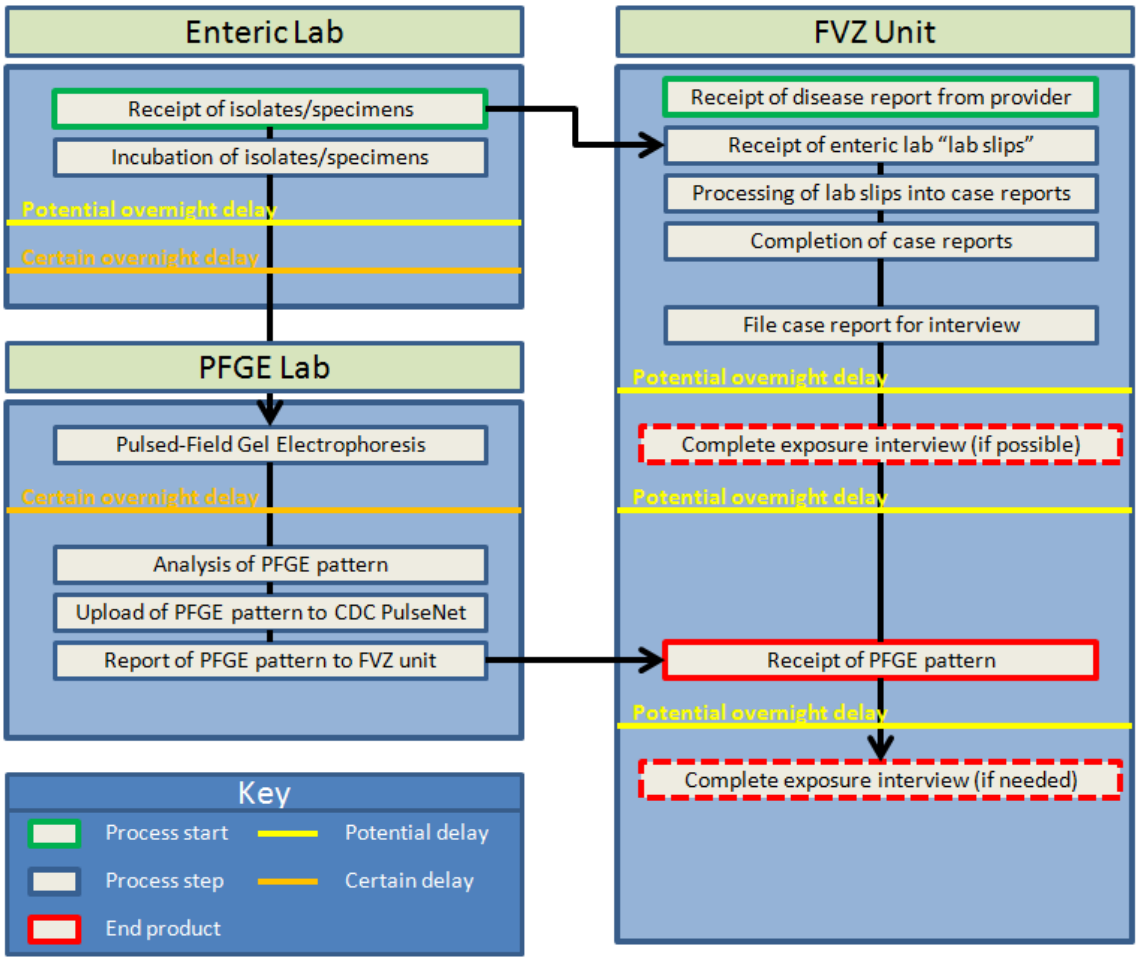


Figure 1 displays the routine process conducted at MDH to produce PFGE patterns and case food exposure histories, often necessary for the detection and successful investigation of outbreaks.

Table 5. Foodborne Disease Surveillance Unit Staff Training and Experience, Minnesota Department of Health, 2011.

Job Title	n	# with Doctoral Degree, # with MPH	Median Years of Work Experience (Range)	Outbreak Investigation Training
Epidemiologist Supervisor	1	1, 0	12	CDC Epidemic Intelligence Service
Epidemiologist Principal	1	1, 0	13	Student Employee
Epidemiologist	4	0, 3	5.25 (2-10)	CSTE Epidemiology Fellow (1), Student Employee (4)
Epidemic Intelligence Service Officer	1	1, 0	1	CDC Epidemic Intelligence Service
Surveillance Support Staff	2	0, 0	11 (10-12)	None
Student Paraprofessional Sr.	7	0, 0	.91 (.16-2)	Student Employees

Table 5 displays the education, work experience, and foodborne disease outbreak-related training of staff in the Foodborne, Vectorborne, and Zoonotic Disease investigation unit at the Minnesota Department of Health.

Table 6. Frequency, Completeness, and Timeliness of *Salmonella* and *E. coli* O157:H7 Surveillance Processes, Minnesota Department of Health, 2009-2011.

Frequency	*Salmonella*			*E. coli* O157:H7		
	2009	2010	2011	2009	2010	2011
# Unique Case-Isolates	575	693	700	130	139	146
# Cases Lost to Follow-Up	77	100	62	16	8	5
# Secondary Cases Identified	7	2	4	0	3	1
# Clusters Investigated	75	87	72	20	13	21
# Confirmed Outbreaks	12	15	15	11	4	8
Completeness						
# PFGE Upload (%)	454* (79)	648 (93)	658 (94)	114* (88)	134 (96)	135 (92)
# Cases Interviewed (%)	492 (85)	601 (87)	638 (91)	120 (92)	132 (95)	140 (96)
# Food History Complete (% of Cases not LTF or Secondary)	475 (96)	566 (96)	589 (93)	114 (94)	124 (97)	128 (91)
Timeliness						
Median Days from Isolate Receipt to PFGE Upload (Range)	3 (1-30)	3 (1-38)	2 (2-13)	4 (2-28)	4 (2-29)	3 (2-10)
Median Days from Isolate Receipt to Case Interview (Range)	7 (-15-65)	7 (-8-115)	6 (-10-44)	6 (-15-35)	5 (-21-34)	3 (-6-79)

*A national crash of the PulseNet reporting software resulted in significant missing data. PFGE patterns were reported to PulseNet via email during the crash.

Chapter 3. Time Series Analysis of Foodborne Disease Surveillance Process Performance, Minnesota, 2009-2011

Methods

Two products produced by routine MDH surveillance processes are frequently prerequisite to the detection and successful investigation of clusters and outbreaks of *Salmonella* and *E. coli* O157:H7: the production of a pulsed field gel electrophoresis (PFGE) pattern, and the production of case exposure history through a standardized case interview. The processes used to create these products have been described in Chapter 2 of this thesis. This evaluation was intended to investigate the timeliness of these processes in time series in order to detect temporal trends and improvement opportunities for routine *Salmonella* and *E. coli* O157:H7 surveillance. Thus, we reviewed electronic and paper records, including original case reports and case interviews, from all reported cases of *Salmonella* and *E. coli* O157:H7 in Minnesota from January 1, 2009 to December 31, 2011.

Timeliness in days from public health laboratory (PHL) receipt of isolates to PFGE pattern upload to CDC's PulseNet was evaluated as a proxy to determine how long it took MDH to produce case-definition information needed to optimize the detection of outbreaks. Dates of PHL receipt and PFGE pattern upload were extracted from laboratory databases in Microsoft Excel 2007.

Timeliness in days from PHL receipt of isolates to case interviews was evaluated as a proxy to determine how long it took MDH to produce case exposure history needed to

detect outbreaks. Dates of case interviews were recorded by hand on individual case interview forms and were abstracted from paper records into a Microsoft Excel 2007 database.

We attempted to evaluate the stability and capability of each of the 4 processes (two for *Salmonella*, 2 for *E. coli* O157:H7) using XMR charts. We evaluated the stability and capability of each process using run charts. Last, we plotted the raw data of each process in a time series to detect and evaluate other subtle trends in performance data that may be missed on statistical process control charts. A Root Cause Analysis (RCA) was initiated to determine the cause of a performance aberration evident in one raw data time series. A focus group was held to determine the root causes of unusually delayed case interviews and cases lost to follow-up. Detailed charting methods are described below.

All data analysis was performed using Microsoft Excel 2007 (Microsoft Corp., Redmond, WA).

XMR-Chart Methods

An XMR chart is series of two charts that plot individual data in a time series in consecutive process iteration order, along with superimposed "control limits". The MR chart is developed and analyzed, and if satisfactory, an X chart is developed and analyzed. Both charts indicate whether or not the performance of the process is predictable with 99.7% confidence, in other words, whether or not the process is statistically "stable" and the level of performance at which it is "capable".

The "moving range" (MR) data are first calculated by subtracting the value of

timeliness of process iteration *i* from iteration *i*+1. The absolute values of each moving range data point are summed and divided by the number of observations, or *k*-1 to create the statistic *MRbar*. The average of the individual data is also calculated as *Xbar*.

The MR data are then plotted in time series under the statics *MRbar* and Upper and Lower Control Limits (*UCLmr* and *LCLmr*). *UCLmr* is calculated as *D3 * MRbar*, while *LCLmr* is calculated as *D4 * MRbar*. Values for *D3* and *D4* are a function of the number of observations in the control chart and are listed in reference tables (40). The MR chart is considered valid if no MR observation lies outside of the limits set by *UCLmr* and *LCLmr*.

The "Individual" (X) chart is a time series chart of actual process data. The process performance mean and upper control limits (*UCLx*) and lower control limits (*LCLx*) are overlaid on top of the time series. The UCL is calculated as *Xbar + A2 * MRbar*, while the LCL is calculated as *Xbar - A2 * MRbar*. Values for A2 are a function of the number of observations in the control chart and are listed in reference tables (40). In the X chart, the presence of any number of patterns indicates special-cause variation, including:

1) Individual data points lying outside of the limits set by *UCLx* and *LCLx*
2) Too few or too many runs (one or more data points above or below the median). (We expected 12-24 runs for charts with 34-36 observations.)
3) Long runs (runs of 8 or more data points)
4) Trends (monotonically increasing or decreasing runs of 6 or more data points)
5) Zigzag pattern (patterns of 14 or more data points that alternatively lie above and below the median).

If the X-chart passes all of these tests, a process is said to be stable and capable at the mean level of process performance. If the X-chart is unable to pass one or more of the tests, that is an indication to investigate in detail the root causes of performance anomalies.

We calculated the monthly timeliness average of all 4 processes for all 36 months of the study period. From these data, we calculated the necessary statistics for an MR chart. X charts were not completed on the basis of MR chart performance.

Run Chart Methods

Run charts are another statistical process control chart. Unlike XMR charts, they do not require data to fall within statistical control limits in order to be valid, and are thus less sensitive to detecting special cause events in process performance.

We calculated the monthly timeliness average of all 4 processes for all 36 months of the study period. We plotted this in a time series and superimposed the median of all monthly timeliness averages over the time series to create a run chart. We evaluated run charts for special cause by looking for the following four patterns that indicate special cause:

1) Too few or too many runs (one or more data points above or below the median). (We expected 12-24 runs for charts with 34-36 observations.)
2) Long runs (runs of 8 or more data points)
3) Trends (monotonically increasing or decreasing runs of 6 or more data points)
4) Zigzag pattern (patterns of 14 or more data points that alternatively lie above

and below the median).

Raw Data Methods

We evaluated raw data in a time series to detect interesting patterns that may not be present in XMR or run charts. Timeliness data for all 4 processes were charted in a time series by consecutive isolate received. Raw data time series charts were qualitatively reviewed and one RCA focus group involving investigators (EEH, CM, KES) and MDH staff was initiated by our MDH project lead (CM).

Results

Annual median and mean process timeliness performance data are presented in Table 8.

MR charts for the 4 processes are shown in in Figures 2-5. None of the four processes under evaluation had moving ranges that satisfied MR chart variability rules, so complete XMR charts were not made or evaluated.

Run charts of the four processes under evaluation are shown in Figures 6-9. Both processes producing PFGE patterns and the *Salmonella*-specific interview process were found to be unstable due to a lack of expected runs and the presence of long runs. All three processes contained a long run from months 26-36, suggesting a systematic change that resulted in sustained, improved performance in the system near the end of 2010 (Figures 6-8). The process of case interviewing *E. coli* O157:H7 case-isolates was found to be stable over three years at a capability of 6.5 days (Figure 9).

Raw data time series charts are shown in Figures 10-13. Of note to investigators in these charts was an apparent dramatic decrease in performance of the *Salmonella* case-interview process in the months of July and August of 2010, as shown in the center of Figure 11. Average timeliness during these two months was higher than during the same months in 2009 and 2011 (median 9.5 days vs. 6.5 days and 6 days). Our MDH project lead (CM) decided to investigate unit resources in determining the root cause of this anomaly. Collaborative root cause analysis concluded that a large number of ongoing *Salmonella* cluster and outbreak investigations ongoing in July and August of 2010 forced MDH to attempt to interview cluster and outbreak cases sometimes months after the receipt of an isolate. 5 *Salmonella* outbreak investigations were ongoing in 2010, while there were just 2 in 2009 and 1 in 2011. MDH protocol is to apply extra effort to interview cases thought to be part of outbreaks on the basis of their PFGE pattern, even if it means attempting interviews months after isolate receipt. In instances when a case of *Salmonella* could not be interviewed within 45 days and was not known to be part of an outbreak, MDH would routinely classify the case as "lost to follow-up" and the data point would appear in the time series as missing data. Thus, in MDH's unique process, average timeliness from isolate receipt to case interview was sacrificed to improve interview completion percentages among high-priority cluster and outbreak cases with the goal of improving the quality of epidemiologic data informing cluster investigations. We have termed this process-specific artifact the "cluster investigation burden".

Lastly, a focus group was convened to understand the root causes of case-isolates that had unusually long time intervals between the PHL isolate receipt and the case

interview. Results of this focus group are displayed in an Ishikawa diagram in Figure 14. One or more of the three main contributing causes may trigger a delayed case interview or loss to follow-up: an issue in the surveillance unit, an issue in the lab, or an issue with the case. Several other more specific contributing factors are listed in the diagram as they are associated with the three main causes. Any case that had a delayed interview or that was lost to follow-up was likely associated with one or more of these factors, but this diagram has not been validated.

Discussion

We have described the timeliness of four specific processes to produce PFGE patterns and case interviews in a foodborne disease surveillance program in Minnesota. Labs participating in CDC's PulseNet are expected to meet certain times to PFGE pattern upload, and our evaluation shows that the enteric and PFGE labs worked together to produce average results that met or exceeded CDC's Public Health Emergency Preparedness Cooperative Agreement target levels from 2009-2011 (3 days for *E. coli* O157:H7).

Kleinman and Abrams noted that statistical process control methods may be too restrictive to evaluate real and complex surveillance methods (41). Our finding of lack of statistical control for all four processes is not surprising, given that the written mission of the surveillance team does not include timely and consistent outbreak response processes. Department processes are designed to a great extent to provide consistent and outstanding timeliness results, as discussed in Chapter 2 of this thesis, but other missions that the

organization is committed to prevent the generation of statistically stable performance data. The written mission of the surveillance unit is to conduct complete surveillance activities, and not to provide consistently low times to case interview.

Over 3 years of analysis, we observed an unstable process for uploading *Salmonella* PFGE patterns and a stable and capable process for uploading *E. coli* O157:H7 PFGE patterns. The finding of process instability in run charts is a testament to the value of their use. Our application of run charts to public health response data revealed potential clues to special, correctable causes in process performance and suggested and improvement over 3 years of evaluation. We conclude that run charts may be a useful tool for demonstrating improvement and identifying times at which root causes of public health preparedness and response performance can be studied and public health processes improved.

Our description of the effect of the cluster investigation burden on timeliness performance should bear relevance to the evaluation of surveillance systems with processes similar to those of MDH. The description of this factor highlights the importance of a holistic, balanced-scorecard approach to public health program performance, especially foodborne disease surveillance. While MDH acted in the best interests of complete surveillance, its written mission, and effective outbreak investigation, its performance in terms of timeliness was negatively impacted. Without our analysis which led to the description of the cluster investigation burden, MDH may have completed future evaluations and made decisions based on performance data without considering the effect of ongoing cluster investigations on performance in short

timeframes. Foodborne disease outbreak detection and investigation performance, regardless of the system and processes, involved is the product of a complex system and measuring just one metric for some evaluation purposes may not provide a complete picture of how the surveillance system is performing.

Lastly, our Ishikawa Diagram of root causes of delayed interviews and losses to follow-up may be of some use to others who plan to evaluate the timelines of case interview processes in the future. While we do not expect the causes identified by our group to apply to other health departments, some causes, such as a language barrier, are likely universal in all surveillance processes. By considering the Ishikawa diagram, MDH administrators can brainstorm organizational and process changes to reduce the incidence of delayed interviews and losses to follow-up in the future.

We conclude that consideration of process performance over time is an imperative in public health systems research and public health quality improvement. Application of statistical process control charts to programs with several customer demands and quality specifications to meet is challenging and requires thoughtful analysis to completely explain program performance to stakeholders. We report another successful application of statistical process control charts to a public health preparedness and emergency response program.

Table 7. Median and Mean Timeliness Performance (in Days) of Routine *Salmonella* and *E. coli* O157:H7 Surveillance Processes, Minnesota Department of Health, 2009-2011

	Median				Mean			
Process Pathogen	2009	2010	2011	Total	2009	2010	2011	Total
Days from public health lab receipt of isolate to PFGE upload								
Salmonella	3	3	2	3	4.4	3.6	3.0	3.6
E. coli O157:H7	4	4	3	4	4.9	4.6	3.9	4.3
Days from public health lab receipt of isolate to case interview								
Salmonella	7	7	6	7	9.7	14.0	6.9	10.2
E. coli O157:H7	6	5	3	5	6.5	5.8	5.3	6.1

Table 8 displays the median and mean days needed to complete each of the four MDH surveillance processes evaluated from 2009 to 2011.

Figure 2. MR Chart, Average Timeliness from Day of Public Health Lab Receipt of Isolate to PFGE Upload, *Salmonella*, Minnesota Department of Health, 2009-2011, by Month

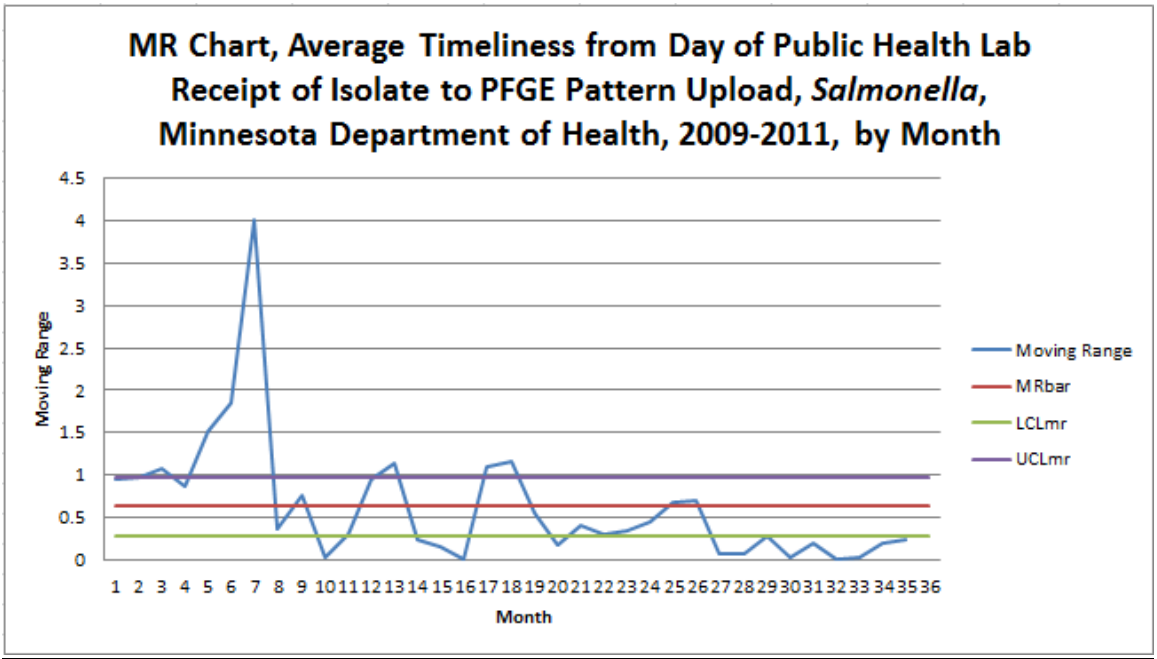


Figure 2 is an MR chart of the timeliness from public health laboratory receipts of *Salmonella* isolates to the upload of PFGE patterns to CDC's PulseNet system. The moving range is a measure of variation inherent in the monthly average timeliness performance of the process, and the method used to calculate the moving range is described in Chapter 3. Also shown is the mean of the moving range over 36 months, "MRbar", and the moving range control limits, "LCLmr" and "UCLmr". Methods used to calculate these control limits are described in Chapter 3 and the spreadsheets used to create this chart are shown in Appendix B. The chart demonstrates that the process is unable to meet MR chart variation requirements, with moving data regularly falling outside of the control limits.

Figure 3. MR Chart, Average Timeliness from Day of Public Health Lab Receipt of Isolate to Case Interview, *Salmonella*, Minnesota Department of Health, 2009-2011, by Month

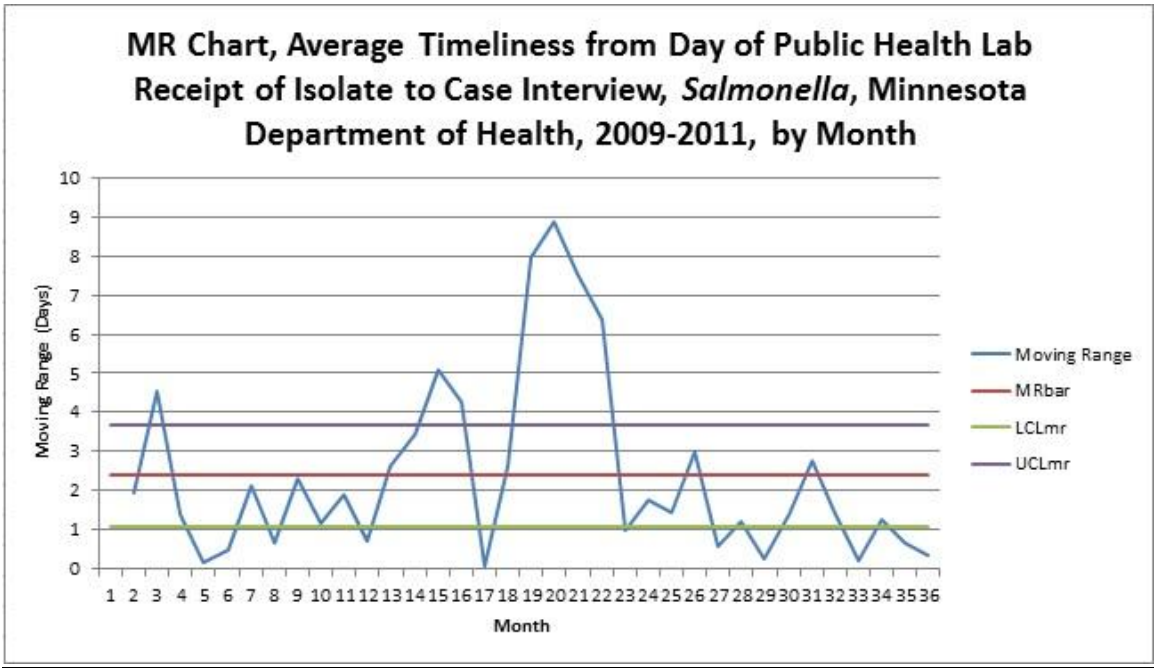


Figure 3 is an MR chart of the timeliness from public health laboratory receipts of *Salmonella* isolates to the completion of case exposure history interviews. The moving range is a measure of variation inherent in the monthly average timeliness performance of the process, and the method used to calculate the moving range is described in Chapter 3. Also shown is the mean of the moving range over 36 months, "MRbar", and the moving range control limits, "LCLmr" and "UCLmr". Methods used to calculate these control limits are described in Chapter 3 and the spreadsheets used to create this chart are shown in Appendix B. The chart demonstrates that the process is unable to meet MR chart variation requirements, with moving data regularly falling outside of the control limits.

Figure 4. MR Chart, Average Timeliness from Day of Public Health Lab Receipt of Isolate to PFGE Upload, *E. coli* O157:H7, Minnesota Department of Health, 2009-2011, by Month

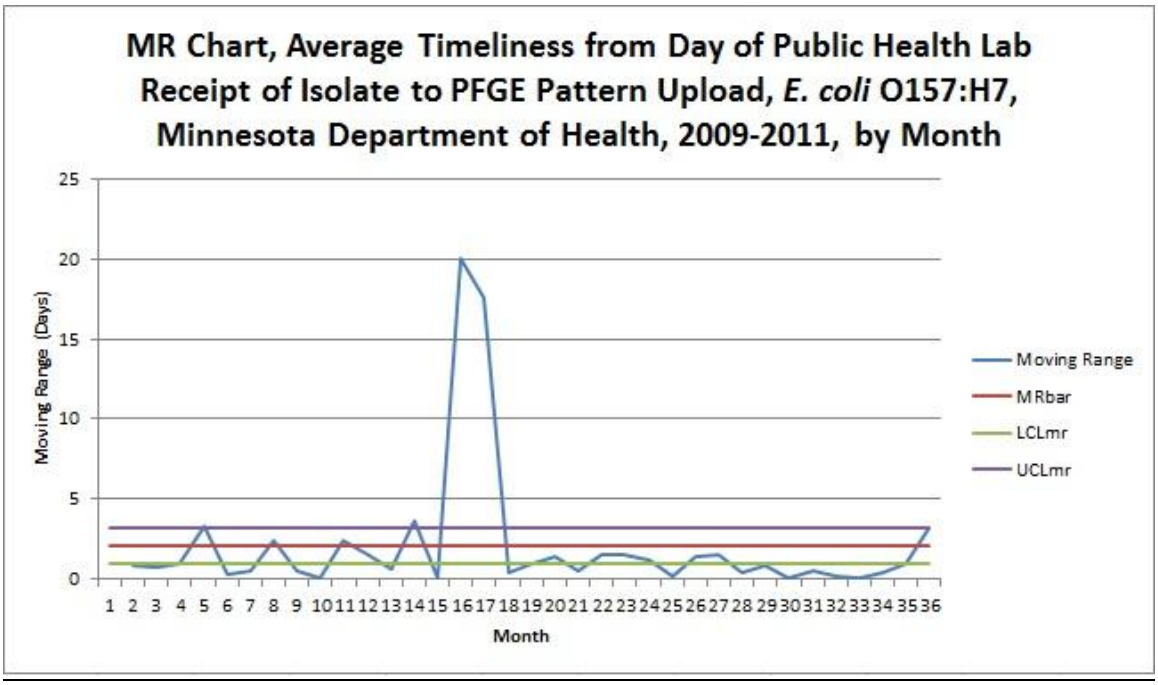


Figure 4 is an MR chart of the timeliness from public health laboratory receipts of *E. coli* O157:H7 isolates to the upload of PFGE patterns to CDC's PulseNet system. The moving range is a measure of variation inherent in the monthly average timeliness performance of the process, and the method used to calculate the moving range is described in Chapter 3. Also shown is the mean of the moving range over 36 months, "MRbar", and the moving range control limits, "LCLmr" and "UCLmr". Methods used to calculate these control limits are described in Chapter 3 and the spreadsheets used to create this chart are shown in Appendix B. The chart demonstrates that the process is unable to meet MR chart variation requirements, with moving data regularly falling outside of the control limits.

Figure 5. MR Chart, Average Timeliness from Day of Public Health Lab Receipt of Isolate to Case Interview, *E. coli* O157:H7, Minnesota Department of Health, 2009-2011, by Month

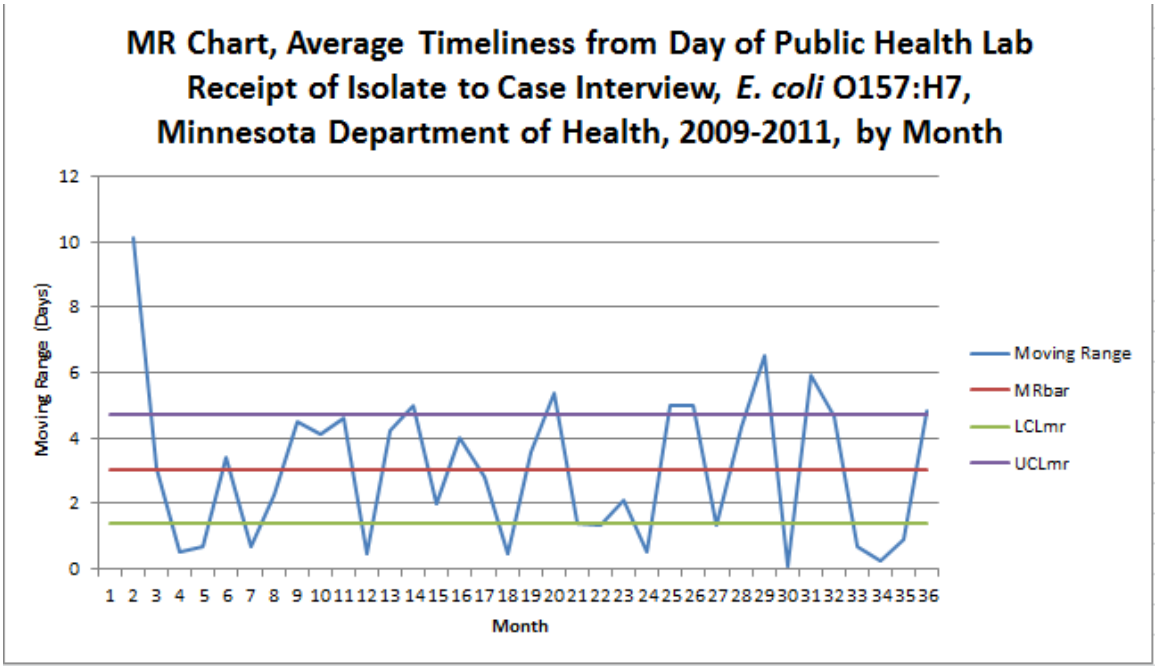


Figure 5 is an MR chart of the timeliness from public health laboratory receipts of *E. coli* O157:H7 isolates to the completion of case exposure history interviews. The moving range is a measure of variation inherent in the monthly average timeliness performance of the process, and the method used to calculate the moving range is described in Chapter 3. Also shown is the mean of the moving range over 36 months, "MRbar", and the moving range control limits, "LCLmr" and "UCLmr". Methods used to calculate these control limits are described in Chapter 3 and the spreadsheets used to create this chart are shown in Appendix B. The chart demonstrates that the process is unable to meet MR chart variation requirements, with moving data regularly falling outside of the control limits.

Figure 6. Run Chart, Average Timeliness from Day of Public Health Lab Receipt of Isolate to PFGE Upload, *Salmonella*, Minnesota Department of Health, 2009-2011, by Month

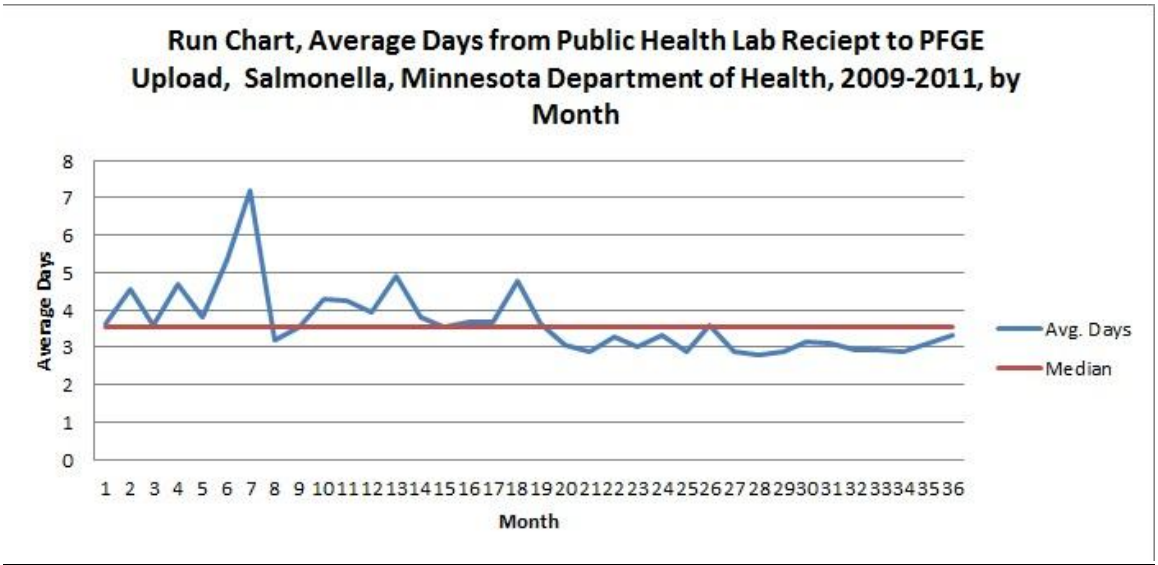


Figure 6 is a run chart of the timeliness from public health laboratory receipts of *Salmonella* isolates to the upload of PFGE patterns to CDC's PulseNet system. The chart suggests that the process is unstable, due to fewer than expected runs, a long run above the median from months 8-18, and a long run below the median from months 19-36. Based on this run chart containing 36 months of data, there is reason to expect that process performance improved in late 2010 and was sustained throughout 2011.

Figure 7. Run Chart, Average Timeliness from Day of Public Health Lab Receipt of Isolate to Case Interview, *Salmonella*, Minnesota Department of Health, 2009-2011, by Month

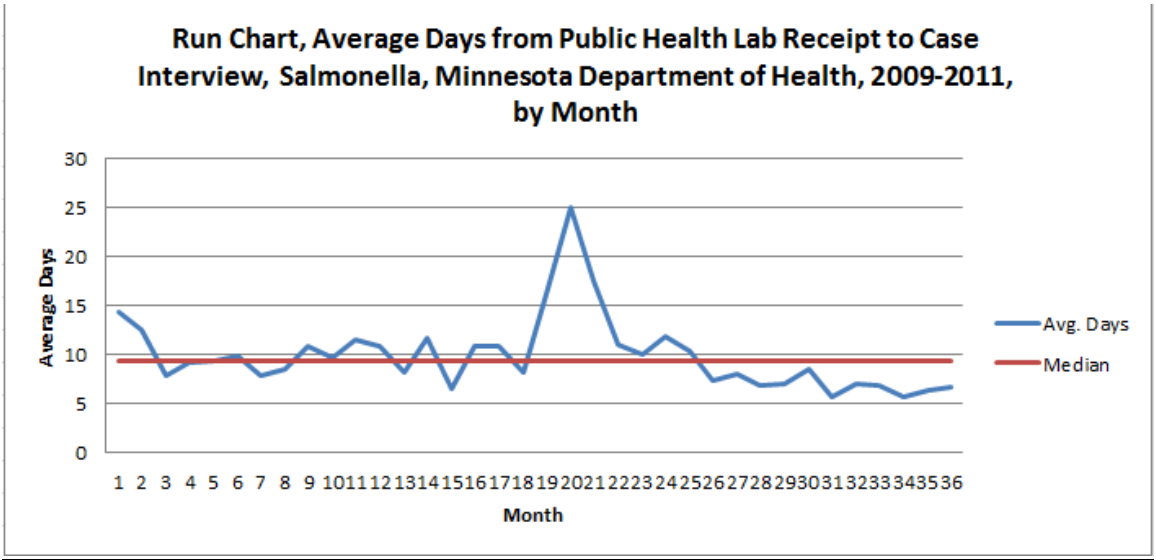


Figure 7 is a run chart of the timeliness from public health laboratory receipts of *Salmonella* isolates to the completion of case exposure history interviews. The chart suggests that the process is unstable due to a long run below the median from months 25-36. Based on this run chart containing 36 months of data, there is reason to expect that process performance improved in late 2010 and was sustained throughout 2011.

Figure 8. Run Chart, Average Timeliness from Day of Public Health Lab Receipt of Isolate to PFGE Upload, *E. coli* O157:H7, Minnesota Department of Health, 2009-2011, by Month

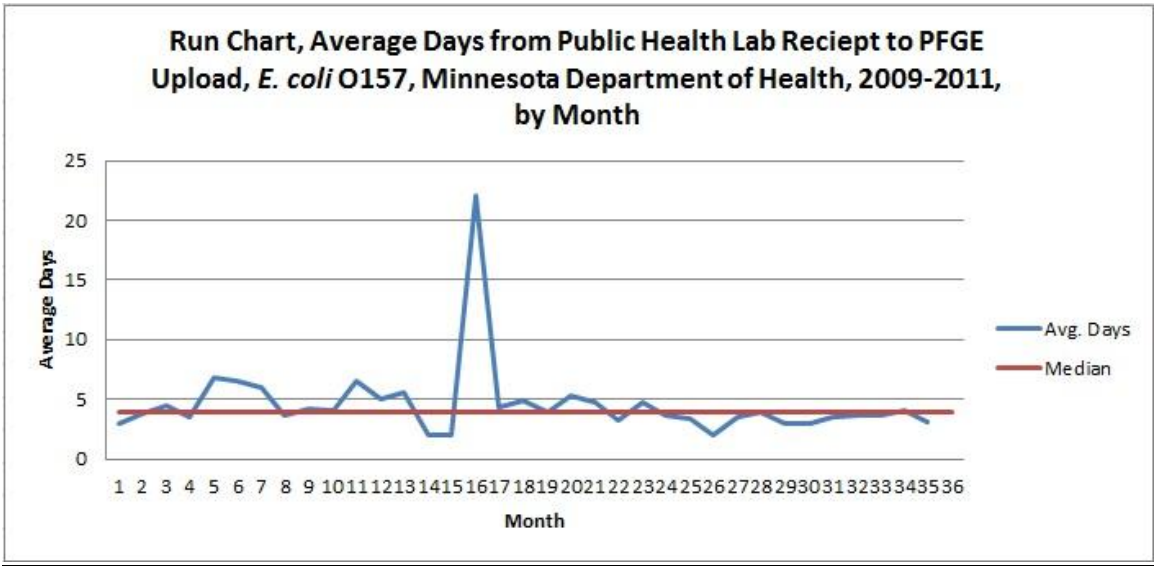


Figure 8 is a run chart of the timeliness from public health laboratory receipts of *E. coli* O157:H7 isolates to the upload of PFGE patterns to CDC's PulseNet system. The chart suggests that the process is unstable due to a long run below the median from months 25-36. Based on this run chart containing 36 months of data, there is reason to expect that process performance improved in late 2010 and was sustained throughout 2011.

Figure 9. Run Chart, Average Timeliness from Day of Public Health Lab Receipt of Isolate to Case Interview, *E. coli* O157:H7, Minnesota Department of Health, 2009-2011, by Month

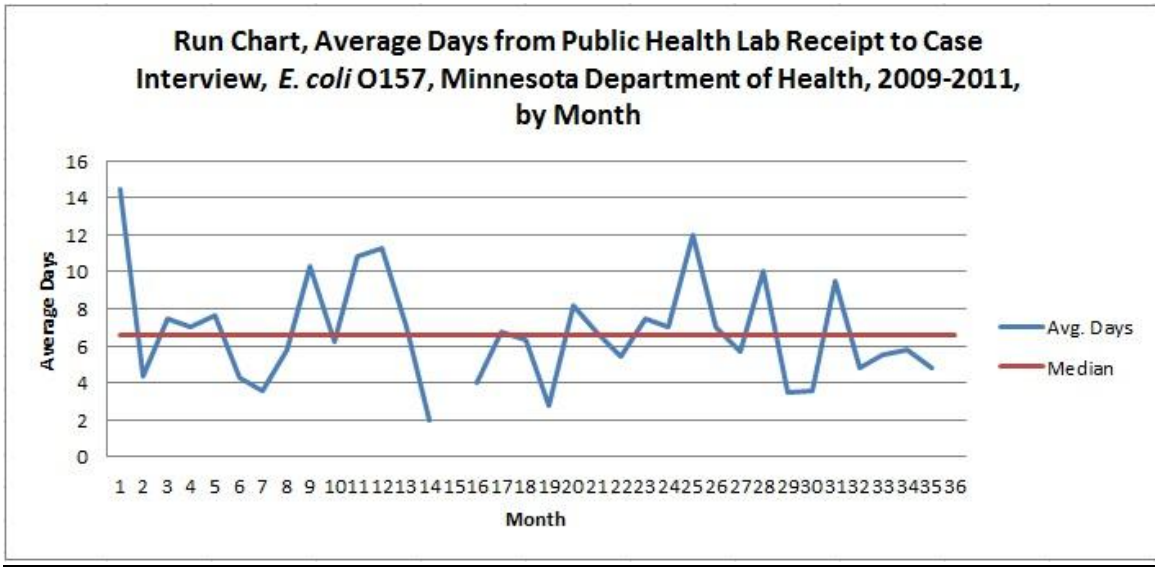


Figure 9 is a run chart of the timeliness from public health laboratory receipts of *E. coli* O157:H7 isolates to the completion of case exposure history interviews. The chart suggests that the process is performing stably and capably at a median timeliness of 6.5 days over 36 months.

Figure 10. Raw Data, Timeliness From Day of Public Health Lab Receipt of Isolate to PFGE Pattern Upload, *Salmonella*, Minnesota Department of Health, 2009-2011, by Consecutive Isolate Receipt

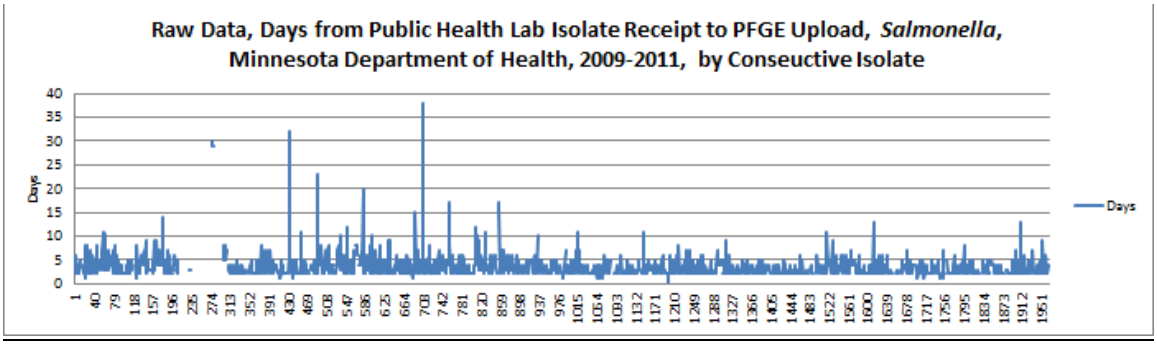


Figure 10 is a time series chart of the timeliness from public health laboratory receipts of *Salmonella* isolates to the upload of PFGE patterns to CDC's PulseNet system. The process timeliness for each reported isolate of *Salmonella* is shown over 36 months of the study period.

Figure 11. Raw Data, Timeliness From Day of Public Health Lab Receipt of Isolate to Case Interview, *Salmonella*, Minnesota Department of Health, 2009-2011, by Consecutive Isolate Receipt

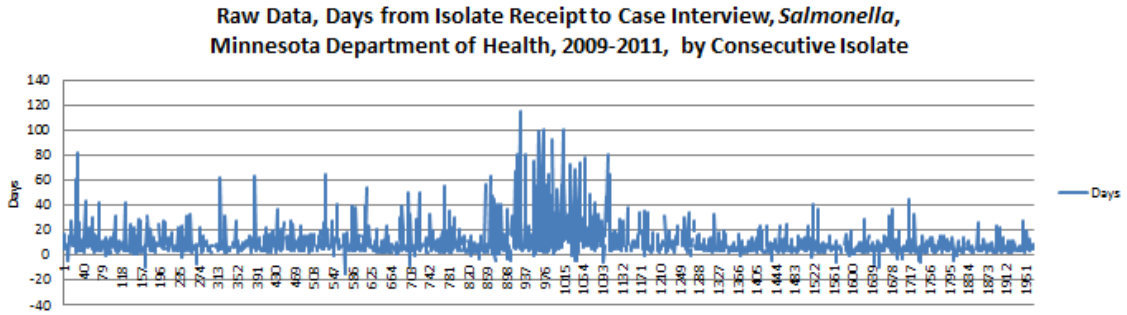


Figure 11 is a time series chart of the timeliness from public health laboratory receipts of *Salmonella* isolates to the completion of case exposure history interviews. The process timeliness for each reported isolate of *Salmonella* is shown over 36 months of the study period. Of note is an apparent concentration of case interviews that were completed months after the receipt of a stool specimen in the months of July and August of 2010. This concentration of delayed performance has been attributed to an unusual concentration of *Salmonella* cluster and outbreak investigations occurring at that time.

Figure 12. Raw Data, Timeliness from Day of Public Health Lab Receipt of Isolate to PFGE Pattern Upload, *E. coli* O157:H7, Minnesota Department of Health, 2009-2011, by Consecutive Isolate Receipt

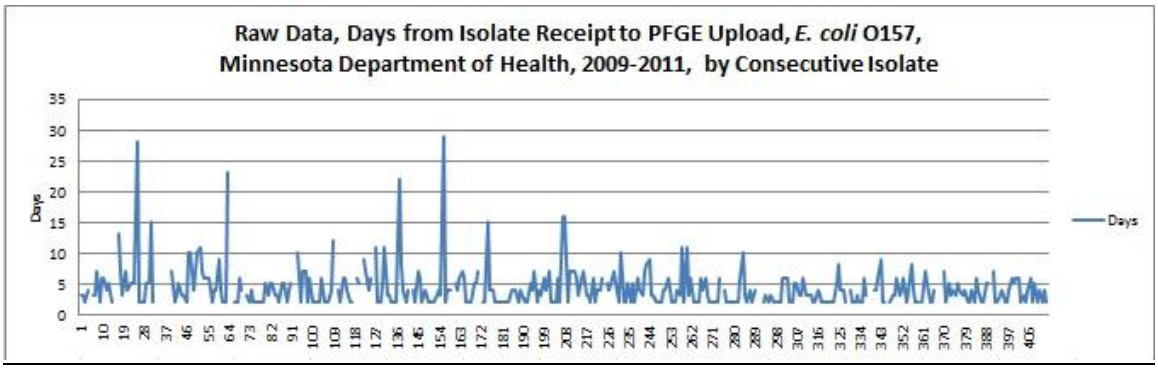


Figure 12 is a time series chart of the timeliness from public health laboratory receipts of *E. coli* O157:H7 isolates to the upload of PFGE patterns to CDC's PulseNet system. The process timeliness for each reported isolate of *E. coli* O157:H7 is shown over 36 months of the study period.

Figure 13. Raw Data, Timeliness from Day of Public Health Lab Receipt of Isolate to Case Interview, *E. coli* O157:H7, Minnesota Department of Health, 2009-2011, by Consecutive Isolate Receipt

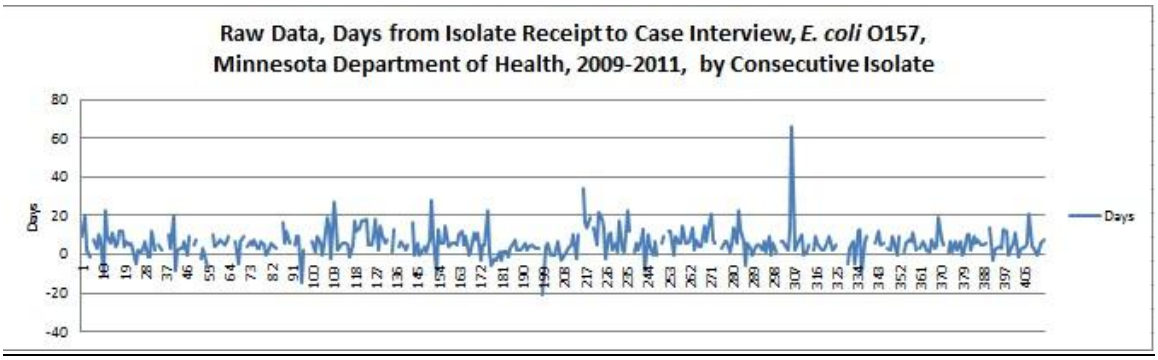
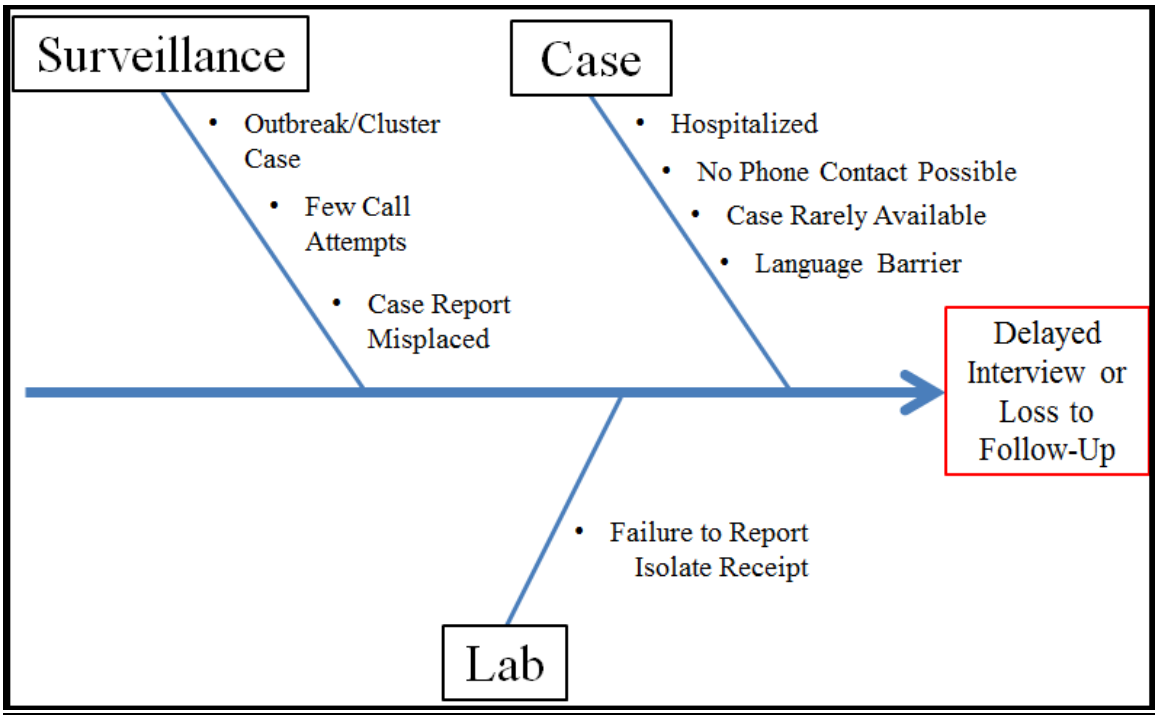


Figure 13 is a time series chart of the timeliness from public health laboratory receipts of *E. coli* O157:H7 isolates to the completion of case exposure history interviews. The process timeliness for each reported isolate of *E. coli* O157:H7 is shown over 36 months of the study period.

Figure 14. Ishikawa Diagram of Root Causes of Losses to Follow-Up and Delayed Case Interviews, Routine *Salmonella* and *E. coli* O157:H7 Surveillance, Minnesota Department of Health, 2009-2011



Conclusion

To build the evidence base for determinants of public health performance and quality improvement, this dissertation has summarized the development of a novel survey to ascertain workforce training and experience factors, the development of a detailed process-specific quantitative performance evaluation, and the novel application of statistical process control charts to foodborne disease surveillance processes conducted by a state health department.

There are several major lessons for public health (specifically, public health preparedness and emergency response), performance evaluation, and quality improvement drawn from this research. A need to evaluate the contributions of outbreak responder training and work experience was identified. The success and difficulties of designing a survey to evaluate outbreak responder training and work experience have been described. The survey also successfully characterized the tasks of different levels of government health departments during foodborne disease outbreak investigations, although the responses evaluated did not come from a representative sample of health departments in the state. Future attempts to survey the public health workforce regarding training and work experience should contain input from responders, validation, and use incentives or a non-traditional enrollment route to ensure the validity of survey results.

A model performance evaluation of a foodborne disease surveillance program in a state health department has been presented. Surveillance system context, resources, staff, and processes have been described in great qualitative detail and the frequency, completeness, and timeliness performance of routine surveillance processes for outbreak

detection has been described using a balanced-scorecard approach. Improvement in the performance of surveillance processes was apparent in both the annual performance summary as well as in the run charts presented within. We encourage the reporting of similar evaluations for comparative effectiveness research, but do acknowledge that it may not be practical or beneficial to a single governmental agency.

Future attempts to apply statistical process control to public health programs can greatly benefit from our experience described above. It has been found that not all surveillance processes are designed for consistency and some public health processes may not be able to reach statistical control due to opposing process demands. This work has demonstrated the utility of run charts in evaluating process stability and capability, and has successfully applied root cause analysis to determine the causes of signals on run charts and in raw performance data time series charts. Performance measurement using quality improvement tools such as statistical process control charts and root cause analysis will be critical for demonstrating the effects of program budget and staff changes and documenting improvement over time, and future applications should note our experience before beginning a performance evaluation in time series. Chapter 3 reported successful applications of root cause analysis and Ishikawa diagrams to surveillance processes.

Several limitations should be noted about the study results and methodologies presented within. Results of the training survey were based on self-reported experience. Additionally, survey respondents were asked to produce a number of times they had participated in outbreak investigations. Many responders reported that this was very

difficult and may not be an accurate reflection of their experience. Some responders would have preferred ranges of numbers that they could choose from. Investigators also failed to enroll a representative survey of Minnesota LHDs and thus our comparisons of the experiences between state and local outbreak responder training and experience cannot be considered valid.

A major limitation of the evaluation of surveillance system performance is the subjectivity of the evaluator. Subjectivity is introduced by evaluator assumptions such as inclusion and exclusion criteria of isolates and cases, the determination of timeliness dates that are difficult to ascertain from record or for isolates that did not follow a conventional reporting path, the determination of interview, demographic, and food history completeness, and the choice of stratification end evaluation methods. An additional limitation to this evaluation is data quality. Data may be scarce, incorrect, or incomplete for some processes under evaluation, and missing data may introduce error into the conclusions drawn from performance evaluations. Evaluator subjectivity and data quality also bear similar significance on the statistical process control chart and raw data time series analyses in Chapter 3.

In spite of the limitations with the studies within, there are several opportunities for research similar to this dissertation to be used to improve public health responses to foodborne disease outbreaks. Advances in survey methodology could better quantify the training and education of larger populations of public health preparedness and response officials. Evaluation of public health program performance in the context of program setting, budget, staff, and processes is critical for internal quality improvement and

critical for federal and academic stakeholders to determine the factors predictive of effective and efficient public health response. Last, increased internal use and public reporting of statistical process control charts to describe program performance will inform public health systems research, comparative effectiveness research, and contribute greatly to the improvement of public health practice throughout the nation.

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Appendix A. Chapter 1 Foodborne Disease Outbreak Responder Training and Work Experience Questionnaire

Demographics:

1. Please enter your age:

2. Please enter your sex:
   Male
   Female

3. Race/Ethnicity:
   White
   Black
   Asian
   Hawaiian/Pac Islander
   Native American/Alaskan
   More than one of the above

   Hispanic
   Non-Hispanic

Education and Training:

4. Educational degrees completed:
   High School
   Associates
   Bachelors
   Professional/Public Health Certificate
   MS/MA
   MPH
   PhD/DrPH
   MD
   DVM
   Other

1. Educational degrees in progress:
   Associates
   Bachelors
   Professional/Public Health Certificate
   MS/MA
   MPH
   PhD/DrPH
   MD
   DVM

Other

2. Formal, non-academic training completed: (*CHECK-ALL*)

Association Public Health Laboratories (APHL)
Program in Infectious Disease and Public Health

CDC/CSTE
Epidemiology
Epidemic Intelligence Service (EIS)
Preventative Medicine Residency (PMR)
Public Health Informatics Fellowship (PHI)
Public Health Prevention Service (PHPS)
Post-Doctoral Fellowship in Prevention Effectiveness Methods
Field Epidemiology Training Programs (FETP)
Public Health Schools without Walls (PHSWOW)
Epidemiology Elective Program for Senior Medical/Veterinary Students
Council of State and Territorial Epidemiologists Applied Epidemiology Fellowship
CDC Experience Applied Epidemiology Fellowship
Project IMHOTEP
CDC-Hubert Global Health Fellowship

Environmental Health
Summer Undergraduate Program in Environmental Health
Collegiate Leaders in Environmental Health
Environmental Public Health Leadership Institute

Laboratory
Emerging Infectious Diseases Advanced Laboratory Training Fellowship
Post-Doctoral Laboratory Research Fellowship

NEHA
Registered Sanitarian/Registered Environmental Health Specialist
Epic-Ready Team Training

3. Foodborne Disease Student Internships
Agency:_____
Duration:_____

4. Non-Formal Training Activities
CDC Epidemiologic Case Studies (yes/no)

Botulism in Argentina
E. coli O157:H7 Infection in Michigan
Salmonella in the Caribbean Exercise
Gastroenteritis in Texas
Pharyngitis in Louisiana
Multistate Outbreak of Cyclosporiasis

NEHA (yes/no)
Environmental Public Health Performance Standards Workshop
Environmental Health Training in Emergency Response
Biology and Control of Insects Workshop

International Food Protection Training Courses
No
Yes

CIFOR Guidelines to Improve Foodborne Outbreak Response
Have used the toolkit and read the guidelines
Have used the toolkit
Have reviewed the guidelines
Have not used either the CIFOR Guidelines or the Toolkit

5. FEMA National Incident Management System Trainings

Overview
IS-700: National Incident Management System (NIMS), an Introduction
IS-800: National Response Framework, an Introduction

ICS Courses
IS-100 Introduction to ICS
IS-200 ICS for Single Resources and initial Action Incidents
IS-300 Intermediate ICS
IS-400 Advanced ICS

NIMS Components/Subcomponents
IS-701 NIMS MACS
IS-702 NIMS Public Information
IS-703 NIMS Resource Management
IS-704 NIMS Communication and Information Management
IS-705 NIMS Preparedness
IS-706 NIMS Intrastate Mutual Aid, an Introduction
IS-707 NIMS Resource Typing
ICS Position-Specific Courses
P-400 All-Hazards Incident Commander
P-430 All-Hazards Operations Section Chief

P-440 All-Hazards Planning Section Chief
P-450 All-Hazards Logistics Section Chief
P-460 All-Hazards Finance Section Chief
P-480 All-Hazards Intelligence/Investigations Function
P-402 All-Hazards Liaison Officer
P-403 All-Hazards Public Information Officer
P-404 All-Hazards Safety Officer

Work Experience:

6. What is the name of the public health agency where you currently work? (open-ended)
7. What is your formal job title? (open-ended)
8. Are you a supervisor/manager? (yes/no)
9. How many total years have you been employed at your current agency? (1-40)
10. How many total years have you been responding to foodborne disease outbreaks? (1-40)

Routine Investigation Experience:

I would like to have these questions displayed in grid form like the ICS-role questions from the bridge collapse. Before seeing the questions for each list, I would like 2 screen questions:

Do you ever investigate small, localized event/establishment outbreaks (wedding reception or restaurant outbreaks) in your current role?
Yes
No

If yes: "You will now be asked about your duties in response to complaint-driven foodborne outbreaks; those that are triggered by a telephone or email complaint from the community." (If No, skip List A+B)

Do you ever conduct pathogen-specific surveillance, case interviews, and/or PFGE-cluster investigations?
Yes
No

"You will now be asked about your duties in response to pathogen-specific surveillance-driven foodborne outbreaks; those that are triggered by the detection of PFGE clusters." (List C)

Questions for Each List:

"You will now be asked about your participation in EPIDEMIOLOGICAL activities in response to event/establishment-based foodborne outbreaks; those that are triggered by a telephone or email complaint from the community." [NEXT>]

(For Non-managers Only)

1. How many times have you EVER performed each task in response to a foodborne disease outbreak?

   0 / Never has been my role
   1-10
   10-50
   50-100
   100+

2. How many times IN THE PAST 2 YEARS have you performed each task in response to a foodborne disease outbreak?

   0 / Has never been my role
   1-10
   10-50
   50-100
   100+

(For Managers Only)

1. Please estimate what percentage of foodborne disease outbreak responses from 2009-2011 your agency completed each task?

   Do not commonly perform (<25%)
   25% - 50%
   50% - 75%
   75% - 100%

2. (IF not common, 25-50, or 50-75) What are the common reasons why your agency does not perform each task?

   Rarely necessary / Not part of protocol / Performed by other agency in state
   Lack of time/personnel
   Lack of trained personnel

List A. Complaint Response – Epidemiology Duties

"Identify etiologic agent"

- Contact healthcare providers of cases who have sought medical attention
- Interview cases to characterize symptoms, incubation period, and duration of illness
- Deliver/Retrieve a stool kit from a suspected case
- Establish a case definition based on confirmed diagnosis or clinical profile of cases

"Identify persons at risk"

- Obtain from event organizer/restaurant a list of persons attending event/eating at restaurant
- Interview persons who attended event or patronized restaurant to determine attack rates
- Contact healthcare providers to identify additional persons seeking medical care who meet the case definition

"Identify mode of transmission and vehicle"

- Interview identified cases and controls or well meal companions about all common exposure sources.
- Calculate odds ratios for specific exposures without a statistical computation package
- Interview persons with identified exposures to determine attack rates and relative risks for specific exposures.

"Identify source of contamination"

- Combine descriptive and analytical epidemiology results to develop a model for the outbreak using a statistical computation package.

"Identify contributing factors (specific ways that food became contaminated or capable of causing illness)"

- Summarize information to identify confirmed or suspected agent
- Summarize information to identify confirmed or suspected food vehicle

"Determine potential for ongoing transmission and needed abatement procedures"

- On the basis of an agent, incubation period, and likelihood of secondary spread, create epidemic curve, and evaluate the course of the epidemic to determine whether additional cases may still be occurring.
- If outbreak appears to be ongoing, review potential abatement procedures.

"You will now be asked about your participation in ENVIRONMENTAL HEALTH activities in response to event/establishment-based foodborne outbreaks" [NEXT>]

List B. Complaint Response – Environmental Health Duties

Identify etiologic agent

- Interview management to determine whether it has noticed any ill employees or any circumstances that could be the cause of a foodborne illness
- Interview Foodworkers to determine illness. This activity could also be conducted by nursing/healthcare staff
- Obtain stool from ill or all food workers. This activity could also be conducted by nursing/healthcare staff
- Obtain and store samples of implicated and suspected food items and ingredients
- Determine whether setting or food item suggests a likely pathogen

Identify persons at risk

- Obtain list of reservations for establishment, credit card receipts, receipts for take-out orders, inventory of food ordered at establishment, or guest lists for events. Where possible, obtain information electronically

Identify mode of transmission and vehicle

- Obtain menu from establishment or event
- Interview Foodworkers to determine food-preparation responsibilities
- Reconstruct food flow for implicated meal or food item
- Identify contributing factors
- Obtain samples of implicated food
- Obtain environmental samples from food contact surfaces or potential environmental reservoirs

Identify source of contamination

- Interview food workers to determine food-preparation responsibilities
- Reconstruct food flow for implicated meal or food item
- Evaluate food flow for implicated meal or food item to identify contamination event at point of preparation or service
- If no contamination event is identified, trace source of ingredients of implicated food item back through distribution to point where a contamination event can be identified or, if no contamination events can be identified during distribution, to source of production

Identify contributing factors

- Evaluate results of environmental investigations, given identification of agent and results of epidemiologic investigation, to identify factors most likely to have contributed to outbreak

Determine potential for ongoing transmission and the need for abatement procedures

- Implement control measures to prevent further exposures
    - Verify that all food workers who pose a risk for transmission have been excluded
    - Verify that potentially contaminated foods have been properly disposed
    - Verify that food contact surfaces and potential environmental reservoirs have been adequately cleaned and sanitized
    - Train staff in safe food-handling practices
    - Modify food-production and food-preparation processes
    - Modify menu
- If any of these measures cannot be verified, review additional abatement procedures, or if further exposure appears likely, alert public or close premises

"You will now be asked about your participation in EPIDEMIOLOGICAL duties in response to PATHOGEN-SPECIFIC surveillance-driven foodborne outbreaks; those that are triggered by the detection of PFGE clusters." [NEXT>]

List C. Pathogen-Specific Surveillance Response – Epidemiology Duties

"Identify mode of transmission and vehicle"

- Interview cases as soon as possible with standardized trawling questionnaire to identify potential common exposures. In some situations, cases are interviewed as soon as they are reported and before an outbreak has been recognized
- Establish case definition on the basis of characteristics of the agent that led to detection of outbreak
- Characterize cases by person, place, and time, and evaluate the descriptive epidemiology to identify pattern potentially associated with particular food items or diets
- Compare trawling questionnaire exposure frequencies against known or estimated background exposure rates, such as those found in the FoodNet Atlas of Exposures, to identify suspected food item
- Interview non-ill community controls or non-outbreak-associated ill persons to obtain detailed exposure information to be used in a case-comparison analysis of exposures
- Obtain shopper card information to identify and verify grocery purchases
- Document brand names and product code information for prepackaged food items

- Analyze exposure information comparing cases to relevant comparison group (e.g., non-ill controls or cases not associated with outbreak) to implicate food item or nonfood-exposure source
- Re-interview cases with targeted questionnaire if preliminary exposure assessment suggests specific food-exposures that were not previously reported by some cases.

"Identify persons at risk"

- Alert health-care providers of possible outbreak to identify additional persons seeking medical care, and review laboratory reports and medical charts at hospitals or physicians' offices to identify potential cases
- Ask cases if they know of others who are similarly ill
- Depending on the nature of the outbreak, take additional steps as warranted. Examples include reviewing employee or school absences, reviewing death certificates, surveying population affected, or directly asking members of the public to contact the health department if they have the illness under investigation

"Identify source of contamination"

- Combine descriptive and analytical epidemiology results to develop a model for the outbreak using a statistical computation package.

"Identify contributing factors"

- Summarize information to identify confirmed or suspected food vehicle

"Determine potential for ongoing transmission and need for abatement procedures"

- Create and evaluate epidemic curve to determine whether additional cases might still be occurring
- If outbreak appears to be ongoing, continue surveillance, and review potential abatement procedures

"You will now be asked about your participation in ENVIRONMENTAL HEALTH duties in response to PATHOGEN-SPECIFIC surveillance-driven foodborne outbreaks; those that are triggered by the detection of PFGE clusters." [NEXT>]

List B. Pathogen-Specific Surveillance Response – Env Hlth/Regulatory Duties

Identify mode of transmission and vehicle

- Contact restaurants, grocery stores, or other locations identified by multiple cases to verify menu choices, identify ingredients, and identify distributors and/or sources for ingredients and/or food items of interest
- Obtain samples of suspected food items

- Conduct informational traceback to determine whether a suspected food vehicle from multiple cases has a common distribution or other point in common
- Conduct formal regulatory traceback of implicated food item or ingredient

Identify persons at risk

- Review foodborne illness complaints to identify undiagnosed cases that could be linked to outbreak
- Contact restaurants, grocery stores, or other points of final service visited by multiple cases to identify employee illnesses or foodborne illness complaints from patrons

Identify source of contamination

- Trace source of implicated food item or ingredients through distribution to point where a contamination event can be identified or to source of production if no contamination events can be identified during distribution.
- Conduct environmental assessment of likely source of contamination, including
    - Reconstruct food flow for implicated food item
    - Interview Foodworkers to determine food-preparation responsibilities and practices before exposure
    - Obtain samples of implicated food or ingredients
    - Obtain environmental samples from food contact surfaces or potential environmental reservoirs

Identify contributing factors

- Evaluate results of environmental investigation, given identification of agent and results of epidemiologic investigation to identify factors likely to have contributed to outbreak

Determine potential for ongoing transmission and need for abatement procedures

- Verify that food workers who may have been infected during outbreak and who pose a risk have been excluded
- Verify that potentially contaminated foods have been removed from distribution
- Train staff on safe food-handling practices
- Modify food-preparation and food-preparation processes
- Modify menu

Appendix B. Chapter 3 Excel Spreadsheets for XMR Charts.

Timeliness from Day of Lab Receipt of Isolate to PFGE Upload, Salmonella, MDH, 2009-2011, by Month

	Salm PHL>Up	Xbar	MR	MR bar	LCLmr	UCLmr	LCLx	UCLx
Jan-09	3.62	3.67138889		0.635143	0.291531	0.978755	3.574212	3.768566
Feb-09	4.57	3.67138889	0.95	0.635143	0.291531	0.978755	3.574212	3.768566
Mar-09	3.59	3.67138889	0.98	0.635143	0.291531	0.978755	3.574212	3.768566
Apr-09	4.67	3.67138889	1.08	0.635143	0.291531	0.978755	3.574212	3.768566
May-09	3.81	3.67138889	0.86	0.635143	0.291531	0.978755	3.574212	3.768566
Jun-09	5.33	3.67138889	1.52	0.635143	0.291531	0.978755	3.574212	3.768566
Jul-09	7.19	3.67138889	1.86	0.635143	0.291531	0.978755	3.574212	3.768566
Aug-09	3.18	3.67138889	4.01	0.635143	0.291531	0.978755	3.574212	3.768566
Sep-09	3.54	3.67138889	0.36	0.635143	0.291531	0.978755	3.574212	3.768566
Oct-09	4.3	3.67138889	0.76	0.635143	0.291531	0.978755	3.574212	3.768566
Nov-09	4.26	3.67138889	0.04	0.635143	0.291531	0.978755	3.574212	3.768566
Dec-09	3.96	3.67138889	0.3	0.635143	0.291531	0.978755	3.574212	3.768566
Jan-10	4.92	3.67138889	0.96	0.635143	0.291531	0.978755	3.574212	3.768566
Feb-10	3.79	3.67138889	1.13	0.635143	0.291531	0.978755	3.574212	3.768566
Mar-10	3.54	3.67138889	0.25	0.635143	0.291531	0.978755	3.574212	3.768566
Apr-10	3.69	3.67138889	0.15	0.635143	0.291531	0.978755	3.574212	3.768566
May-10	3.69	3.67138889	0	0.635143	0.291531	0.978755	3.574212	3.768566
Jun-10	4.79	3.67138889	1.1	0.635143	0.291531	0.978755	3.574212	3.768566
Jul-10	3.62	3.67138889	1.17	0.635143	0.291531	0.978755	3.574212	3.768566
Aug-10	3.07	3.67138889	0.55	0.635143	0.291531	0.978755	3.574212	3.768566
Sep-10	2.9	3.67138889	0.17	0.635143	0.291531	0.978755	3.574212	3.768566
Oct-10	3.3	3.67138889	0.4	0.635143	0.291531	0.978755	3.574212	3.768566
Nov-10	3	3.67138889	0.3	0.635143	0.291531	0.978755	3.574212	3.768566
Dec-10	3.34	3.67138889	0.34	0.635143	0.291531	0.978755	3.574212	3.768566
Jan-11	2.89	3.67138889	0.45	0.635143	0.291531	0.978755	3.574212	3.768566
Feb-11	3.58	3.67138889	0.69	0.635143	0.291531	0.978755	3.574212	3.768566
Mar-11	2.87	3.67138889	0.71	0.635143	0.291531	0.978755	3.574212	3.768566
Apr-11	2.8	3.67138889	0.07	0.635143	0.291531	0.978755	3.574212	3.768566
May-11	2.88	3.67138889	0.08	0.635143	0.291531	0.978755	3.574212	3.768566
Jun-11	3.16	3.67138889	0.28	0.635143	0.291531	0.978755	3.574212	3.768566
Jul-11	3.12	3.67138889	0.04	0.635143	0.291531	0.978755	3.574212	3.768566
Aug-11	2.93	3.67138889	0.19	0.635143	0.291531	0.978755	3.574212	3.768566
Sep-11	2.94	3.67138889	0.01	0.635143	0.291531	0.978755	3.574212	3.768566
Oct-11	2.9	3.67138889	0.04	0.635143	0.291531	0.978755	3.574212	3.768566
Nov-11	3.1	3.67138889	0.2	0.635143	0.291531	0.978755	3.574212	3.768566
Dec-11	3.33	3.67138889	0.23	0.635143	0.291531	0.978755	3.574212	3.768566

Timeliness from Day of Lab Receipt of Isolate to Case Interview, Salmonella, MDH, 2009-2011, by Month

	Salm PHL>Int	Xbar	MR	MR bar	LCLmr	UCLmr	LCLx	UCLx
Jan-09	14.36	9.91		2.378857	1.091895	3.665819	9.546035	10.27397
Feb-09	12.43	9.91	1.93	2.378857	1.091895	3.665819	9.546035	10.27397
Mar-09	7.88	9.91	4.55	2.378857	1.091895	3.665819	9.546035	10.27397
Apr-09	9.27	9.91	1.39	2.378857	1.091895	3.665819	9.546035	10.27397
May-09	9.43	9.91	0.16	2.378857	1.091895	3.665819	9.546035	10.27397
Jun-09	9.92	9.91	0.49	2.378857	1.091895	3.665819	9.546035	10.27397
Jul-09	7.8	9.91	2.12	2.378857	1.091895	3.665819	9.546035	10.27397
Aug-09	8.48	9.91	0.68	2.378857	1.091895	3.665819	9.546035	10.27397
Sep-09	10.8	9.91	2.32	2.378857	1.091895	3.665819	9.546035	10.27397
Oct-09	9.65	9.91	1.15	2.378857	1.091895	3.665819	9.546035	10.27397
Nov-09	11.55	9.91	1.9	2.378857	1.091895	3.665819	9.546035	10.27397
Dec-09	10.85	9.91	0.7	2.378857	1.091895	3.665819	9.546035	10.27397
Jan-10	8.24	9.91	2.61	2.378857	1.091895	3.665819	9.546035	10.27397
Feb-10	11.68	9.91	3.44	2.378857	1.091895	3.665819	9.546035	10.27397
Mar-10	6.59	9.91	5.09	2.378857	1.091895	3.665819	9.546035	10.27397
Apr-10	10.84	9.91	4.25	2.378857	1.091895	3.665819	9.546035	10.27397
May-10	10.78	9.91	0.06	2.378857	1.091895	3.665819	9.546035	10.27397
Jun-10	8.17	9.91	2.61	2.378857	1.091895	3.665819	9.546035	10.27397
Jul-10	16.12	9.91	7.95	2.378857	1.091895	3.665819	9.546035	10.27397
Aug-10	24.98	9.91	8.86	2.378857	1.091895	3.665819	9.546035	10.27397
Sep-10	17.43	9.91	7.55	2.378857	1.091895	3.665819	9.546035	10.27397
Oct-10	11.05	9.91	6.38	2.378857	1.091895	3.665819	9.546035	10.27397
Nov-10	10.08	9.91	0.97	2.378857	1.091895	3.665819	9.546035	10.27397
Dec-10	11.83	9.91	1.75	2.378857	1.091895	3.665819	9.546035	10.27397
Jan-11	10.41	9.91	1.42	2.378857	1.091895	3.665819	9.546035	10.27397
Feb-11	7.43	9.91	2.98	2.378857	1.091895	3.665819	9.546035	10.27397
Mar-11	8	9.91	0.57	2.378857	1.091895	3.665819	9.546035	10.27397
Apr-11	6.81	9.91	1.19	2.378857	1.091895	3.665819	9.546035	10.27397
May-11	7.05	9.91	0.24	2.378857	1.091895	3.665819	9.546035	10.27397
Jun-11	8.45	9.91	1.4	2.378857	1.091895	3.665819	9.546035	10.27397
Jul-11	5.71	9.91	2.74	2.378857	1.091895	3.665819	9.546035	10.27397
Aug-11	7.11	9.91	1.4	2.378857	1.091895	3.665819	9.546035	10.27397
Sep-11	6.92	9.91	0.19	2.378857	1.091895	3.665819	9.546035	10.27397
Oct-11	5.68	9.91	1.24	2.378857	1.091895	3.665819	9.546035	10.27397
Nov-11	6.32	9.91	0.64	2.378857	1.091895	3.665819	9.546035	10.27397
Dec-11	6.66	9.91	0.34	2.378857	1.091895	3.665819	9.546035	10.27397

Timeliness from Day of Lab Receipt of Isolate to PFGE Upload, E. coli O157:H7, MDH, 2009-2011, by Month

	O157 PHL>Up	Xbar	MR	MR bar	LCLmr	UCLmr	LCLx	UCLx
Jan-09	3	4.594		2.060571	0.945802	3.175341	4.278733	4.909267
Feb-09	3.8	4.594	0.8	2.060571	0.945802	3.175341	4.278733	4.909267
Mar-09	4.5	4.594	0.7	2.060571	0.945802	3.175341	4.278733	4.909267
Apr-09	3.5	4.594	1	2.060571	0.945802	3.175341	4.278733	4.909267
May-09	6.8	4.594	3.3	2.060571	0.945802	3.175341	4.278733	4.909267
Jun-09	6.57	4.594	0.23	2.060571	0.945802	3.175341	4.278733	4.909267
Jul-09	6.04	4.594	0.53	2.060571	0.945802	3.175341	4.278733	4.909267
Aug-09	3.6	4.594	2.44	2.060571	0.945802	3.175341	4.278733	4.909267
Sep-09	4.14	4.594	0.54	2.060571	0.945802	3.175341	4.278733	4.909267
Oct-09	4.11	4.594	0.03	2.060571	0.945802	3.175341	4.278733	4.909267
Nov-09	6.5	4.594	2.39	2.060571	0.945802	3.175341	4.278733	4.909267
Dec-09	5	4.594	1.5	2.060571	0.945802	3.175341	4.278733	4.909267
Jan-10	5.6	4.594	0.6	2.060571	0.945802	3.175341	4.278733	4.909267
Feb-10	2	4.594	3.6	2.060571	0.945802	3.175341	4.278733	4.909267
Mar-10	2	4.594	0	2.060571	0.945802	3.175341	4.278733	4.909267
Apr-10	22	4.594	20	2.060571	0.945802	3.175341	4.278733	4.909267
May-10	4.4	4.594	17.6	2.060571	0.945802	3.175341	4.278733	4.909267
Jun-10	4.84	4.594	0.44	2.060571	0.945802	3.175341	4.278733	4.909267
Jul-10	3.9	4.594	0.94	2.060571	0.945802	3.175341	4.278733	4.909267
Aug-10	5.3	4.594	1.4	2.060571	0.945802	3.175341	4.278733	4.909267
Sep-10	4.8	4.594	0.5	2.060571	0.945802	3.175341	4.278733	4.909267
Oct-10	3.3	4.594	1.5	2.060571	0.945802	3.175341	4.278733	4.909267
Nov-10	4.75	4.594	1.45	2.060571	0.945802	3.175341	4.278733	4.909267
Dec-10	3.6	4.594	1.15	2.060571	0.945802	3.175341	4.278733	4.909267
Jan-11	3.4	4.594	0.2	2.060571	0.945802	3.175341	4.278733	4.909267
Feb-11	2	4.594	1.4	2.060571	0.945802	3.175341	4.278733	4.909267
Mar-11	3.5	4.594	1.5	2.060571	0.945802	3.175341	4.278733	4.909267
Apr-11	3.86	4.594	0.36	2.060571	0.945802	3.175341	4.278733	4.909267
May-11	3	4.594	0.86	2.060571	0.945802	3.175341	4.278733	4.909267
Jun-11	3	4.594	0	2.060571	0.945802	3.175341	4.278733	4.909267
Jul-11	3.46	4.594	0.46	2.060571	0.945802	3.175341	4.278733	4.909267
Aug-11	3.6	4.594	0.14	2.060571	0.945802	3.175341	4.278733	4.909267
Sep-11	3.68	4.594	0.08	2.060571	0.945802	3.175341	4.278733	4.909267
Oct-11	4.08	4.594	0.4	2.060571	0.945802	3.175341	4.278733	4.909267
Nov-11	3.16	4.594	0.92	2.060571	0.945802	3.175341	4.278733	4.909267
Dec-11		4.594	3.16	2.060571	0.945802	3.175341	4.278733	4.909267

*Orange boxes indicate months with 1 case-isolate data point.

**Red boxes indicate months with 0 data points.

Timeliness from Day of Lab Receipt of Isolate to Case Interview, E. coli O157:H7, MDH, 2009-2011, by Month

	O157 PHL>Int	Xbar	MR	MR bar	LCLmr	UCLmr	LCLx	UCLx
Jan-09	14.5	6.742059		3.049143	1.399557	4.698729	6.27554	7.208578
Feb-09	4.4	6.742059	10.1	3.049143	1.399557	4.698729	6.27554	7.208578
Mar-09	7.5	6.742059	3.1	3.049143	1.399557	4.698729	6.27554	7.208578
Apr-09	7	6.742059	0.5	3.049143	1.399557	4.698729	6.27554	7.208578
May-09	7.67	6.742059	0.67	3.049143	1.399557	4.698729	6.27554	7.208578
Jun-09	4.25	6.742059	3.42	3.049143	1.399557	4.698729	6.27554	7.208578
Jul-09	3.57	6.742059	0.68	3.049143	1.399557	4.698729	6.27554	7.208578
Aug-09	5.83	6.742059	2.26	3.049143	1.399557	4.698729	6.27554	7.208578
Sep-09	10.33	6.742059	4.5	3.049143	1.399557	4.698729	6.27554	7.208578
Oct-09	6.21	6.742059	4.12	3.049143	1.399557	4.698729	6.27554	7.208578
Nov-09	10.8	6.742059	4.59	3.049143	1.399557	4.698729	6.27554	7.208578
Dec-09	11.25	6.742059	0.45	3.049143	1.399557	4.698729	6.27554	7.208578
Jan-10	7	6.742059	4.25	3.049143	1.399557	4.698729	6.27554	7.208578
Feb-10	2	6.742059	5	3.049143	1.399557	4.698729	6.27554	7.208578
Mar-10		6.742059	2	3.049143	1.399557	4.698729	6.27554	7.208578
Apr-10	4	6.742059	4	3.049143	1.399557	4.698729	6.27554	7.208578
May-10	6.8	6.742059	2.8	3.049143	1.399557	4.698729	6.27554	7.208578
Jun-10	6.33	6.742059	0.47	3.049143	1.399557	4.698729	6.27554	7.208578
Jul-10	2.78	6.742059	3.55	3.049143	1.399557	4.698729	6.27554	7.208578
Aug-10	8.17	6.742059	5.39	3.049143	1.399557	4.698729	6.27554	7.208578
Sep-10	6.78	6.742059	1.39	3.049143	1.399557	4.698729	6.27554	7.208578
Oct-10	5.42	6.742059	1.36	3.049143	1.399557	4.698729	6.27554	7.208578
Nov-10	7.5	6.742059	2.08	3.049143	1.399557	4.698729	6.27554	7.208578
Dec-10	7	6.742059	0.5	3.049143	1.399557	4.698729	6.27554	7.208578
Jan-11	12	6.742059	5	3.049143	1.399557	4.698729	6.27554	7.208578
Feb-11	7	6.742059	5	3.049143	1.399557	4.698729	6.27554	7.208578
Mar-11	5.67	6.742059	1.33	3.049143	1.399557	4.698729	6.27554	7.208578
Apr-11	10	6.742059	4.33	3.049143	1.399557	4.698729	6.27554	7.208578
May-11	3.5	6.742059	6.5	3.049143	1.399557	4.698729	6.27554	7.208578
Jun-11	3.58	6.742059	0.08	3.049143	1.399557	4.698729	6.27554	7.208578
Jul-11	9.5	6.742059	5.92	3.049143	1.399557	4.698729	6.27554	7.208578
Aug-11	4.81	6.742059	4.69	3.049143	1.399557	4.698729	6.27554	7.208578
Sep-11	5.5	6.742059	0.69	3.049143	1.399557	4.698729	6.27554	7.208578
Oct-11	5.75	6.742059	0.25	3.049143	1.399557	4.698729	6.27554	7.208578
Nov-11	4.83	6.742059	0.92	3.049143	1.399557	4.698729	6.27554	7.208578
Dec-11		6.742059	4.83	3.049143	1.399557	4.698729	6.27554	7.208578

*Orange boxes indicate months with 1 case-isolate data point.

**Red boxes indicate months with 0 data points.

Appendix B displays the Microsoft Excel data tables used to produce the XMR charts displayed in Chapter 3. Column 2 shows the average monthly timeliness of the processes described above all 4 charts. Column 3, “Xbar”, is the mean of all data points in column 2. Column 4, “MR”, is the moving range, an absolute value calculated by subtracting the column 2 value for iteration *i* from iteration *i*-1. Column 5, “MR bar” is the mean of all column 4 values. Columns 6 and 7, “LCLmr” and “UCLmr” are the lower and upper control limits used on the MR chart, and the methods used to calculate these values are presented in Chapter 3. Lastly, columns 8 and 9, “LCLx” and “UCLx” are the lower and upper control limits used on the X chart, not shown in this thesis, and the methods used to calculate these limits are presented in Chapter 3.