A Network Analysis of Information Use in a Public Health Organization

by

Jacqueline Carty Merrill~Matzner

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ABSTRACT

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Organizational network analysis was used to study information use in a health department. Public health performance depends on specialized information that travels throughout an organization via communication networks among employees. In most cases, the interactions that occur within these networks are poorly understood and unmanaged. The goals of this study were to determine what links existed between information use and performance, and to assess organizational network analysis as a tool for public health management.

Data on communication links among the health department's staff was obtained via survey, with a 93% response rate. Data on resources, tasks and knowledge was obtained from a concurrent research study for secondary analysis. These data were configured in matrices: agent x agent, agent x resources, agent x task, agent x knowledge, and agent x external organizations. These were analyzed as meta-matrix using Organizational Risk Analyzer (*ORA*) software. This produced reports at the individual, program, and organization level.

The results yielded graphical representations of network structure and statistical reports on: quality of the information network; employees in key positions in the network; the status of experienced staff; and an analysis of a planned merger of two divisions. Findings revealed problems in information flow, including the likelihood that sub groups are controlling knowledge and resources; overspecialization of knowledge; potential for significant knowledge loss through retirement; little back up for personnel turnover; and informational silos. The findings suggest that the department needs greater redundancy and better cross program coordination, but has strengths such as efficient communication paths and good social density in the programs. The department's leaders offered feedback on specific strategies they intend to use to address knowledge loss, to increase shared situation awareness, and to take advantage of network strengths.

This study has demonstrated that organizational network analysis has utility for this health department. Insights from the analysis have informed strategies for improving performance. The technique has potential for public health information management. Additional research is needed to refine network analysis methods for the public health domain.

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DEDICATION

To Mary Klohr Merrill and Charles E. Merrill, Jr.

Few people are as fortunate as I, to have experienced the degree of approbation and generosity that you bestowed upon me.

It is because of you that I have realized this professional achievement.

CHAPTER 1 INTRODUCTION

This chapter presents an overview of the dissertation project. It describes the scope of the problem investigated, the project's specific aims and associated research questions, and a brief description of the research approach. The concepts upon which the research design is based are defined and a conceptual model is presented, followed by an explanation of the project's significance.

1.1 Problem Statement

Public health agencies are multi-dimensional arrangements of information processing networks that construct meaning, create knowledge, and make decisions. Thus they can be characterized as complex organizations (Principia Cybernetica, 1999). Complex organizational behavior is patterned on that of complex adaptive systems, in which structure and process emerge from interactions within and between individuals, resources, knowledge, tasks, and other organizations (Carley & Heinz, 2001). These relationships are critical to individual and organizational decision making and action. The overall structure of an organization determines how information diffuses among individuals, with consequences for the speed, quality and accuracy of organizational decisions and performance (Carley, 2002a). Thus, effective flows of information are understood as critical to performance (Galbraith, 1973; Lumpkin, 2002).

The combined collection, analysis, use, and communication of health-related information sustain all public health services (Lasker *et al.*, 1995; Lee, 2001). The use of information is an essential component of the structural capacity of health departments, and public health performance depends on the effectiveness of information use (Koo *et al.*, 2002; Turnock, 2000). Results from a survey of public health workers displayed in Table 1 illustrate the range of information public health workers indicate they need to perform more effectively. Yet, despite the importance of information to the practice of public health, the complex information needs of the public health workforce are not well met (Alpi, 2005; Association of State and Territorial Health Officials, 2004a; Hinman, 2002; Lee *et al.*, 2003; New York Academy of Medicine, 1998; Rambo *et al.*, 2001).

Table 1 Information needs of public health workers in Washington State

Public Health Information Needs (Rambo, 2000)
1) Better tools and resources for contacting experts
2) Updates on pertinent legislative issues and events
3) Structured information ("metadata") characterizing the contents of data sets
4) Outcome measures and "best practice" resources
5) Better scheduling software and event calendars
6) Standard templates for frequently used applications
7) Synthesized, knowledge-based information from external databases

The dynamics within complex systems can obscure our understanding of the real relationship between information and performance, due to frequently difficult-to-comprehend interactions among multiple elements of the organizational system (Radzicki, 1997; Sterman, 2000). For example, health department structure can contribute to unmet information needs when publicly funded mandates result in

"silos" in which different program teams might address interrelated problems, use similar interventions, or share a target population, all the while working in parallel, with little integration across program areas (Kitch & Yasnoff, 2002). A clear understanding of the flow of information in the public health organization is required to justify allocating limited public resources to manage information needs. Hence it is essential to demonstrate how information use is linked to agency performance.

Network analysis is a tool for unraveling organizational complexity. It is an empirical descriptive research method derived from social science and graph theory. When applied to an organization, network analysis allows simultaneous analysis of many interrelated elements in the organizational system. This approach reveals aspects of individual and system behavior that may not be evident to those embedded within the system. Through comprehending the complexities of how information flows between and amongst people, resources and tasks in an organization, it is possible to more accurately identify ways to improve how people access, use, and share information, with the goal of improved performance. This proposal is based on the proposition that analysis of the information network in a public health organization can describe and provide insight into relationships among the complexities described above, and suggest areas where improved flows of information can influence organizational performance.

1.2 Purpose

The research described here is an empirical, descriptive, cross-sectional analysis of the information network in a health department. The goals of this research are to afford the agency's leadership with a better understanding of the complex patterns of information use in the agency, and to contribute to general knowledge about information use in public health work. This has been accomplished by describing the information network, and by identifying links between workers, resources, tasks and knowledge that may influence agency performance. The analysis has produced network diagrams and statistical models that describe and provide insight into how information is used in the organization.

1.3 Research Objectives

The objectives of this study are to:

1. Empirically describe the structure of information flow in a health department using organizational network analysis.
2. Determine possible links between information flow and agency performance, as suggested by the network model
3. Assess the utility of the method as a diagnostic tool for public health information managers

The project's specific aims and associated research questions are displayed in Table 2.

Table 2 Study objectives, specific aims and research questions

Study Objective	Specific Aims	Research Question
1. Empirically describe the structure of information use (information flow) in a health department using organizational network analysis.	1a) Collect relational data on the agency-wide communication network 1b) Produce visual and quantitative network models that describe information flow	1. What is the structure of information flow in the health department's communication network?
2. Determine possible links between information flow and organizational performance, as suggested by the network model	2. Analyze the network visualizations and statistics to determine possible links between information flow and performance.	2. What relationships between information flow and performance are suggested by the model?
3. Assess the utility of organizational network analysis as a diagnostic tool for public health information managers	3. Collect feedback from department leadership on a) the expected impact of the analysis b) value of this method for managing information	3a) How do department leaders expect to use the findings to make an impact on information management? 3b) What is the value of network analysis for public health information managers?

1.4 Theoretical Framework

Several theories are interrelated to form the framework for this study: organizational theory, which is extended by information processing theory; and network theory, which is informed by graph and complexity theory. These theories are briefly described here and discussed more fully in Chapter 2.

Contemporary organizational theory incorporates aspects from general systems theory (Bertalanffy, 1968) in viewing an organization as a collection of agents (usually representing human actors, but sometimes intelligent machines) that

interact and produce some form of output that is beyond the capacity of any single agent (Chang & Harrington, 2004; Wertheim, 2001). Information processing theory extends organizational theory by characterizing these interactions as an information processing network operating under conditions of uncertainty (Galbraith, 1973). Information is viewed as ubiquitous and distributed widely across multiple agents (people, groups, machines) within organizations (Carley & Wallace, 2001). Uncertainty is the difference between the amount of information needed to perform a task and the amount of information already possessed by the organization (Galbraith, 1977). This difference, and how it is managed, determine the quality of output, or performance. The greater the uncertainty of the task, the greater will be the amount of information that must be processed to achieve a given level of performance. Organizations evolve to accommodate uncertainty and to reduce the need or increase the capacity for information processing.

Network theory is based on linkages among units within a network (Wasserman & Faust, 1994). A network is an interconnected system of things or people (Princeton University Cognitive Science Laboratory, 2003). In an organization, networks are comprised of *nodes* that represent agents, knowledge, tasks, or resources, and *links* that show relationships between the nodes. Depending on the scale of analysis, an agent may represent an individual, a project team, a division, or an entire organization (Dooley, 2002). Agents have varying degrees of connectivity with other agents through which information and resources flow.

These interdependent "node-link" structures, while simple in concept, become related in multifaceted ways as networks grow and develop. The resulting complexity can be graphically displayed and analyzed using mathematical expressions that are based on the properties of graphs, i.e. graph theory.

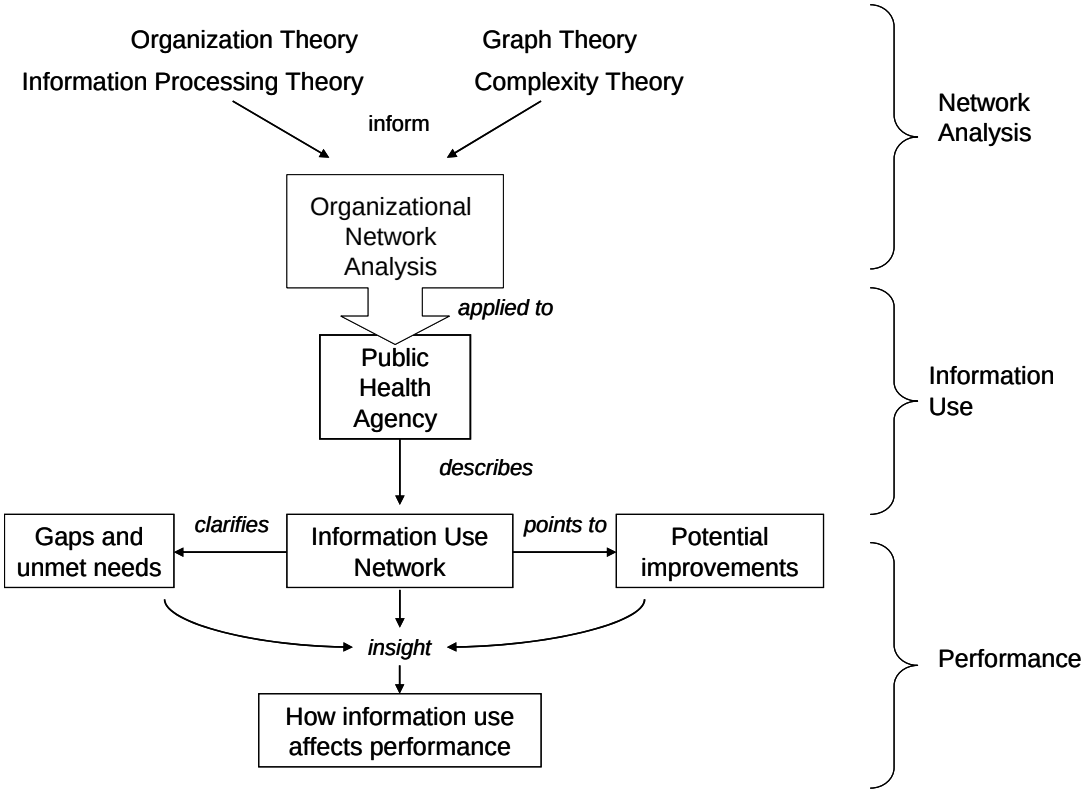
Complexity is the quality of being intricate and compounded (Princeton University Cognitive Science Laboratory, 2003) and refers to the number of connections among elements, or the rate at which relationships among elements of a system change. Complexity theory describes the uncertainty created by non-linear dynamics in systems, where small changes are amplified through many interactions with other variables so that the eventual effect is unpredictable (Pearson Education, 2004). A fundamental principle of complexity theory holds that the structure of a system gives rise to its behavior (Sterman, 2000). The study of complexity has found that the inter-related behaviors of even the simplest network are difficult or impossible to grasp by human cognition without assistance (Krackhardt, 2002).

1.5 Conceptual Model

This study is based upon three concepts. The first is the notion of organizational *network analysis*, a means for understanding complex behaviors of dynamic organizational systems. The second concept is that of *information use* in the public health organization. The interaction of these concepts creates a means to examine aspects of *performance*, which depends on how information is used in

the complex processes of a public health agency. These concepts are defined below and discussed more fully in Chapter 2. A model developed from these concepts, displayed in Figure 1, guided this research.

Figure 1 Conceptual model



Organizational Network Analysis

Organizational network analysis is an application of *social network analysis* (a method that is typically focused on connections between individuals) to an organizational entity. It is a descriptive, empirical technique for mapping and measuring relationships between people, groups, and organizations with the

resources, knowledge and tasks that are used to perform work. The technique draws upon theories of organizations, networks and complexity to produce models representing the structure of relationships that would be infeasible to describe without relational concepts (Wasserman & Faust, 1994). The results yield insight into organizational behavior.

Organizational network analysis derives from the notion that traditional organization charts and process maps fail to capture the complex web of information interactions. True patterns of information exchange are not explicit and therefore tend to be unmanaged processes in most organizations (Stephenson, 1996). Organizational network analysis provides both a graphical and a quantitative analysis of complex human systems to describe the flow of information along existing pathways in organizations (Krebs, 2005). When the results of network analysis are interpreted in relation to formal organizational hierarchies, opportunities for improvement can be discovered.

Information use

Information use, broadly interpreted, includes how information flows and how information resources and information technologies form, maintain, and serve specific communities of practice (University of Michigan School of Information, 2004). Information use is any activity involving the delivery, accessibility, collection, organization, or visualization of information; this might involve initiation of a search for information, selection of information sources, the process

of exploration for new or needed information, methods for formulating or focusing information requirements, the process of collecting information, viewing information, or presentation and delivery of information (Kuhlthau, 2001). In the context of the public health agency it can include typical business information processing such as text writing, drawing, calculating, filing and communicating information (Aalst & Hee, 2002). Information use is part of specialized tasks such as field investigations, inspections, surveillance, sample collection, or direct provision of health services. Information flow is an aspect of information use in the agency's communication network. This flow of information is essential to public health performance (Association of State and Territorial Health Officials, 2004a; Lee, 2001; Lumpkin, 2002; Ross, 1998).

Public Health Organizational Performance

Organizational performance is an interaction between *organizational knowledge* (a function of individual training, knowledge and information processing capabilities), and *organizational structure* applied to the work of the organization (Carley, 2002a). If we apply this definition to public health, then knowledge in any public health agency is a function of staff trained in public health plus public health data, information and knowledge. Accordingly, public health organizational structure is comprised of mission, structural capacity, processes and outcomes (Handler *et al.*, 2001). These elements interact to determine how well public health can perform its mission: assuring conditions in which people can be healthy (Institute of Medicine, 1988). In a given public health agency,

performance will be defined by the specific goals that fit that agency's structural capacity and that guide processes for addressing the needs and concerns of the communities served (Turnock & Handler, 2001). Network analysis allows us to describe organizational complexity within the framework of the information network. The results yield insight into how these interactions may influence performance (Carley & Hill, 2001).

Table 3 displays these concepts in relation to the measures used in this study. Measures are further explained in Chapter 3, Table 14. The formulas used to calculate these measures in *ORA* are supplied in Appendix D.

Table 3 Conceptual elements in relation to network measures

Concept	Measure
Network Analysis	Individual level Cognitive demand Degree Centrality Betweeness Centrality Eigenvector Centrality Betweeness Centrality/Degree Centrality Shared situation awareness Network level Density of the social network Complexity of the overall network Average situation awareness between agents Network Centralization Transitivity (presence of transitive groups)
Information use	Diversity of knowledge and resources Redundancy of resources, assignments, and knowledge Communication speed Efficiency of message transmission
Performance	Impact of findings on the organization Managerial Value Changes to organizational processes Redeployment of resources Function changes Cross program support

1.6 Significance

This work is important because it i) produces a model that describes the complex network that exists between public health workers and information use, and ii) provides insight into how the flow of information in a public health organization might influence performance, and iii) it demonstrates the utility of network analysis for managing information in a public health agency.

Although network analysis is a technique that has proven useful for managing information and improving performance in organizational systems (Chang & Harrington, 2004; Cross & Parker, 2004; Kilduff & Tsai, 2003; Krebs, 2005), there is no documentation of the method applied to a public health agency's organizational structure. Since many public health professionals don't have the skills to make strategic decisions about how information is managed (Mandl & Lee, 2002), they need methods to help them understand and direct these processes (Ross, 2002). The research reported here provides insight into the relationships, resources and behaviors regarding information use in a public health agency. The results distinguish between the formal organizational structure and how work actually gets done in the network. Interpretation of the results suggests how the flow of information in public health work is related to agency processes. This study tests an empirical technique to assist public health professionals in identifying the value of information management in relation to organizational performance.

This project is further important because it helps define the value of the information network within a public health agency. Limited public funding streams demand adequate justifications for all investments that must be balanced against a wide range of demands for public health resources. It is important to determine how information use affects public health processes to justify committing scarce resources to sustain and improve information structures (Ross, 2002). Mays et al (1997, 2004) and Bialek (1998, 2004) have extensively documented scarce funding for public health infrastructure investments. This scarcity is illustrated by U.S. public health expenditures at the state level during 2001. Public health services, including direct care, community-based, and population health services, comprised only 4.4% of all states' expenditures, and just 14.7% of all health care expenditures. Translated to New York State, total health care expenditures in 2001 were $35.6 billion, of which only $5.2 billion (or about $274 for each of 19 million New Yorkers) was allocated to the public health system (Fund, 2003). Techniques that can describe a quantifiable relationship between how information is used and organizational performance will support planning for improvements in public health structural capacity.

This study is also important as health systems research because it contributes knowledge regarding a method to evaluate how information is used in public health organizations. It is a widespread assumption that improvements in information use will result in an improved public health system in general, and improvements in services provided by the specific agency (Association of State

and Territorial Health Officials, 2004a; Lumpkin & Richards, 2002; Milio, 2000). It has been difficult to empirically demonstrate this assumption due to limited research on public health systems to use as a basis for evaluation (Roper & Mays, 2000), and limited collaboration between public health services researchers and informatics researchers (Mandl & Lee, 2002). In addition, this work meets a need for increasing collaboration between informatics researchers and public health systems researchers, a goal of the public health informatics agenda recognized by the American Medical Informatics Association (Yasnoff *et al.*, 2001).

1.7 Relationship to New York Academy of Medicine Project

This dissertation research was conducted as part of a pilot project, “Increasing Public Health Departments' Organizational Effectiveness through Information,” funded by the National Library of Medicine (# N01-LM-1-3521) through the New York Academy of Medicine.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

The objective of this chapter is to provide reference and explanation for the research study, based on the conceptual model described in Chapter 1. The model consists of three main elements: organizational *network analysis* and its foundations; *information use* in organizations and specifically in public health organizations; and how these two are coupled toward the goal of better understanding organizational *performance*.

Literature was retrieved as an ongoing process from reference databases, keyword and author searches (using health sciences, social science, computer science and business reference databases), as well as World Wide Web subject searches. Search topics included but were not limited to: organizational theory and analysis, systems analysis, social network analysis, complexity and graph theory, information use and information management, public health information needs, organizational performance, and public health performance. Keyword searches using Internet services were conducted specifically directed at “gray literature” produced by government, academia, and business and industry in print and electronic formats not controlled by commercial publishers (New York Academy of Medicine, 1999).

2.2 Organizational Network Analysis

Organizational Theory and Information Processing Theory

The view of what comprises an organization has fluctuated with changing schools of thought, and there are many definitions. One characteristic that distinguishes organizations from other collections of people is a commitment to achieving some goal(s) by means of an explicit and stable structure of task allocations, roles, and responsibilities (Starbuck, 1965). Thus many organizational definitions center on goals and objectives. For example, early classic organizational theory defines an organization as a structure of relationships, power, objectives, roles, activities, communications and other factors that exist when persons work together. A neo-classical definition places greater stress on formal and informal aspects of an organization as “a group of persons with a common objective” (University of Washington, 1999). Other definitions include “a structured process in which individuals interact for objectives" (Hicks & Gullett, 1976, p 23) and “a set of social relations deliberately created, with the explicit intention of continuously accomplishing some specific goals or purposes" (Stinchcombe, 1965, p. 142).

Over time organizational theory has progressed from the rational administrative approach of sociologist Max Weber (1947) to views that encompass a wide variety of influences on the behavior of organizations and the individuals that participate in them. Information technology pioneer Norbert Wiener's cybernetic interpretation defines an organization as a system consisting generally of inputs,

process, outputs, feedback, and environment (Wiener, 1954). Systems theory has long been used as a framework for understanding organizational performance and outcomes, and has been applied extensively to quality management in business, healthcare and public health.

Contingency theory came into favor around 1980 and remains influential (Carley & Wallace, 2001). The theory maintains that organizational structures evolve to suit environmental conditions. For example, an organization with well-defined tasks and a rigid hierarchy is well suited for stable conditions. In dynamic environments a distributed structure is more advantageous, where tasks are flexible and cooperation is based on expertise rather than hierarchical positions (Burns & Stalker, 1961). The most effective organizations achieve both differentiation *and* integration in boundary-spanning functions in response to environmental demands (Lawrence & Lorch, 1967).

The relational tradition views an organization as a series of interactions between individuals, in which communication reduces uncertainty in the environment (Weick, 1979). Relational and systems views are combined by defining an organization as "a collection of agents that interact and produce some form of output" (Chang & Harrington, 2004). By modifying this definition to stipulate that agent interactions occur *in response* to an organization's environment, the contingency view is incorporated. The systems, contingency and relational views are relevant for public health organizations that are embedded in governmental and community systems, and continually strive to match organizational response

to an array of shifting population health needs. Table 4 traces schools of thought influencing organizational theory in the last century.

Table 4 Schools of organizational thought and their components by decade (Wertheim, 2001)

School of thought	Decade	Description
Authoritarian	Prior to 1900	Emphasizes division of labor and importance of machinery to facilitate labor
Scientific management	1910s-	Describes management as a science with employers having specific responsibilities; encourages scientific selection, training of workers and equal division of work between workers and management
Classical school	1910s-	Lists duties of manager for controlling performance; called for specialization, chain of command
Human relations	1920s-	Emphasizes importance of attitudes and feelings of workers; informal roles and norms impact performance
Classical school revisited	1930s	Re-emphasizes the classical principles
Group dynamics	1940s	Encourages individual participation in decision making; impact of work group on performance
Bureaucracy	1940s	Emphasizes order, system, rationality, uniformity, and consistency in management; led to equitable treatment for all employees by management
Leadership	1950s	Stresses the importance of groups having both social task leaders
Decision theory	1960s	Suggests that individuals "satisfice" when they make decisions; so-called garbage can model
Socio-technical school	1960s	Calls for considering technology and work groups when understanding a work system
Environmental and technical system	1960s	Describes mechanistic and organic structures and their effectiveness w/ specific environmental conditions and technological resources
Systems theory	1970s	Represents organizations as open systems with inputs, internal transformations, outputs, and feedback; systems strive for equilibrium
Contingency theory	1980s	Emphasizes fit between organization processes and characteristics of the situation
Relational	1980s	Cites communication as a basis for human organizing
Post modern organization theory	1990s onward	New organizational forms mediated by technology and informed by chaos and complexity theories, e.g. virtual organizations, self-organizing systems, networked organizations.

Information Processing Theory

Galbraith defines the organization as an information processing entity (Galbraith, 1973, 1974b, 1977). In organizations, inadequate information leads to uncertainty, defined as the difference between information needed (to make a decision or perform a task) and the information available. Missing information reduces organizational managers' ability to preplan. Galbraith's theory holds that the greater the uncertainty of the task, the greater the amount of information that must be processed between decision makers during the execution of the task to get a given level of performance. Organizations reduce uncertainty through better planning and coordination, often by rules, hierarchy, or goals.

Galbraith cites contingency theory to explain how variations in organization design evolve from strategies for increasing pre-planning ability and decreasing the level of performance required for continued viability (Galbraith, 1973). There are several strategies that firms use to reduce uncertainty by either i) reducing the amount of information processed, or ii) increasing the ability to handle more information (Galbraith, 1977; Rollag, 2000). These strategies include:

1. Creation of slack resources, such as extending delivery times, adding more money to the budget, and building inventory. All strategies have inherent costs.
2. Creation of self-contained tasks to simplify management of exceptions in routine procedures.

3. Investment in vertical integration systems to condense the flow of information (e.g., computer and decision support systems).
4. Creation of lateral relationships to move decision making to where the information exists. There are various strategies to achieve this:

- Direct contact between managers across groups who can jointly solve problems.
- Liaison rules or liaison personnel to bridge sub-systems and reduce need for hierarchical decision making.
- Task forces composed of multi-department groups to solve a particular problem.
- Teams designed to perform a specific task.
- Integrating roles using cross-group program managers to improve joint decision making.
- Managerial linking roles where a manager has formal authority over budgets or planning.
- Matrix organization where linked managers are part of two departments in a dual-authority relationship.

Organizational integration strategies can reduce uncertainty, but result in higher personnel and administrative costs. There is no best way to organize. Galbraith recommends a strategy that has the least cost, in context of the organization's environment. If an organization doesn't implement a higher strategy, lower performance happens automatically, and slack resources will be used to reduce overload in the decision hierarchy (Galbraith, 1974b).

Network Analysis and Graph Theory

The social network perspective encompasses theories, models, and applications that are expressed in terms of relational concepts or processes (Krebs, 2005). Network methods focus on the ties between individuals, or larger subgroups of individuals, or entire networks (Wasserman & Faust, 1994). Network analyses can be ego-centered, concentrating on focal actor interrelations, or they can be whole network studies, as is this dissertation. The key feature distinguishing network theory and measurement from traditional data analytic methods is use of structural or relational variables (Wasserman & Faust, 1994). Relations are linkages between people, groups, or organizations. Relational variables can take the form of transactions (e.g., who gives what to whom), communication (e.g., who talks to whom), boundary penetration (e.g., who's on whose board of directors), instrumental relations (e.g., who asks whom for expert advice), sentiment relations (e.g., friendship cliques), power relations (e.g., who follows whom in informal group), or kinship relations (e.g., who's related to whom) (Van der Veer Martens, 2005).

Network analysis enables researchers to represent relational data and explore the nature and properties of those relations (Monge & Contractor, 2003). Central principles underlying the network perspective include the following (Hanneman, 2001; Wasserman & Faust, 1994):

- Actors and actions are viewed as interdependent rather than independent, autonomous units.

- Relational links between actors are channels for the flow of resources (either material or nonmaterial).
- Network models view the network structural environment as providing opportunities for or constraints on individual action.
- Network models present structure (such as social, economic, political) as lasting patterns of relations among actors.

Relational data are analyzed using techniques based on graph theoretic methods (Wasserman & Faust, 1994). Graph theory supplies i) a vocabulary for denoting social structural properties, ii) mathematical operations to quantify these properties and iii) a method for proving theorems about graphs that can be used to infer how well they represent social structures (Kilduff & Tsai, 2003; Wasserman & Faust, 1994, p 93).

A graph is a finite set of dots called vertices (or nodes) connected by edges (or arcs), also called links in social network analysis. To create a network graph, individuals are represented as points or nodes in a network and the relationships that connect them (such as “communicate with” or “provide information to”) are represented as lines that connect the nodes. Each line indicates an information link between two people. Diagrams can show people in central or peripheral positions, or the existence of subgroups. Graphs can be notated in the form of a matrix, which allows quantitative calculation of network structure to be performed using operations from linear algebra (Scott *et al.*, 2005).

Matrices are vectors whose components are arranged in a rectangular array instead of a single row or column (Bogomolny, 1996). Relational, positional or spatial data are organized into an adjacency matrix where rows and columns represent individuals or resources. Within each cell of the matrix numbers are used to represent the existence or absence of a direct relation, or frequency or strength (value) of the relation, where each node is assigned a column (*i*) and a row (*j*) (Anderson, 2002; Scott et al., 2005). If the matrix as a whole is called N, the contents of a given cell are denoted N*ij*. Figure 2 shows an adjacency matrix.

Figure 2 Example of an adjacency matrix
1 = relationship, 0 = no relationship

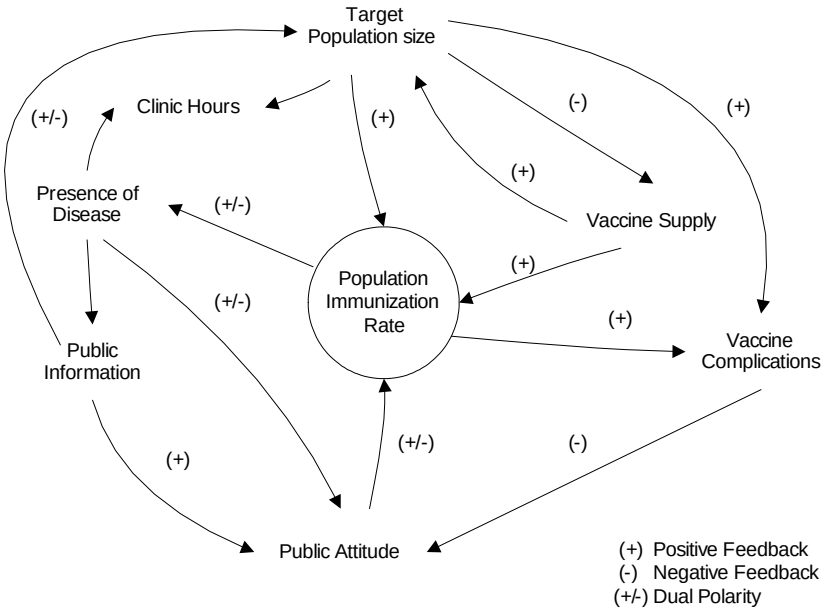
	a	b	c	d
a	0	1	1	1
b	1	0	1	0
c	1	1	0	1
d	1	0	1	0

Complexity Theory

Complexity theory describes the uncertainty created by dynamic interactions in non-linear systems, where cause and effect are not proportional. Complexity refers to the number of connections among events, or the rate at which relationships among elements of a system change (Swenson, 2002). Internal processes are linked at many levels, and any activity within a single process creates *feedback* that is *dynamic* in its potential to affect other system components, frequently in unpredictable and not easily recognized ways (Sterman, 2000). As interactions proliferate, a robust system will typically self-organize and adjust to the new conditions, thereby building complexity (Elliott & Kiel, 2004). We consider these systems to be complex and adaptive. Figure 3

presents an example of this dynamic in a public health context—amongst factors affecting immunization rates.

Figure 3 Example of a feedback loop in public health
(Merrill *et al.*, unpublished manuscript)



Complex systems are characterized by behaviors that *emerge* as a result of often nonlinear, non-sequential interactions among a large number of system components. For example, symptoms of a problem, which are often separated from the actual problem by time and space, can seem counter to human intuition; policy interventions can frequently yield short-term successes but long-term failure, or the reverse; and internal system feedback often counters external policy intervention (Radzicki, 1997). Large organizations typically conform to this dynamic. Table 5 defines characteristics of complexity (Sterman, 2000) in the context of the public health system.

Table 5 Characteristics of complexity in the public health system

Characteristic	Description	Example in PH Systems
Dynamic and unpredictable	Change in systems occurs at many time scales and these can interact. For example, a pattern sustains for years then crashes suddenly	Sudden introduction of a new language group into a community creates an immediate need for modified public health services and new health educational methods.
Tightly coupled	The actors in the system interact strongly with one another and with the natural world, i.e. interconnectedness.	Birth certificate data exists as legal documentation, a source for surveillance, and a quality of care document.
Governed by feedback	Due to tight coupling among actors, actions' feed back or triggers that generate new situations, that then affect subsequent actions.	A water contamination warning stimulates public concern and activism, and results in demands for different level of service.
Nonlinear	Effect is rarely proportionate to cause, and what happens locally in a system often does not apply in other states of the system.	Public belief that rare, invisible risks are highly dangerous compared to 'ordinary' risks puts high demands on system resources for essential services.
History Dependent	Each choice precludes others, and the outcomes ensue from this "path dependence."	Previous decisions on zoning or sewage disposal limits choices when population density changes.
Self-organizing	The dynamics of systems arise spontaneously from their internal structure.	Scope and quality of services offered by an agency are determined by its staffing profile and local jurisdictional structure.
Adaptive	The capabilities and decision rules of the agents in complex systems change over time.	Evolution of PH priorities from infectious diseases, to direct services, to essential services, to chronic disease and bioterrorism.
Counterintuitive	Cause and effect are distant in time and space, while system analysts tend to look for causes near the events they seek to explain.	Mid-20th century choices to increase convenience (prepared foods, malls, drive thru services, freeways) changed activity and dietary patterns resulting in increases in chronic disease such as diabetes, obesity.
Policy resistant	The complexity of systems in which actors are embedded often overwhelms any ability to understand them, thus seemingly obvious solutions actually worsen a situation.	Hiring for bioterrorism preparedness programs taps a limited worker pool, thereby depleting already understaffed programs and weakening system capacity that preparedness is designed to strengthen.
Trade-offs	Time delays in feedback channels mean the long-run response of a system to an action is often different from its short-run response.	In late 1980's recognition of folate link to infant neural tube defects initially led to supplements for individual women, followed by 1998 FDA mandate to fortify commercial grain products w/ folic acid.

Network Theory and Organizational Network Analysis

Organizational network analysis (ONA) is an application of social network analysis methods to the whole network of an organization. The unit of analysis extends beyond the individual, to a set of interrelated objects or actors and the linkages among them regarded as a bounded social collective (Marsden, 2005). There is an extensive and exponentially growing body of literature on the application of network methods in the study of organizations (Borgatti & Foster, 2003; Brass *et al.*, 2004). Research topics span interpersonal, inter-unit, and inter-organizational networks.

ONA methods apply organizational and information processing theories to examine the ways management uses formal networks to achieve its objectives, and to examine how organization is achieved through informal interactions between individuals (Farace *et al.*, 1992). These methods draw on concepts from network theory and complexity theory to provide a picture of the communication dynamics and to aid human cognition in understanding these dynamics by mapping and measuring of relationships and flows between people, groups, organizations, computers or other information/knowledge processing entities (Krebs, 2005). For intra-organizational analysis, individuals are represented as a set of interconnected nodes. Each node represents an information processing resource—limited in its ability to accommodate and analyze incoming information (Carley & Hill, 2001). Each connection between nodes is a channel for the flow of information. Analysis starts with objective representation of each

individual on a set of specified attributes, typically binary, to represent dimensions of organizational knowledge (Harrison & Carroll, 2001). Communication and information used in an intra-organizational network fall into three categories: scope, function, and structure (Farace et al., 1992).

1. Scope explores the volume of information individuals receive, and the characteristics of group structures. Aspects of groups include patterns of who influences whom, and leadership or role distribution.

2. Function can be examined through the coordination of tasks, the pathways through which information is communicated.

3. Structure explores emergent patterns or regularities in the transmission of messages, who talks to whom, and the overall flow of information through the organization.

ONA identifies patterns in behaviors that are independent of pre-existing titles and group labels, and can verify or repudiate assumptions about how individuals and groups are formally supposed to act (Haythornthwaite, 1996). These insights into organizational structure can guide managers on when and how to modify structures within the context of the existing organization (Kwait *et al.*, 2001).

Network Modeling

Models are the representation of one system by another (Loerch, 2004) and are generally simplified descriptions of a complex entity or process (Princeton University Cognitive Science Laboratory, 2003). The goal is to relate the model to reality and in the process gain insight that may lead to useful modifications (Chang & Harrington, 2004). Models can serve as a bridge between theoretical and empirical work (Heitsch *et al.*, 2000) by organizing theoretical beliefs and empirical observations about a system, and serving as aid in identifying important

system aspects (Loerch, 2004). Networks are but one of several modeling techniques applied to organizational systems. Table 6 catalogues organizational modeling methods and describes their application.

In applying ONA, comparison of a hierarchical chart with the network in the same agency usually reveals a striking contrast between the group's formal and informal structure (Cross, 2004). For example, an individual that appears as a peripheral agent on a team in the formal organizational structure can have a pivotal role in

Table 6 Comparison of organizational modeling methods
(K. M. Carley & Wallace, 2001)

Method	Focus	Represents	Goal	Output
General intellective simulation models	Explain or theorize about a specific organizational behavior	Organization as a set of non-linear equations or interacting agents	Test effect of change in a process, action or policy	How organization will behave under various conditions
Distributed artificial intelligence and multi-agent models	Representation of knowledge; decision making as search	Task and knowledge about how agent does task	Explain organizational phenomena; test coordination	Task scalability; representation of human behavior
Organizational engineering models (emulation models)	Overall organizational response (not agent)	Formal task flow, workflow, communication paths	Analyze planned policy change; insights on problems	Address specific what-if questions
Social network models	Network adaptation and change	Structure as relations among individuals or organizations	Understand how knowledge affects/is affected by network position	Explain/describe performance, information diffusion, innovation, power, turnover
Mathematical/logic based models	Generative aspects of organizational form	Organizations and processes using formal logic	Test internal validity of theory	Complete proofs of organizational behavior

the informal network if he or she is highly connected to others, or acts as a boundary spanner connecting groups. The informal role of such individuals has significant implications for how information flows in the organization, which are not described by the formal structure. In another example, a "rhetoric-reality gap" can be revealed in some organizations (Jablonsky & Barsky, 1999). Superficially, organizations may profess a participatory orientation where managers may tell employees to "take ownership" of work processes, all the while retaining full managerial control. Such situations can impair management credibility and employee effectiveness. Network analysis can identify these dynamics by showing that senior managers at the core of the organization are still the employees with the highest influence ratings and centrality values (Barsky, 1999).

Network analysis has been used in clinical health care to compare communications in family care practices and to identify differences that affect performance (Scott et al., 2005). The method has been applied to hospital communication networks to find linkages between different functional units and to identify where opportunities could be created to improve facilities management (Heng *et al.*, 2005).

There has been limited use of network methods in the public sector and in public health (Agranoff & McGuire, 1999; Rivera & Rogers, 2004). However, public health researchers increasingly recognize the utility of network methods to examine disease transmission patterns, particularly sexually transmitted diseases,

and to predict potential effects of disease control policies (Cabral *et al.*, 2003; De *et al.*, 2004; Diekmann & Heesterbeek, 2000; Klovdahl *et al.*, 2001; Morris, 2004; Pourbohloul, *et al.*, 2005). Network analysis also has been applied to the relationships among public health organizations at the state and community level. Knauss and colleagues examined interorganizational relationships within state tobacco control networks (Knauss *et al.*, 2004). Kwait and colleagues modeled relationships among urban HIV/AIDS service organizations (Kwait, *et al*., 2001). Eisenborg and Swanson used the method to study client referral patterns in Healthy Start programs (Eisenberg & Swanson, 1996). Provan and colleagues used the method to examine community networks providing mental health services (Provan *et al.*, 2004). Provan and colleagues also have put forth a framework for evaluating public sector organizational networks (Provan & Milward, 2001). The framework proposes that network analysis may be applied at several levels to evaluate effectiveness of public sector agencies at the community level, at the inter-agency level and at the intra-organizational level. In the literature to date no network studies were found examining intra-organizational structure in a public health department.

Network Analysis with the Organizational Risk Analyzer (ORA)

To capture the variety of networks that exist within organizations, researchers have extended organizational network analysis with a meta-matrix model to formalize the interdependencies between individual agents in an organization and

the tasks, knowledge and resources they bring to bear on their work (Carley & Kamneva, 2004; Krackhardt & Carley, 1998). The meta-matrix is defined as the networks connecting people, knowledge, resources and tasks, as displayed in Table 7.

The meta-matrix method provides both a means for representing an organization, and a set of measures for analyzing the resulting data. The method is characterized by Carley as "dynamic network analysis" (Carley, 2002b).Various aspects of organizations can be described in terms of these interlocked networks. The first row of Table 7 represents organizational elements that are most readily changed, manipulated, or altered by the manager. These four matrices are the focus of this analysis. The rest of the meta-matrix elements can be changed, but are more constrained by factors such as organizational mission, existing technology, material assets, or particularly in the case of public health, legislative mandate (Carley & Kamneva, 2004).

Carley and Reminga developed the Organizational Risk Analyzer (*ORA*) application, which was used in this study (Carley & Reminga, 2004). *ORA* takes as input one or more matrices in the meta-matrix for an organization, from which it calculates network measures that describe the relations among personnel, knowledge, resources and tasks. *ORA* contains over 75 measures of organizational structure and vulnerability based on work in social networks, operations research, organizational theory, knowledge management, and task

management (Reminga & Carley, 2005). A subset of twenty-one *ORA* measures was applied in this study. They are described in Chapter 3, Table 14.

Table 7 Meta-matrix used in dynamic network analysis
(Carley & Kamneva, 2004)

	People	Knowledge	Resources	Tasks
People	Social Network *Who talks to, works with, and reports to whom*	Knowledge Network *Who knows what, expertise or skills*	Resource Network *Who has access to, or can use which resource*	Assignment Network *Who is assigned to task, who does what*
Knowledge		Information Network *Connections among types of knowledge*	Resource Usage Requirements *Knowledge to use resources*	Knowledge Requirements *Knowledge needed for tasks*
Resources			Inter-operability Requirements *Connections among resources*	Resource Requirements *Resources needed for tasks*
Tasks				Precedence Dependencies *Tasks related to tasks*

2.3 Information Use

Information is defined within a hierarchy of meaning that begins with essential data, which is processed and analyzed to become information, which is interpreted to become knowledge (Cleveland, 1985). Knowledge is the basis for addressing uncertainty and improving performance (Cyert & March, 1963). Information has attributes of accuracy, timeliness, utility, relevance, quality and accessibility (Saracevic, 1992). Information *flow* defines the ways information

moves throughout a system, or how the use of information is structured in the organization's communication network (Bishop, Forthcoming). Information flow is a key factor in how organizations learn and adapt because the way information spreads determines the speed with which individuals can act and plan their future activities (Stacey, 1996; Wu *et al.*, 2004). Network analysis captures information flow via the links employees use to exchange and share information.

Information in Organizations

Organizations are consumers, managers and purveyors of information (Feldman & March, 1981). Complex organizational systems are multi-dimensional arrangements of information processing networks that construct meaning, create knowledge, and make decisions (Principia Cybernetica, 1999). Organizations are composed of intelligent adaptive agents (both human *and* machine) constrained and enabled by their positions in a network linking agents and knowledge, in the form of resources and information (Carley & Hill, 2001). Information, as an integral part of organizational processes, is an aspect of the dynamics of systems. Information flows contribute to dynamic system change. When the flow of information is unpredictable it can produce paradoxical effects that affect meanings, roles and outcomes in organizations (Sawyer & Rosenbaum, 2000). The adaptability of organizations and their ability to function depends critically on their information-processing capabilities (Kampfner, 1999).

Information in Public Health

The combined collection, analysis, use, and communication of health-related information is the most important public health service, under girding all others (Lasker et al., 1995). To accomplish their mission, public health workers rely on data reflecting a wide variety of risk factors such as air quality, poverty, access to healthcare, education status, and the presence of hazardous chemical or biological agents, behaviors and exposures. They monitor the occurrence of health events, health conditions and deaths, as well as the activities of both the healthcare and public health systems, and their effects on health (Koo et al., 2002). Public health directors classify public health and clinical information flows into ten data categories (Association of State and Territorial Health Officials, 2004a):

1. Infectious disease data
2. Vital health statistics data including data on births and deaths
3. Chronic disease data (e.g., obesity, cancer, cardiovascular, diabetes)
4. Environmental health data
5. Sexually transmitted disease and tuberculosis data, including data on HIV
6. Immunization data
7. Early detection surveillance data, including reportable diseases
8. Maternal and child health data
9. Occupational health data
10. Other data on illegal substances, drugs, and many additional topics

Public health knowledge is created when such data and information is: a) evaluated for accuracy and relevance; b) transformed to meet current or potential need; c) structured and organized for retrieval; analyzed and interpreted; or d) made accessible when and where needed for decisions (Association of State and Territorial Health Officials, 2005).

Public Health as a "Fractile" Enterprise

The structure of public health agencies presents considerable challenges to effective information flow (O'Carroll, 2002a). Public health agency infrastructures have evolved as components of state and local governments. Local public health services can be centralized, as units and/or staff of the state health agency, or decentralized as units of local government. They can also be subject to shared authority of both the state agency and the local government, or to mixed authority of local governments in some jurisdictions and by the state in other jurisdictions (Public Health Foundation & Turning Point Performance Management Collaborative, 2002). Public health services are primarily supported by categorical funding streams, a tradition that has resulted in agencies organized in specialized programmatic areas, mandated to serve specific sub-populations or to address unique health problems (Public Health Foundation, 2004a). These systems allow agencies to manage programs, provide services, and to direct prevention and control activities. The separation also has fostered information security and confidentiality. However, because information is fragmented often, it cannot be aggregated or accessed. This has led to duplication of effort, information gaps and strained cooperative working relationships, and has made it difficult to accomplish the mission of public health (CDC/ATSDR Steering Committee on Public Health Information and Surveillance System Development, 1995). For these reasons public health has been referred to as a "fractile" enterprise (Ross, 1998, p. 885). In addition, most local public health agencies

count on a mix of local, state, and federal funding for new information system development. Nearly half believe that they cannot rely on local sources alone to fund even their high-priority initiatives (National Association of County and City Health Officials & Public Health Informatics Institute, 2004). Thus, significant information needs persist within public health systems.

Turner's assessment of Oregon county health nurses' information needs found that the chief barriers to timely access to accurate and up-to-date information were basic—a lack of access to computers, email and support services (Turner & Stavri, 2003). A study of Tennessee public health workers found significant barriers to computer use and access to electronic resources that could support evidence-based public health practice (Lee et al., 2003). Results from a survey of local health administrators identified functional areas in which flows of information could be improved with information technology (Burke & Evans, 2003). The activities that were identified and displayed in Table 8 are at the heart of public health work.

Table 8 Public health activities where information use can be improved (Burke & Evans, 2003)

Public Health Activity
Disease mapping
Quality of service/quality assurance
Patient tracking for hospitals/clinics
Availability of services in the community
Vital statistics
Environmental health
Analysis of data/statistics
Dissemination of information to public/special groups
Immunizations
Laboratory reports

2.4 Performance

Information and Performance

The overall structure of an organization determines how information diffuses among individuals, with consequences for the speed, quality and accuracy of organizational decisions and performance (Cyert & March, 1963; Galbraith, 1974b). Yet the consequences that arise as a result of feedback loops in complex organizational systems can result in unexpected responses (Bennet & Bennet, 2004; Forrester, 1961; Sterman, 2000). The plethora of factors that can interact in complex, non-linear ways include: intelligence, cognitive capabilities, skills or training, available resources, quality and quantity of information, volatility of the environment, legal or political constraints, and the outcome desired (e.g., efficiency, accuracy, minimal cost) (Carley & Wallace, 2001).

Information processing theory maintains that there is no single optimal design for all conditions, but that there may be a set of optimal designs for particular conditions, and organization can be changed to improve performance (Galbraith, 1973). Seminal work by Feldman and March (1981) describes how systematic information collection in organizations typically exceeds the ability for the organization's members to use that information. They link this persistent and ever-increasing need for information to social values concerning personal and organizational competence. Information availability and its form of delivery have the potential to change the individual's process of information seeking itself (Wilson, 2000). The way in which information is provided can engender cognitive

changes in the mental processes involved in recognizing and associating like information--a phenomenon of "meta cognition" that develops over time (Carley & Hill, 2001; Carley *et al.*, 1998).

Early studies of organizational networks have shown how the structure of networks affect the rate of information diffusion and influence the ability of individuals to acquire and use information, which in turn affects the speed, quality and accuracy of decisions (Bavelas, 1950; Leavitt, 1951). Even small changes in the structure of information networks in an agency can result in dramatically different behavior at both the individual and the organizational level (Carley & Hill, 2001). Any changes in the information network will interact with changes in other networks, such as social networks and knowledge networks, to affect overall organizational performance (Sawyer & Rosenbaum, 2000). Effective management of information is critical, and changes in information networks can have powerful consequences for organizational performance (Carley, 2002a). Table 9 lists principles of information processing in relation to performance.

Table 9 Organizational information processing principles and performance (Carley, 2002a)

Principle	Explanation
Bounded rationality	Organizational agents are bounded in capability and knowledge concerning dissemination, acquisition, storage, and processing of information
Information ubiquity	Large quantities of information are widely distributed across multiple agents within and among organizations; thus performance depends on distribution of information
Task orientation	Organizations and agents continually engaged in tasks requiring communicating, analyzing, adapting and processing organizational information, using technologies
Distributional constraints	Organizational performance is a function of information sharing and the process of searching for and combining information
Uncertainty	Uncertainty about task outcomes, environmental conditions, and other aspects of organizational life influence organization activity
Organizational intelligence	Resides in the distribution of knowledge and procedures within and among agents and in the linkages among agents
Path dependence	As agents and organizations learn, their intelligence is irrevocably restructured; thus the organizational history can have dramatic consequences for structure and performance
Necessity of communication	In order to function, agents within an organization need to communicate. Formal and informal communication flow affect organizational culture, intelligence and performance

Information and Public Health Performance

Management strategies that improve the way in which information flows in an organization are known to improve performance in business (Carley & Harrald, 1997; Carley & Hill, 2001; Carley, *et al*., 1998; Dodds *et al.*, 2003; Feldman & March, 1981; Galbraith, 1977; Pijl, 1994; Wilson, 2000) and in public health organizations (Allee *et al.*, 2004; Alpi, 2005; Association of State and Territorial Health Officials, 2004a, 2005; Public Health Foundation, 2004a; Rambo et al.,

2001). An organization's planned approach to collecting, evaluating, cataloging, integrating, sharing, improving, and generating value from its intellectual and information-based assets is knowledge management (Association of State and Territorial Health Officials, 2005). In order to develop knowledge management strategies, managers must understand the nature of the organizational structure and the processes that are used to collect, manage, and disseminate information (Gamache, 2005). Management strategies that improve the flow of information support performance of public health services (Koo et al., 2002).

For instance, a strategy that aggregates data from several sources can reveal outbreak patterns and disease clustering, and geographic displays can visibly target the likely source of widespread incidents and, by identifying what is available in and near the source area, promote efficient deployment of resources (Bath *et al.*, 2002; Lasker et al., 1995). In another example, Swain et al. (2004) demonstrated how Open Space Technology, a form of conferencing in which participants self-organize through consensus, aided public health planning in the City of Milwaukee Health Department. The intervention effectively allowed complex public health outcome planning to occur at a considerable reduction in financial resources, and was recognized as an effective and rapid means to distribute information and knowledge throughout the organization's management team. Fos et al. (2004) developed a decision support system to assist in budgeting and planning at the Mississippi State Department of Health. The resulting model permitted better recognition of achievable improvements in county capacity

versus expending resources on unachievable projects. The system is used for real-time budgeting and planning, as well as simulation, to assist in strategic financial decision making. In addition, analytic strategies, such as data mining, modeling and simulation techniques can be critical for policymakers, who need to make increasingly difficult decisions about public health capacity in times of tightening budgets and "downsized" government (O'Carroll, 2002a).

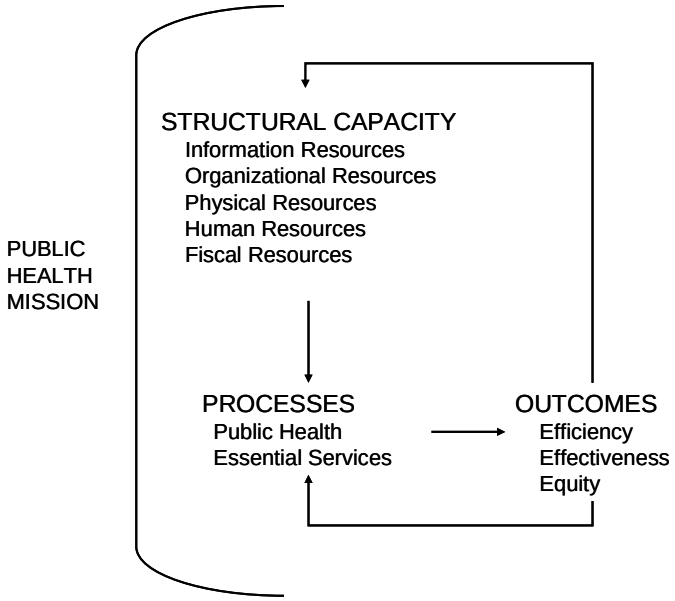
Stanley and colleagues (Stanley *et al.*, 2003) suggest that access to information for decision making is related to public health performance. They analyzed health outcomes for local public health jurisdictions according to self-reported performance on twenty measures. Through factor analysis, they found that jurisdictions with better outcomes reported higher performance for practices termed 'evidence-assisted decision making.' Similar findings resulted from a study by Canadian researchers who evaluated the influence that systematic reviews had on public heath decision makers in Ontario (Ciliska *et al.*, 1999). Although the time required to absorb the information was a barrier for most users, the subjects indicated that their decision-making had been beneficially affected. This investigation highlights the utility of an intervention such as literature synthesis to improve practice as well as to increase information utilization. Norwegian researchers explored how workers in that country's local agencies used research-based information, and found public health workers had significant unrealized needs for such information that, if met, had the potential to change public health performance (Forsetlund & Bjorndal, 2001).

Performance measures are quantitative measures of an agency's capacities, processes or outcomes (Public Health Foundation, 2004b). Public health agencies use a variety of frameworks in their performance management efforts.[1] However, these frameworks mainly focus on external factors and overall service management, and do not specifically target internal organizational processes. For example, typical public health performance measures will address an agency's capacity to undertake a specific public health service (e.g., immunizations), the specific things done to provide the service, and the consequences of having provided the service (Luchiello, 1999). Network analysis, as a method of evaluation, allows us to describe the complexity of interactions within the framework of the organization's internal information network. The results yield insight into how dynamic interactions *within* the agency may influence performance (Carley & Hill, 2001). Handler and colleagues (Handler et al., 2001) have developed a framework that conceptualizes public health performance at the system level. The framework identifies effectiveness, efficiency, and equity as broad system outcomes that are achieved by means of public health processes that rely on the structural capacity of the public health system. Structural capacity

[1] Performance management frameworks and models in use by 25 state health agencies in 2002 were identified as part of a survey on performance management practices (Public Health Foundation & Turning Point Performance Management Collaborative, 2002). In rank order the frameworks used were: Healthy People 2000/2010 Objectives; Core Public Health Functions (Assessment, Policy Development, Assurance); Ten Essential Public Health Services; State-specific performance frameworks; Community assessment & planning frameworks, like APEX*PH*, MAPP, & PATCH; Health People Leading Health Indicators; National Public Health Performance Standards Programs; HEDIS or other clinical performance measurement systems; Federal performance frameworks, such as GPRA; Healthy Cities/Healthy Communities; Baldrige Award Criteria; Other; Balanced Scorecard; and None.

consists of five resources: information, organizational, physical, human, and fiscal, as displayed in Figure 4.

Figure 4 Framework conceptualizing public health system performance (Handler et al., 2001)



Organizational network analysis applied as an evaluation method within the Handler framework focuses on structural capacity by empirically describing how information resources interact with organizational and human resources. In doing so, it provides insight as to how these interactions contribute to processes at the level of a single public health agency.

The Association of Public Health Laboratories and Public Health Informatics Institute have published a multi-dimensional logic model for evaluation of information systems in a public health agency (Association of Public Health Laboratories & Public Health Informatics Institute, 2005). The multi-stage model

includes a dimension that expressly addresses organizational impact of information-related initiatives. While the logic model is intended for use in evaluating technical information systems, the following elements from the model can serve as a guide for assessing where network analysis findings might have organizational impact:

- managerial value
- changes to organizational processes
- redeployment of resources
- function changes
- cross program support
- policies affecting use of, access to, or integration of information/communication

These six elements target *specific* aspects of structural capacity and process, which are expressed as broad concepts in the Handler framework (Figure 3). Thus they supply a useful means for considering the value of a network analysis of information use in a single public health agency, within the framework of public health system performance.

2.5 Knowledge Gaps Addressed by the Proposed Study

This study will contribute knowledge about the usefulness of network analysis to management of the public health agency. There has been limited use of network methods in public health. Application has been limited to studies of inter-organizational relationships, health behavioral networks or infectious disease networks. Public health agencies are part of state and local government. The organizational structure of these agencies derives from legislative mandates and the health needs of specific populations served. Thus, public health agencies have less structural flexibility than organizations in the private sector, which have been the main focus of organization network analysis. This study tests the usefulness of network analysis applied to the internal structure of a public health agency.

There is a fundamental need for public health to better analyze and develop its infrastructure (Institute of Medicine, 1988, 2002; U.S. Department of Health and Human Services, 2000). An understanding of how information flows in public health agencies is an important aspect of transforming information into the knowledge needed to support public health practice (Association of State and Territorial Health Officials, 2005). By describing patterns of interaction among the people and information in a public health organization, this study will help to answer questions about the flow of knowledge across functional and organizational boundaries and how to target opportunities where increased knowledge flow will have the most impact (Anklam, 2003).

This analysis will contribute knowledge on aspects of complexity in a public health agency to aid information management. Dynamics of information exchange is an important but understudied aspect of collective communication, coordination and problem solving in networked systems, including organizations and public bureaucracies (Dodds et al., 2003). The way in which organizations use information is changing in response to the complexity and dynamism of the environment in which most organizations operate (Pijl, 1994). Building effective intra-organizational information networks is recognized as an important strategy to improve performance (Katz & Lazar, 2003). Yet there is limited empirical research on how strongly information–efficient networks promote performance of real organizations, largely due to the difficulty of collecting data, and possibly due to an assumption that an information-efficient structure is a proxy for optimal group performance (Flap *et al.*, 1998). In public health, there is an impetus to develop integrated information systems, but little empirical evidence regarding the value of this. Yet in some organizations too much integration has been linked to overburdened individuals, missed deadlines and higher costs (Carroll & Burton, 2000). As a tool and technique for developing policies for complex and uncertain systems (Bankes, 2002), organizational network analysis provides insight into the dynamics of information use. Knowledge derived from this network analysis can fill gaps in understanding the ways that a public health agency depends on information and how information use contributes to complexity in a public health organization.

This research will begin to answer questions on how a public health agency can adapt to the contingencies of public health work by the way information is used in organizational processes. There is no consensus on the optimum design for a public health organization (Barry, 2000; Centers for Disease Control and Prevention Office of Workforce Policy and Planning, 2002; National Association of County and City Health Officials, 2004). However, recent findings from a survey on public health performance show that state health departments most frequently measure, report, and use performance data related to their information systems, second only to data on their compliance with health statutes (Public Health Foundation & Turning Point Performance Management Collaborative, 2002). This study begins to establish an empirical basis for evaluating how information networks operate in public health organizations that can inform planning. It will contribute to establishing how information flow in public health agencies might be structured to improve performance.

CHAPTER 3 METHODOLOGY

This chapter presents the research method as applied in this study. It describes the research design, explains the rationale for the research approach, and describes the research setting and sample. The procedures for obtaining data, preparing the data for analysis, and the analysis process are also documented. The network measures used in the analysis are defined in table format.

3.1. Introduction to the Overall Design Strategy

Research Design

The research design is a descriptive, empirical organizational network analysis. The analysis was accomplished by means of three specific aims. The first was to collect relational data on the flow of work-related information from the full network of employees (N = 156) of a county health department and to produce visual and quantitative models that describe the relationships and flows of information in the department. The second aim was to determine what possible links between information flow and performance were suggested by the model. The third aim was to collect feedback from the department's leadership to determine the management value of the analysis and what impact the findings may have on management of the organizational information network. These aims in relationship to the study design and data collection strategies are detailed in Table 10.

Table 10 Project research design and data collection plan

	Aim I	Aim 2	Aim 3
Aim	a) Collect relational and descriptive data on the agency-wide communication network b) Produce visual and quantitative network models to describe information flow	Determine possible links between information flow and organizational performance, as suggested by the network model	Assess the utility of organizational network analysis as a diagnostic tool for public health managers
Research Question(s)	1. What is the structure of information flow in the health department's communication network?	2. What relationships between information flow and performance are suggested by the model?	3a) How do department leaders expect to use the findings to make an impact on information management? 3b) What is the value of network analysis for public health information managers?
Data Collection	1. Collect relational data using network survey. 2. Transpose data obtained from New York Medical College survey for secondary analysis.	1. Collect feedback and direction on interpreting results from presentation of preliminary findings to health department leadership	1. Documentation of discussion during presentation of final research findings to department leadership 2. Request specific feedback on the value and expected impact of findings
Data Analysis	1. Quantitative analysis of network data using *ORA* 2. Graphical representation of network structures 3. Preliminary description of the network	1. Interpretation of empirical findings incorporating feedback from the department's leadership	1. Summarize feedback
Result	Preliminary empirical description of the information network in the department	1. Descriptive empirical model of the network 2. Interpretation of how network patterns may affect performance	Narrative summary a) Expected impact of findings b) Value of the network analysis method

Rationale

Organizational network analysis is based on the understanding that organizations are complex systems where intelligent agents interact to shape the environment and the organization's performance. These factors include the knowledge and relationships of agents, their available resources, and the cognitive demands of the task environment. By examining these factors collectively, organizational network analysis provides both a visual and a mathematical analysis of complex human systems that is not possible using probability-based statistical methods (Carley & Wallace, 2001). The technique can uncover gaps in information flow and knowledge exchange. This knowledge can help managers find opportunities for information improvements, such as smoothing the flow of information across functional and organizational barriers, connecting isolated teams or individuals, and prioritizing areas where information improvements will have the most impact (National Electronic Library for Health, 2004).

Data Sources And Analysis Program

The analysis uses two sources of survey data to map network relationships:

1) A questionnaire developed and administered to capture specific network data from individual employees in the health department.

2) Data collected by New York Medical College (NYMC) for separate but related research with the department was made available to this project for secondary analysis.

Analyses of the primary and secondary data sets were performed using *ORA* (Carley & Reminga, 2004).

Ethical Considerations

Organizational network data are sensitive. Network data describe the relationships and position of specific individuals in the organizational network. These are not traditional data where attribute and subject can be separated but retain meaning (Van der Veer Martens, 2005). The researcher must be able to record the link between individuals; thus anonymity in data collection is not possible (Borgatti & Molina, 2003; Scott, 2000; Wasserman & Faust, 1994). This can create risks for respondents. The nature of respondent risk for this study was identified and addressed in the following ways:

1. It could become known that an employee declined to participate in the survey due to missing data that obviously identifies him or her in the completed model. The health department's leadership informed agency staff about the project via email stipulating that any employee's agreeing or not agreeing to participate will not affect their employment, that there will be no obligation to participate, and there will be no negative consequences associated with declining to participate.

2. It is likely that an individual's place in the completed network model could identify him/her even though no name is used. The department's leadership agreed that the focus of the analysis is an organizational

diagnostic tool for the betterment of the organization, and not an evaluation of individual performance, that no negative consequences will be associated with participation, and individual responses will remain confidential. This information was also included in the email sent to staff to inform them of upcoming data collection.

The information described above was also provided as an introduction on the paper survey, which can be found in Appendix B.

For data analysis and presentation of results, all employees were coded with letters and numbers. During a presentation of preliminary findings to the department's leadership (consisting of two top managers plus the department's strategic planning consultant), the sensitivity of the data and the ability to identify individuals was obvious. At that time the department leaders and the researcher agreed that individual level data (key actors) would be shared with general managers in a limited and selective manner to ensure protection of confidentiality, and that the focus of any presentations to general management staff would be on program level findings only.

Status of the Project in Regard to Human Subject Review

The study was submitted to the Institutional Review Board (IRB) at Columbia University Medical Center. The study involved collection of data from public employees performing their regularly assigned work, with the cooperation of their employer; therefore it was exempted from full IRB review under federal

exemption §46.101(b) 5. NYMC entered into a contractual agreement to share data with this project. The data sharing arrangement was submitted to the IRB at NYMC, and was allowed as an amendment to their existing data collection plan. Appendix A contains the IRB information sheet and study overview. In addition, the health department submitted the research plan and the survey to the human resources branch of the county executive's office and received approval to conduct the survey.

3.2 Research Procedures

Setting

The setting is a county health department with 156 employees. The department serves an 800 square mile, mixed urban, suburban, and semi-rural county in an Eastern state. The county has a population of around 280,000 individuals. The state is the major funding source for the county's public health activities, supplemented by grants and fees for services. The department's annual expenditures total about $30,000,000.

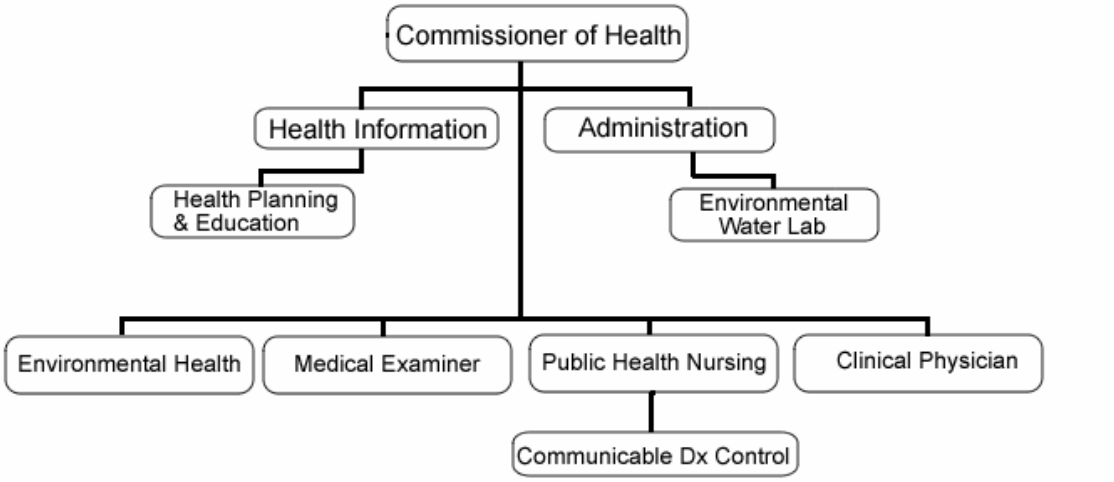
The department's structure and functions are determined by a combination of state law and county government. Legal mandates for the department can be found in the State Sanitary Code and in other articles of the State Code, and in the County Sanitary Code. It is classified as a full time public health department by the state, because it provides environmental health services, as well as other services in 9 major divisions and 19 distinct program areas. Figure 5 displays the department's organizational structure at the divisional level.

The characteristics of this department make it an ideal site to test the value of network methods in a local health agency. The departmental programs are representative of the range of public health services required to meet the needs of urban, suburban and semi-rural populations. The department has adequate numbers of staff to allow network analysis at the program level as well as at the full organizational level. The staff represents a range of public health titles and

programmatic specialization, and is large enough to adequately represent public health workforce issues, such as an aging workforce.

However, the department's status as a public agency presents a challenge for applying the findings of an organizational network analysis. While the method has proven usefulness in the private sector, there is no track record of its usefulness in public agencies, which operate as part of local government and have comparatively limited capacity for restructuring organizational processes. This research serves as a case study for application of the ONA method in a public health agency.

Figure 5 Formal hierarchy of the county health department



Sample

This study is a whole-network analysis and was not performed using any sampling technique (Marsden, 2005). Therefore, every employee was asked to provide information for this study and analysis included all personnel employed by the department (N =156). Information was collected about each employee's ties with each of the other 155 employees, as well as with 85 external organizations. Secondary data from a survey conducted by NYMC (described below) supplied data on employees' demographic attributes plus work-related knowledge, tasks and resources.

Survey Development

A primary social network survey was assembled using standard network analysis questions (Cross & Parker, 2004; Krackhardt & Hanson, 1993; Newman, 2003). These questions were selected to measure work-related relationships and communication among workers within the health department and with other agencies, and to elicit patterns in how individuals receive and share information in their routine work. To limit missing data due to non-response, the researcher asked two-sided questions (to whom do you give and from whom do you get information) to allow reconstruction of an agent's network position even if his or her data were missing or incomplete (Stork & Richards, 1992). The selected survey questions were reviewed with an expert on network survey methods, and wording of some questions was modified. The survey also collected qualitative data on information barriers and external work-related contacts, the analysis of

which is not presented here. Table 11 describes the relational data that was obtained from the questions in the primary social network survey.

Table 11 Relational domains captured by the social network survey

Relational Domain	Survey Question	Source
Information network	Do you receive work-related information from each person listed below?	Cross, modified by Carley
	To whom do you give work-related information?	Cross
	Who is important in terms of helping you think about complex problems posed by your work. These may or may not be people that you communicate with on a regular basis.	Cross
	I understand what knowledge and skills this person has. This does not mean I have these skills or knowledge, but I understand what skill and knowledge capacity they possess.	Cross, modified by Carley
External Network-organizations	From the following list of community agencies, please indicate how often you communicate with each agency in order to do your work. If you communicate with an agency or group not listed, please add it at the end of the list.	Department leadership, modified by Carley

The design of the paper questionnaire used recognition to aid respondents in identifying their network connections by providing a checklist of all 156 agency staff, organized by program and title. This method yields more accuracy than asking respondents to freely recall their network connections (Flap et al., 1998; Hlebec & Ferligoj, 2002). The survey was piloted with 2 employees to determine if it was understandable and to assess the time required to complete it. Completion time ranged between 15 minutes and 25 minutes for a minimally and a highly connected employee, respectively. Both remarked on the difficulty tracking rows on the long checklist. To address this, alternate lines were shaded

and divisions and programs were visually separated. When the survey was administered, the researcher acknowledged its length and stressed the importance of accurate and complete data. Respondents were encouraged to take a break to refresh their concentration rather than provide faulty responses**.** Figure 6 displays the survey format.

Figure 6 Survey format

NAME	TITLE	Question 5A	Question 5B	Question 5C	Question 5D
		Get info	Give info	Discuss issues	Understand skills
COMMISSIONER'S OFFICE					
Last name, first name	Commissioner				
Last name, first name	Confidential Admin. Assistant				
Last name, first name	Clinical Physician				
Last name, first name	Office Assistant				
PUBLIC HEALTH INFORMATION OFFICE					
Last name, first name	Director				
Last name, first name	Secretary				
Last name, first name	Program Assistant				
Last name, first name	Office Assistant				
Last name, first name	Ryan White Contract Coordinator				
Health Planning and Education					
Last name, first name	Director				
Last name, first name	Epidemiologist				
Last name, first name	Biostatistician				
Vacant (to replace name)	Senior PH Education Coordinator				
Last name, first name	PH Education Coordinator				
Last name, first name	PH Education Coordinator				
Last name, first name	Public Health Nurse				
Last name, first name	Public Health Nurse				
Last name, first name	PH Nutritionist				
Last name, first name	GIS Technician				
ADMINISTRATION AND FISCAL DIVISION					
Last name, first name	Assistant Commissioner				
Last name, first name	Senior Accountant				
Last name, first name	Receptionist				
Last name, first name	Principal Program Assistant				
Last name, first name	Principal Program Assistant				
Last name, first name	Account Clerk				
Last name, first name	Account Clerk				

Additional data for secondary analysis were obtained from NYMC. These data were collected for research to assess the information needs and level of informatics competency of public health workers. The NYMC survey was

adapted from a questionnaire used to benchmark information use in local health agencies by Lee and colleages (2003). The survey questions were derived from the categories of information use defined in a statement of informatics competencies for public health workers (O'Carroll, and the Public Health Informatics Competencies Working Group, 2002b). The NYMC survey contains 50 single and multipart items. Data obtained from selected questions were converted to binary variables for network analysis. Table 12 describes network matrices, relational domains, variable types, and data conversion for analysis in ORA. The data dictionary is supplied in Appendix C.

Data Collection

The researcher met with the health department leadership to plan data collection in 3 sites operated by the Department. The schedule was planned to minimize disruption to work routines. Employees were informed about the study via email. The department's administrative staff assisted in arranging appointments for administering the survey. The network survey and the NYMC survey were administered at the same time. Follow up sessions were scheduled for absent employees.

Table 12 Data from NYMC survey converted to node sets in the meta-matrix

Node Set	Relational Domain	Variable (count)	Data type	Conversion
Attributes	Homophily (common frame of reference)	Age	Nominal	None
		Title	Nominal	None
		Experience	Nominal	None
		Education	Nominal	None
		Role	Nominal	None
	Proximity	Work location	Nominal	None
		Program	Nominal	None
Task	Cognitive demand	Job level (4)	Categorical	Additive by level
		Information Use-relevance (26)	Scale	0=not relevant or somewhat relevant 1=relevant or highly relevant
		Self identified functional roles (27)	Y/N	0= N, 1=Y
		Communication with outside agencies (85)	Y/N	0= N, 1=Y
Knowledge	Knowledge	Information use - skill/proficiency (26)	Scale	0=not aware 1=aware to proficient
		Education level (6)	Ordinal	Additive by level
		Experience level (6)	Ordinal	Additive by level
Resource	Access to resources	Information use-needed on a regular basis (26)	Interval	0=seldom or never 1=daily, weekly or monthly

Secondary data collection

Respondents were asked to share the information they provided on the NYMC survey voluntarily, by writing the unique identifier they used on that survey on the

face page of the network survey. This step allowed the NYMC data to be linked to the network survey data.

Data Preparation

Network survey data were entered into a matrix as rows of comma-separated values. Employees were identified by a letter and number code. Vacant positions and agents who declined to complete the survey were retained in the database to allow reconstruction of important network positions based on answers to bidirectional survey questions (Newman, 2003).

Data accuracy

Reliability of network analysis depends on accurate data entry. After data entry was completed, 100% of the surveys were re-checked by at least one person.

Preparation of Secondary Data

Researchers at NYMC provided spreadsheets containing unprocessed anonymous data on all respondents. These data were matched with the unique identifier supplied on the network survey and sorted to correspond to the identifier codes in the agent x agent table. Then the data were transformed into relational values as described in Table 11. Unmatched data were discarded and the resulting non-responses were coded “0.”

3.3 Data Analysis

Preliminary Analysis

Prepared data were imported into the Organization Risk Analyzer (*ORA*) computer program. *ORA* runs on a PC with a Windows 2000 or XP operating system. The system interface is developed in JAVA and the measures are programmed in C++ (Reminga & Carley, 2005). *ORA* uses the meta- matrix as the main unit of input to represent the design structure of an organization, as described in Chapter 2. Analysis is based on formal logic, matrix algebra, and discrete and continuous equations to calculate patterns of connections among individuals and resources in the organization (Carley & Reminga, 2004). The results are index numbers that convey aspects of the distribution of relational ties among the nodes in a network (Hanneman, 2001). *ORA* generates formatted statistical reports in computer screen displays and log files. In addition, it has tools for visualizing network data as graphs or charts.

Network measures are derived from graph theory, where a network N is comprised of two sets of nodes, U and V, and a set of edges $E \subset UxV$. An element $e = (i,j)$ in E indicates a tie or relationship between nodes where $i \in U$ and $j \in V$. Nodes represent *actors* or *agents*, which are discrete individuals, or collective social units (group, departments), and network elements such as resources or tasks (Reminga, 2005). Measures are binary or valued. For example, if we know only that Agent A (a member of the U set of individuals)

and Agent B (a member of the V set of individuals) communicate then n(*i,j)* = 1, and if they do not communicate then n(*i,j)* = 0. Network data can be given a value between 0 and 1 to indicate a quality of the relation, such as communication that is frequent, infrequent, or not at all. Valued data were not used in this study.

Informant Accuracy

The preliminary graphs generated with data from four communication questions showed much higher connectivity than expected. It seemed possible that this group overstated their ties due to the culture of public health, which associates great value with inclusiveness, collaboration and cooperation. This is called expansiveness bias, a type of ego bias defined as a tendency to indicate extra relational ties (Marsden, 2005). It is the error that arises from individuals over reporting interactions because they exaggerate the characteristics of the relationship and/or have different norms for reporting a relationship (Feld, 1991). Aggregation of individual data into a global measure tends to wash away this type of bias because the effect of one person's report of exaggerated ties will be cancelled out by the same bias in others (Kumbasar *et al.*, 1994). Therefore, on the advice of a network expert, the four communication network matrices were combined into a single matrix. A positive response to all four questions was entered as a tie; all else was entered as no tie.

Preliminary Presentation of Results

Accurate interpretation of network findings is essential to distinguish patterns from random noise, and to assess the veracity of the network structures generated

from the data (Breiger, 2003). Statistical analyses of network ties can be difficult to interpret for two reasons: 1) data are not independent observations and 2) results represent an organization about which the researcher may have little firsthand knowledge to guide interpretation. Therefore, to conduct a meaningful network analysis, the findings must be interpreted in collaboration with the organization's representatives (Cross & Parker, 2004; Scott, 2000). This step was particularly important for this analysis, as there is no baseline knowledge about the network structure of a local health department.

After generating a set of *ORA* visualizations and reports, preliminary results were presented to the department's leaders via web conferencing, with three goals in mind:

1. To collaboratively interpret early findings together with the external network expert (Dr. Carley) and the department's leadership.
2. To direct the focus of the analysis on areas of greatest interest for the department's leadership.
3. To stipulate the goals the department had for the final analysis of the results after seeing a sample of the visualizations and reports available in *ORA.*

Findings from this presentation resulted in the following actions:

- For the purposes of analysis, the department's leaders wanted to consolidate 19 program groups into 13 like-tasked groups.

- Knowledge redundancy was found to be extremely high, so education and experience variables were re-formatted to reflect education as a summative node set.
- Resources scores and complexity scores were considered low because the resources and task matrices were not very dense, so additional variables were added to represent communication with outside organizations as discrete tasks.

Goal stipulation

The department's leaders were asked to identify their goals for the network analysis. They responded with three items:

1. To capture information about resources and to identify where there was inadequate communication, they wanted reports on all programs.
2. To assess potential for change in the programs, they requested information on job function, knowledge, and resources.
3. To analyze the planned merger of CDC (Communicable Disease Control) and PHN (Public Health Nursing) divisions.

Final Analysis of Network Data in *ORA*

The feedback from the presentation of preliminary analyses allowed development of a new analysis plan:

- An overall network description.
- A report on key actors in the network.

- An organization quality report comparing 10 of 13 program groups. (The other 3 programs had less than 5 employees, a number too low to produce accurate network results.) The ten programs and their codes are displayed in Table 13.
- Leaders requested that the public health nursing division be analyzed as a unit, and that 3 of its programs also be analyzed individually.
- A report on the status of experienced staff.
- An analysis of the planned merger between CDC and PHN divisions.

Table 13 Codes used to represent the department and ten programs

Program	Code
Department of Health (full network)	DOH
Public Information Office	PIO
Administration	Admin
Communicable Disease Control	CDC
Environmental Engineering	EnvEng
Environmental Health	EnvHlth
Public Health Nursing (includes PrevServ, HomeHlth & Clinical)	PHN
Preventive Services	PrevServ
Home Health Unit	HomeHlth
Clinical Services	Clinical
Children with Special Needs	SpNeeds

The analysis of organizational quality centered around 21 specific measures selected to capture cohesion and prominence, and network quality at the level of the individual, program, and full network. The network measures reported on in this study are described and defined in Table 14 (Burt, 2001; Hanneman, 2001; Hawe *et al.*, 2004; Kilduff & Tsai, 2003; Krebs, 2005; Scott, 2000; Wasserman & Faust, 1994). Documentation for all *ORA* measures is provided in Appendix D.

Table 14 Organization network measures in *ORA*
The following abbreviations are used to define the matrices used for input data: AA = agent x agent; AK = agent x knowledge; AR = agent x resource; AT = agent x task. Definitions are derived from Reminga & Carley, 2005 unless otherwise noted. See Appendix D for further documentation of *ORA* measures.

ORA Report	Measure	Definition	Input Data	Output Level
Key Actor Emergent Leader	Cognitive Demand	Average of graph row vector terms (depending on number of input graphs); measures total amount of effort expended by each agent to do tasks	AA, AK, AR, AT	Node
Key Actor In-the know	Degree Centrality	Number of direct connections a node has (normalized sum of row and column degrees); indicates how likely a node is to receive what flows through the network	AA	Node
Key Actor Potentially Influential	Betweeness Centrality	The number of times that connections must pass through a single node in order to be connected; extent that one person is a broker of indirect connections between all others in network; influences what flows in the network	AA	Node
Key Actor Leader of Strong Clique	Eigenvector Centrality	A variant of degree centrality that shows connections to centrally located nodes. A node connected to many well connected nodes has a high score, but a node connected to many isolates has a low score, even if it has a high degree.	AA	Node
Key Actor Connects Groups	High betweeness centrality, low degree centrality	A node with few direct connections, but if removed from the network will result in a new component. These are boundary spanners that connect their group to others.	AA	Node
Key Actor Good Group Knowledge	Situation Awareness Between Agents	Similarity of actor pairs in social interaction, physical distance and socio-demographic data	AA, AA:attributes	Node
Organizational Quality	Diversity Knowledge	Distribution of difference in idea sharing; measures the degree to which knowledge is equally known. Herfindahl-Hirshman index of market share (economics) applied to column sums of AK matrix	AK	Graph

Table 14 continued

ORA Report	Measure	Definition	Input Data	Output Level
Organizational Quality	Diversity Resource	Distribution of difference in resource sharing; measures the degree to which resources are equally accessed. Herfindahl-Hirshman index of market share (economics) applied to column sums of AR matrix	AR	Graph
Organizational Quality	Redundancy Access	Average number of redundant agents/resources. An agent is redundant if there is already an agent that has access to that resource. Column redundancy of AxR matrix	AR	Graph
Organizational Quality	Redundancy Assignment	Average number of redundant agents assigned to tasks. An agent is redundant if there is already an agent that has the task. Column redundancy of AxTmatrix	AT	Graph
Organizational Quality	Redundancy Knowledge	Average number of redundant agents/knowledge. An agent is redundant if there is already an agent that has that knowledge. Column redundancy of AxK matrix	AK	Graph
Organizational Quality	Overall Complexity	Density of the Meta-Matrix. The ratio of the number of edges versus the maximum possible edges for the meta-matrix	AA, AK, AR, AT	Graph
Organizational Quality	Social Density	Density of the agent network. The ratio of the number of edges versus the maximum possible edges for the agent network	AA	Graph
Organizational Quality	Shared Situation Awareness	Average shared situation awareness across agents. The similarity of actor pairs based on social interaction, physical distance, socio-demographic data.	AA with attribute	Agent, Dyad
Organizational Quality	Communication Speed/Avg	The average shortest path length between node pairs (i,j) where there is a path. If there are no such pairs, then Average Speed is zero. Average inverse closeness centrality for network nodes.	AA	Graph
Organizational Quality	Communication Speed/Min	The maximum shortest path length between node pairs (i,j) where there is a path. If there are no such pairs, then Minimum Speed is zero.	AA	Graph

Table 14 continued

ORA Report	Measure	Definition	Input Data	Output Level
Organizational Quality	Efficiency	The degree to which each component in a network contains the minimum edges possible to keep it connected; degree to which there are efficient communication cycles between agents (Krackhardt, 1994)	AA	Graph
Organizational Quality	Efficiency Global	Measures efficiency of transporting a piece of information in parallel where all nodes in the network concurrently exchange information (Latora & Marchiori, 2001). Measures the closeness of the nodes in the network as the inverse geodesic distances (shortest path) between all node pairs.	AA	Graph
Organizational Quality	Efficiency Local	Measures efficiency of transporting a piece of information in sequence along nodes in the network (ibid). Measures the closeness of the nodes in each ego network as the inverse closeness of the ego networks.	AA	Graph
Organizational Quality	Network Centralization	The centralization of a square network based on total degree centrality of each node. Indicates asymmetry in the distribution of connections, indicates the degree to which communication is centralized around a single agent or small group.	AA	Graph
Organizational Quality	Transitivity	A measure of cohesion. The percentage of edge pairs (*i*,*j*) (*j*,*k*) in the network such that (*i*,*k*) is also an edge in the network. Indicates collaborative groups (Schank & Wagner, 2004). Correlates with social density.	AA	Graph

CHAPTER 4 RESEARCH FINDINGS

This chapter presents the research findings generated by the *ORA* analysis program from the relational network data. The findings represent an empirical description of the health department's network structure, which affords insight into how information flow in the network contributes to the organizational processes and influences performance. They are presented in response to the following research questions

1. What is the pattern of information flow in the health department's communication network?
2. What relationships between information flow and performance are suggested by the model?

The results of this analysis were presented to the department's leadership. Their feedback is presented in response to research question #3:

3 a)What is the value of network analysis for public health information managers?

b) How do department leaders expect to use the findings to make an impact on information management?

4.1 Survey Response

Network analysis provides the best results when complete network data are available (Hanneman, 2001; Scott, 2000). The full network of relationships is necessary to properly measure the structural concepts of network analysis and to give a complete picture of relations in the population (Hanneman, 2001). The department's leaders understood this. In an attempt to achieve the highest possible response rate, attendance at the data collection sessions was required, although completing the survey remained voluntary. Extra data collection sessions were scheduled for employees who were absent due to sick leave, vacations, or other reasons. Borgatti and colleagues have determined that if network data collection misses 5% of ties then the correlation between true and observed centrality will be in > .90. They conclude that centrality measures are robust when error is under 10% (Borgatti *et al.*, in press). The response rate to the network survey was 93%. Only 4 employees declined to provide an ID number to allow linkage to NYMC data, for a response rate of 90%. Table 15 displays the survey response rates.

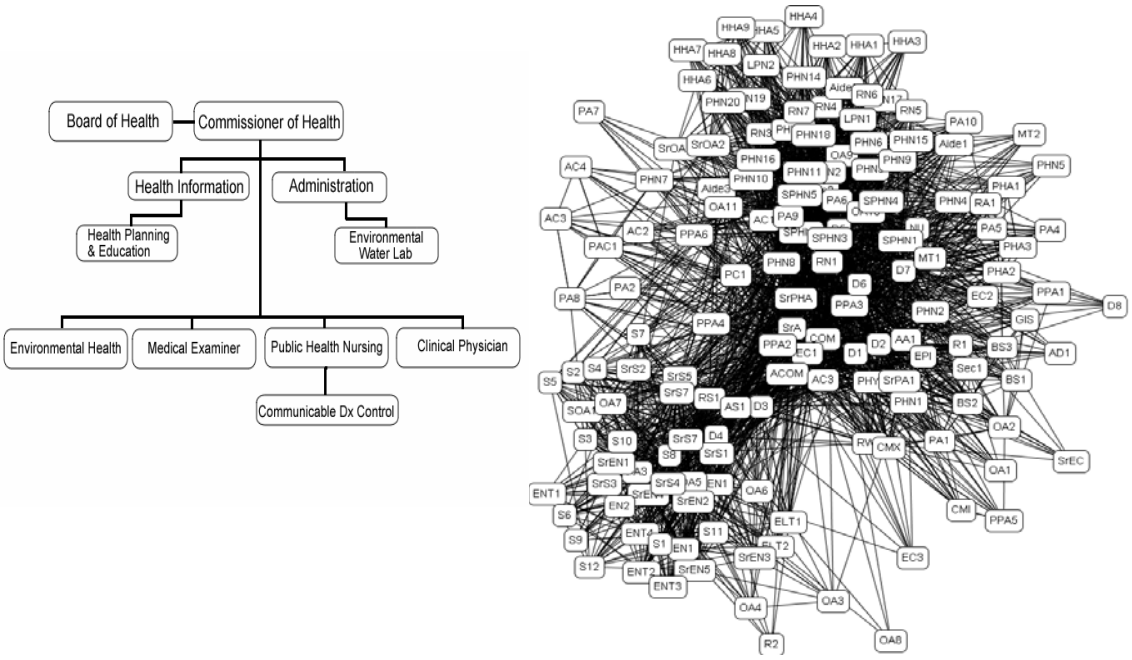
Table 15 Response rate to the study

Employee survey response	
Total employees	156
Vacant positions	4
Total employee minus vacancies	152
Surveys not completed	11
Network surveys completed	141
Response rate for network survey	93%
NYMC surveys completed	141
# declined NYMC data match	4
Response rate for NYMC survey	90%

4.2 Overall Structure of the Agency Network

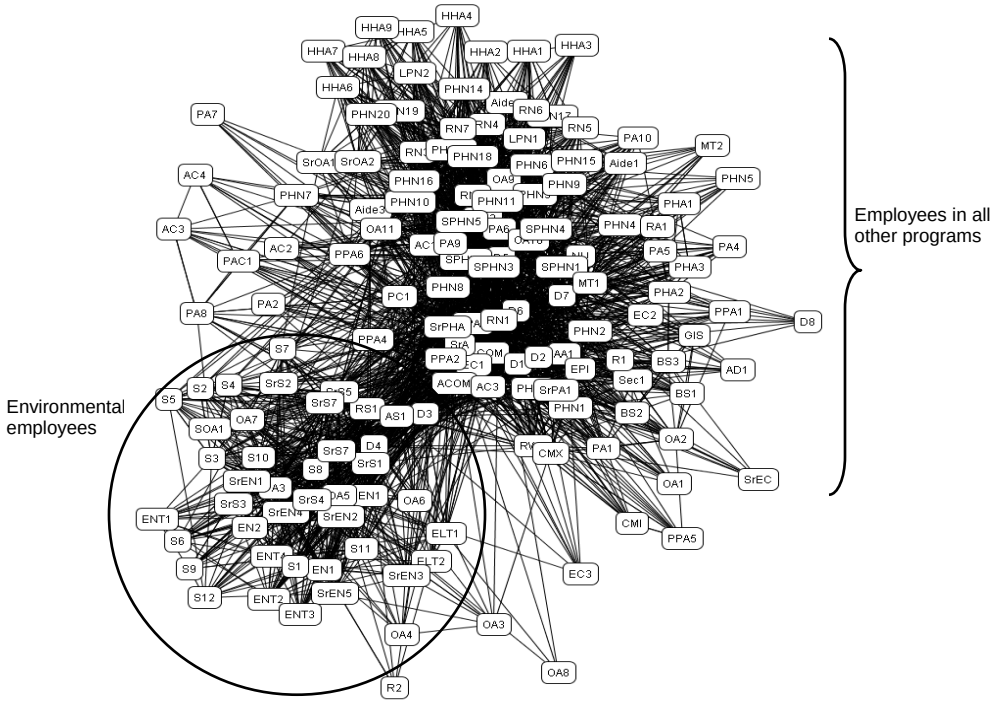
The formal hierarchy of the agency is compared with the full network structure, comprised of 156 agents and the communication links between them, in Figure 7. The web of interconnections in the full network presents a sharp contrast with the formal organizational structure. This visual comparison vividly illustrates the network of relationships that employees form across functions and divisions to accomplish their work (Krackhardt & Hanson, 1993). It shows two well-connected clusters with many peripheral agents that are less tightly connected to two densely connected cores.

Figure 7 Comparison of formal hierarchy with network structure



Although it is not possible to display here, graphic visualization in *ORA* allows subgroups to be colored by attributes such as program affiliation or worksite. Colored visualization of the graph above shows the two main structures are comprised of 1) all environmental programs, i.e., Environmental Health, Environmental Engineering, Environmental Water Lab; and 2) all other programs, i.e. Public Information Office, Public Health Nursing, Administration, Communicable Disease Control, offices of Commissioner, Physician and Medical Examiner. The peripheral agents in the network largely represent front line staff, who work directly with the community and in the department's two satellite offices. Figure 8 shows the full network with two subgroups delineated.

Figure 8 Full network illustrating two sub-groups



4.3 Empirical Description of the Network

Key Actors

Table 16 displays results identifying key actors who are critical to network operations. These measures describe structural attributes of agents' positions in the network (Analytic Technologies, 2000). See Chapter 3**,** Table 14 for the graph theoretic definition of these measures. There are just 11 agents ranking among the top five within 6 strategic roles.

Table 16 Key actors in the full network

Report	Measure	Meaning	Agent by Rank	Score (0-1)
Emergent Leader	Cognitive demand (effort used by agent to do tasks)	Act as informal group leaders; coordinate, direct and delegate	1 SrPHA	0.304
			2 COM	0.249
			3 EC1	0.246
			4 D5	0.220
			5 RN1	0.218
In-the-Know	Total degree centrality	Most connected, can spread information quickly; most likely to hear gossip and rumors	1 SrPHA	0.603
			2 SPHN2	0.497
			3 D5	0.468
			4 COM	0.452
			5 EC1	0.429
Leader of Strong Clique	Eigenvector centrality	Agents connected to well-connected others; spread information quickly	1 SrPHA	0.250
			2 SPHN2	0.209
			3 D5	0.203
			4 RN1	0.195
			5 COM	0.194
Potentially Influential	Betweeness centrality	Percentage of information flowing through an agent; information brokers, liaisons, gatekeepers	1 SrPHA	0.064
			2 AS1	0.054
			3 COM	0.045
			4 SPHN2	0.043
			5 D5	0.038
Connects Groups	High betweeness, low degree centrality	Boundary spanners; connect otherwise unconnected groups	1 AS1	0.250
			2 D3	0.193
			3 SrPHA	0.170
			4 RS1	0.159
			5 COM	0.159
Good Group Knowledge	Actors w/ most similar interactions, attributes and proximity	Shared situation awareness among agents; enable collaboration	1 SPHN2	0.207
			2 D5	0.199
			3 SPHN5	0.193
			4 SPHN3	0.190
			5 COM	0.166

Emergent Leader reflects the personnel, tasks and resources that each agent needs to contend with (Carley & Krackhardt, 1999). Individuals high in this dimension tend to act temporarily as group leaders. This is an informal role. Individuals high on this dimension tend to engage in task-shedding; they direct and delegate to others, and they try to encourage coordination. SrPHA (senior public health advisor), a member of the Communicable Disease Control division, tops this list. COM (Commissioner) appears low on this list, suggesting that as the organization's leader he will tend to delegate rather than micro-manage. RN1 (registered nurse), who has little status in the formal hierarchy, emerges as an informal leader who could help facilitate change in the organization.

In-the-Know reports on highly connected agents, those in a good position for receiving what flows through the network (Borgatti, 1995). They have power due to their control over forwarding or not forwarding information (Haythornthwaite, 1996). They can spread information the most quickly, and are most likely to hear gossip and rumors. SrPHA has ties with 60% of the agents, and is the most central person in the network. SPHN2 (supervising public health nurse), who is responsible for a large front line staff, appears as next most central.

Leader of Strong Clique reflects the fact that not all connections are equal—an agent with a small number of high-quality contacts may actually be in a better position in the communication network than one with a larger number of unexceptionable contacts (Newman, 2002). This group of agents is identical to

those with high degree centrality with one exception: RN1's connections to well-connected others put her in a stronger network position than the otherwise well-connected EC1 (educational coordinator).

Potentially Influential report indicates the percentage of information that passes through one person on the way to another, and reflects the control that person has over the flow of information between others. These people can serve as brokers, gatekeepers, or liaisons that can influence others due to the many links that pass through them (Freeman, 1979). Again, SrPHA ranks highest on this measure. AS1 (an assistant public health sanitarian in the environmental group) appears as a potential gatekeeper for information flow between the full network and the environmental programs, the major sub-group in the agency.

Connects Groups shows agents in a position to span boundaries by connecting otherwise poorly connected groups. These people are well-positioned to be innovators, because they have access to ideas and information flowing in other clusters of people, and their participation is important for the success of organizational changes. The top scoring agents, AS1 (assistant sanitarian) and D3 (director), are associated with the environmental sub-group.

Good Group Knowledge reports on agents that share a common understanding with most others regarding who is responsible for what tasks and what the information requirements are for the tasks. This understanding is similar to

transactive memory, which is defined, in a group or organization, as *knowing who knows what* (Graham, 2004). These individuals enable collaboration. Except for COM, all are part of the largest division in the agency, Public Health Nursing.

Organizational Quality Report

The organization quality report is displayed in Table 16. It presents an overview of the key characteristics of the organization as a whole. In general, these measures are most valuable when used to contrast two or more branches of an organization. Each of these measures captures a structural feature of the organization (rather than individual agents) that has implications for the organization's decision-making or planning activities, or for its overall culture. These quality measures, as calculated by *ORA*, are defined in Table 17. The findings are explained below.

Diversity/Knowledge and Diversity/Resource characterize the network in terms of resource and knowledge distribution. They measure the extent to which knowledge and resources are non-uniformly distributed across agents. Diversity scores for both knowledge and resources in the agency overall, and in all programs, are very high (> 0.9), which means it is very likely that some people have a great deal of knowledge and resources and others have very little.

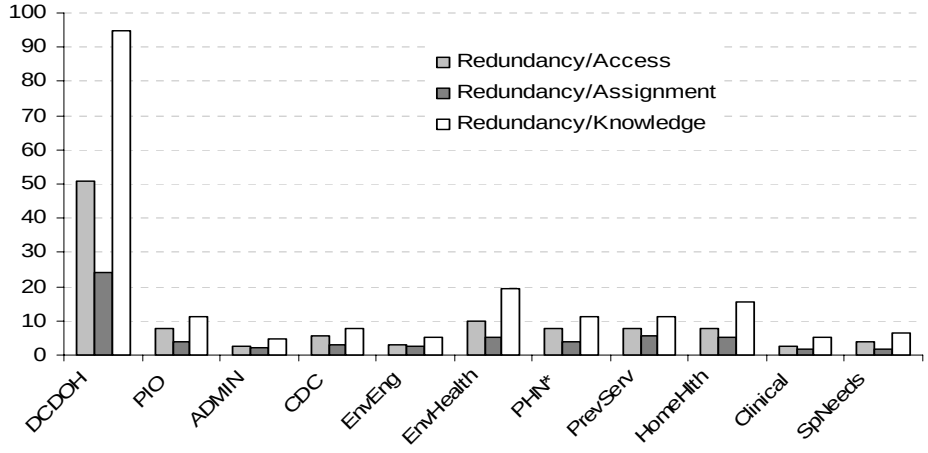
Table 17 Comparison of network measures of organizational quality
All scores are normalized to range between 0-1, except shared situation awareness where range is 0-500

Measure	DOH	PlO	Admin	CDC	EnvEng	EnvHlth	PHN*	PrevSrv	HomeHlth	Clinical	SpNeeds
Agent Count	156	18	10	14	11	34	51	20	27	10	11
Knowledge Count	39	39	38	38	37	38	38	38	38	38	38
Resource Count	52	51	36	47	36	49	46	41	42	41	40
Task Count	190	141	114	120	56	118	145	118	129	108	109
Organization Count	85	85	68	68	15	64	75	72	67	59	61
Diversity/Knowledge	0.971	0.971	0.968	0.971	0.969	0.971	0.971	0.970	0.970	0.972	0.971
Diversity/Resource	0.971	0.977	0.955	0.974	0.959	0.968	0.977	0.967	0.962	0.969	0.967
Redundancy/Access	51	8	3	5	3	10	8	8	8	3	4
Redundancy/Assignment	24	4	2	3	3	5	4	6	5	2	2
Redundancy/Knowledge	95	11	5	8	5	20	11	11	16	5	6
Overall Complexity	0.211	0.370	0.264	0.369	0.369	0.264	0.288	0.385	0.293	0.335	0.351
Social Density	0.149	0.418	0.305	0.566	0.446	0.305	0.335	0.645	0.360	0.500	0.436
Shared Situation Awareness	199	82	98	89	38	98	166	162	84	53	49
Communication Speed/Avg	0.486	0.636	0.600	0.732	0.672	0.600	0.627	0.765	0.676	0.857	0.657
Communication Speed/Min	0.250	0.333	0.500	0.333	0.333	0.250	0.333	0.333	0.333	0.500	0.333
Efficiency	0.785	0.478	0.306	0.282	0.356	0.585	0.533	0.205	0.486	0.389	0.467
Efficiency/Global	0.612	0.788	0.878	0.879	0.855	0.723	0.744	0.908	0.775	0.844	0.806
Efficiency/Local	0.850	0.913	0.933	0.919	0.867	0.879	0.904	0.958	0.915	0.925	0.910
Network Centralization/Total Degree	0.460	0.490	0.360	0.372	0.432	0.352	0.420	0.277	0.400	0.280	0.505
Transitivity	0.507	0.621	0.791	0.801	0.771	0.641	0.689	0.841	0.721	0.842	0.648

*includes Preventive, Home Health & Clinical

Redundancy of Access/Assignment /Knowledge also characterize the network in terms of resource and knowledge distribution. These measures indicate the number of agents with the *same* resources, tasks or knowledge respectively, based on the variables that were measured (see Table 12, p.60). The full network has very high knowledge redundancy. There are 95 people in the department who have the same knowledge. Within the programs knowledge redundancy appears less pronounced because the agents are distributed across programs, but their knowledge redundancy remains relatively higher. This means many agents have the same knowledge. This could indicate their knowledge is more specialized than they need to do the work. Otherwise, the programs have very low redundancies in resources (access) and task capacity (assignment). Figure 9 compares redundancies by count. Figure 9 displays access, assignment and knowledge counts in *ratio* to staff counts. Redundancies in resource access and assignment are especially low in Administration, Environmental Engineering and Clinical. Knowledge redundancy is high.

Figure 9 Redundancy counts for access, assignment and knowledge

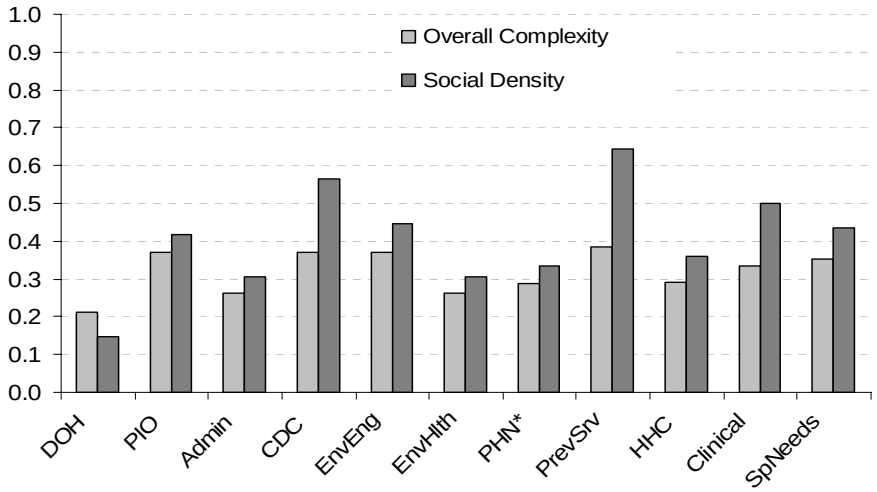


*PHN includes Preventive Services, Home Health and Clinical

Overall Complexity and Social Density measures are compared in Figure 10 because they manifest network density on two levels. Complexity is the density of the *meta-matrix.* The measure represents the complexity of the organizational design by comparing existing links to all possible links for all five matrices. It reflects the degree of interdependency among the organization's components. Social density measures the agent x agent matrix alone by comparing existing links to all possible links. It reflects the level of organizational cohesion (Contractor *et al.*, 1996). Although the range for both measures is 0-1, interpretation differs because density is relative to size (Scott, 2000). The number of possible links in the overall organization (5 matrices) is much higher than the number of possible links between agents (1 matrix). Accordingly, for this network, for complexity a low score is considered to be <0.5, while for social density a low score is considered to be < 0.3 (Carley, 2005b).

Social density for the overall department is lower than at the program level, indicating less communication *between* programs than *within* programs. The complexity scores for the department overall, and for all of the programs, are in the low range (< 0.5). All programs have low complexity but moderate to high social density (> 0.3 < 0.7), a combination suggesting fast rumor propagation but less chance that there will be chains of errors occurring.

Figure 10 Comparison of complexity and density

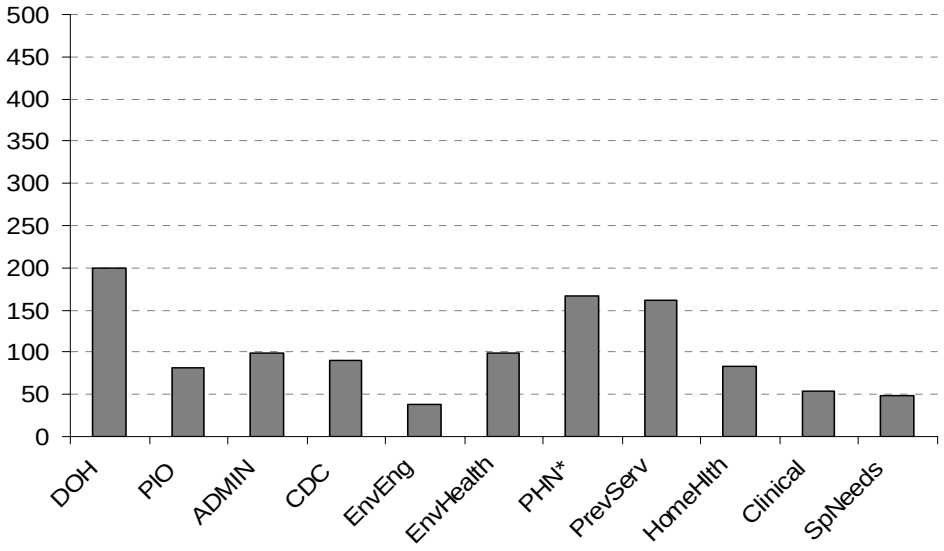


*PHN includes Preventive Services, Home Health and Clinical

Shared Situation Awareness across agents is an indicator of organizational effectiveness. Figure 11 compares shared situation awareness across agents. Although there has not been enough research done to specify an optimal score for this measure, the range is up to 500 (K. M. Carley & Reminga, 2004). The department's scores are low, a feature that is found in organizations with silos [2]. The score for the full network is higher than in the programs. Employees may be more aware of what is going on in the department overall, at least in their sub-area of expertise, than they are of what is going on in their program. The Preventive Services program has higher shared awareness than any of the other programs, and contributes to the high score of the Public Health Nursing Division, of which it is a part. Environmental Engineering has the lowest score of all the groups.

[2] A silo is a tightly vertically integrated team wherein the individuals tend to work closely together, but interactions with other parts of the organization (other silos) tend to be limited or only initiated through management. Silos are a source of poor communication and duplicative problem solving, and their existence can frustrate organizational change efforts (Doerscher, 2004)

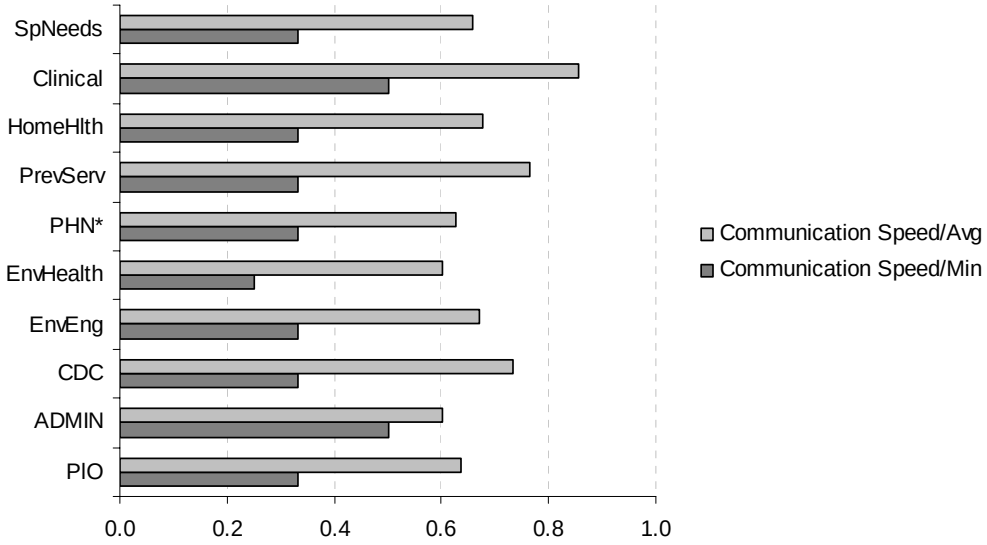
Figure 11 Comparison of situation awareness



*PHN includes Preventive Services, Home Health and Clinical

Speed/Average and Speed/Minimum indicates how quickly a typical message moves through the communication network. The higher the average value, the faster information moves. The gap between average and minimum speeds suggests how predictable communication is. When the gap is narrow, people get information close to the same time. Figure 12 compares communication speeds. Average speed is higher in the programs than in the department overall. The fastest average speed (0.86) is in Clinical Services, but the minimum speed in the all programs is > 0.50. Information moves quickly in the programs, but the average is nearly double the minimum speed in most programs. Administration alone shows predictable information flow with a gap of only 0.1 between average and minimum speeds.

Figure 12 Comparison of communications speed in the programs



*PHN includes Preventive Services, Home Health and Clinical

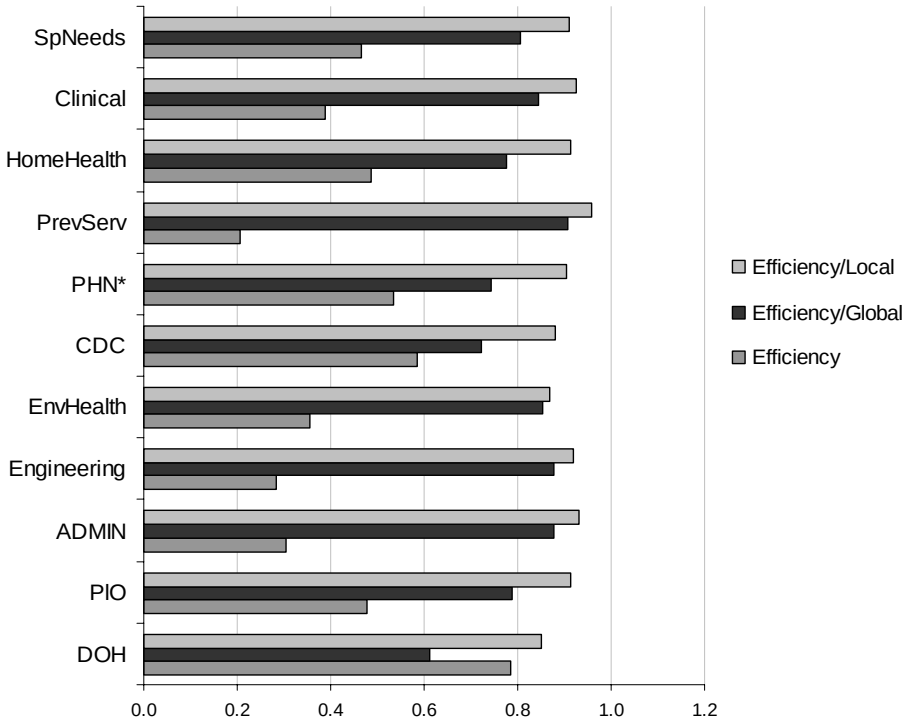
Efficiency is the extent to which agents are involved in *unnecessary* redundant communication cycles (Krackhardt, 1994). It reflects the minimum edges possible to keep the network connected, and can be interpreted as an answer to the question "Is information getting to the people who need it without going to those who don't need it?" Higher numbers indicate greater efficiency. The department as a whole is efficient (0.79). Efficiency is less good within the programs. Preventive Services (0.21), CDC (0.28), Administration (0.31), and Environmental Engineering (0.36) show the greatest tendency for unnecessarily redundant communication cycles.

Efficiency/Global measures how well information flows through the network if agents communicate concurrently (Latora & Marchiori, 2001). It reflects if, in the *overall design of the system,* communication links are present where needed to move information

and not present where they are not needed. Higher numbers indicate greater efficiency, or fewer unnecessary parallel links. In the department as a system (0.61), and within the programs as sub systems (0.72 – 0.91), links are present to move information efficiently.

Efficiency/Local measures how well information flows if agents communicate sequentially (Latora & Marchiori, 2001). It reflects if *individual agents* communicate with the agents with whom they need to communicate to move information, and do not communicate unnecessarily, or fewer unnecessary sequential links. Higher scores indicate greater local efficiency. In the department (0.85) and in the programs (0.88 – 0.93), the sequence of communication among individuals is quite efficient.

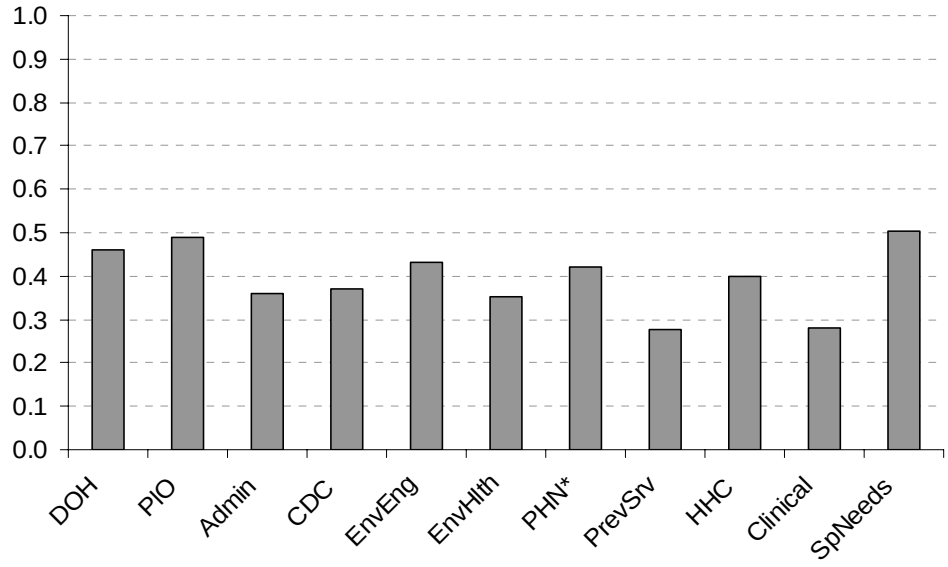
Figure 13 Comparison of efficiency measures



*PHN includes Preventive Services, Home Health and Clinical

Network Centralization/Total Degree expresses communication inequality in the network. It is calculated as a percentage of a star-like network of the same size, where all nodes have only one connection to the central node (Hanneman, 2001). It can be interpreted as akin to "command and control" or the extent to which one person, or a small set of people, is the central or controlling factor in the group. Higher numbers indicate a greater tendency that one person is calling the shots. Lower scores indicate that communication is more distributed. If all nodes were linked to only one central node (a star graph), the score would be 1. If all nodes were linked (a complete graph), the score would be 0. With this understanding, scores approaching 0.5 indicate centralization. Figure 14 compares network centralization in the full network and in the programs. At the program level, centralized communication is found in Special Needs (0.51) and the Public Information Office (0.49). The department as a whole tends to operate in this way as well (0.46). More distributed communication is found in Preventive (0.28) and Clinical Services (0.28).

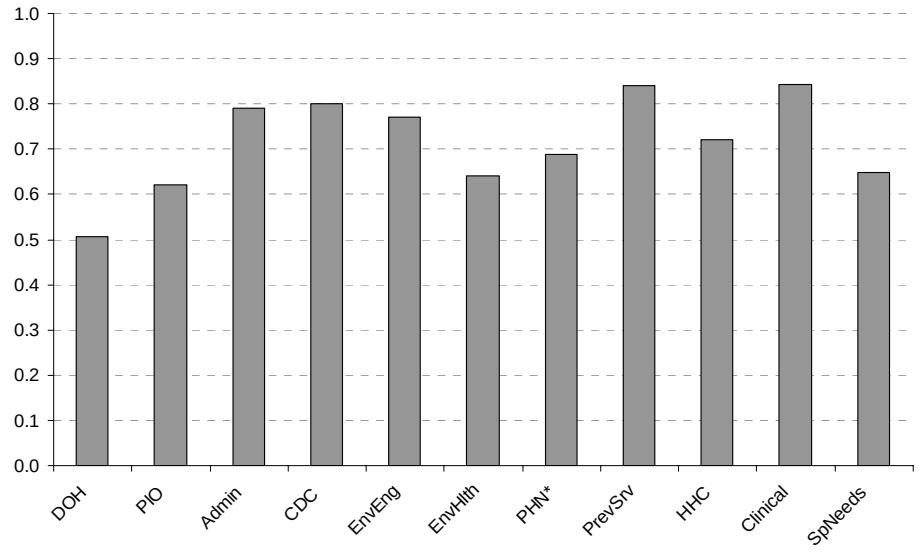
Figure 14 Comparison of network centralization/total degree



* PHN includes Preventive Services, Home Health and Clinical

Transitivity measures the number of transitive triples in the graph and reflects the extent to which there is equilibrium and consistency in communication flow (Carley, 2005b). For example, if *A* sends information to *B*, that is usually forwarded to and used by *C*, transitivity creates a direct link from *A* to *C*, thereby increasing information flow in the network (Contractor et al., 1996). It is a measure of self organization and high scores indicate the presence of collaborative groups (Heylighen & Bollen, 2002; Schank & Wagner, 2004). Scores > 0.5 indicate good transitivity. Figure 15 illustrates transitivity scores.

Figure 15 Comparison of transitivity



* PHN includes Preventive Services, Home Health and Clinical

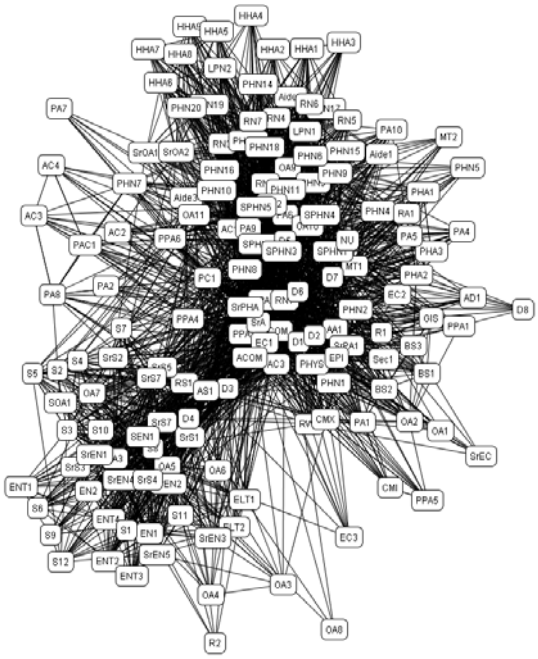
Report on Experienced Staff

Retention of experienced staff and loss of staff to retirement are significant concerns for public health agencies (Association of State and Territorial Health Officials, 2004b). In the health department network, experienced staff are employees with "greater than 20 years of public health experience," or the job level "Senior Staff" or "Supervisory and Management Staff." The department has 26 people with over 20 years of experience. Among all 32 managers, 13 have over 20 years of experience. Among all 16 senior staff, 4 indicated over 20 years on the job, and an additional 5 did not supply experience data, but are known to be longtime public health employees. Figure 16 displays the full network with different experienced staff removed**.** Statistics for the four networks are displayed in Table 18**.** Loss of senior staff results in a highly centralized network (0.82), but loss of supervisors markedly decreases centralization (0.26). The network is noticeably less dense, with isolation of supervisory staff (Figure 16, image #4). Average communication speed decreases when supervisors are removed, but is no more predictable because minimum speed is also reduced. There is less shared awareness. Complexity, already low, becomes even lower.

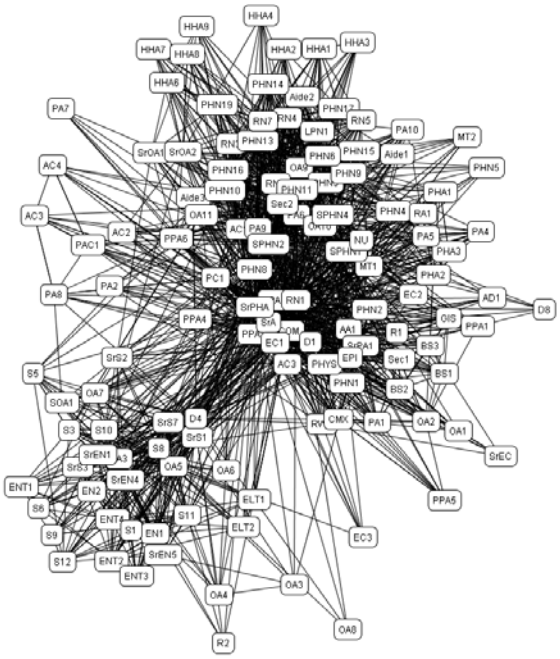
Table 18 Effect of isolating experienced staff in the network

Measure	Full Network	Senior Staff Removed	> 20 years Experience Removed	Supervisors Removed
Agent Count	156	140	130	124
Shared Situation Awareness	199	181	128	96
Overall Complexity	0.21	0.21	0.20	0.18
Social Density	0.15	0.15	0.13	0.10
Avg Communication Speed	0.49	0.48	0.46	0.42
Min Communication Speed	0.25	0.25	0.25	0.20
Network Centralization	0.46	0.82	0.46	0.26

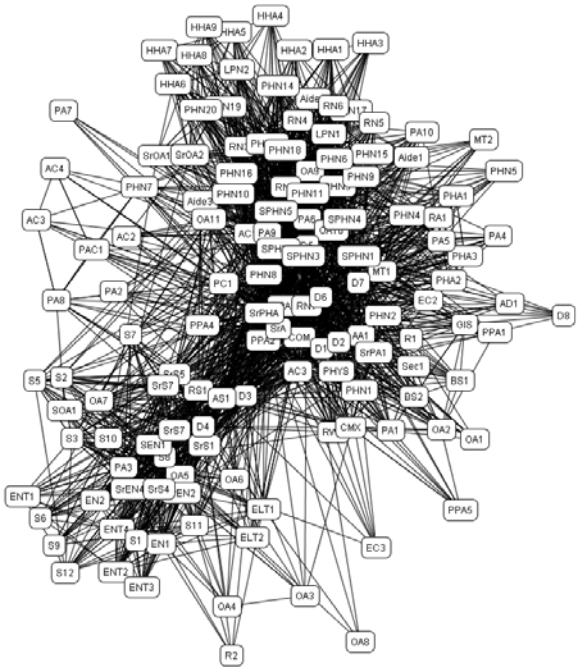
Figure 16 Visualization of the effect of isolating experienced staff



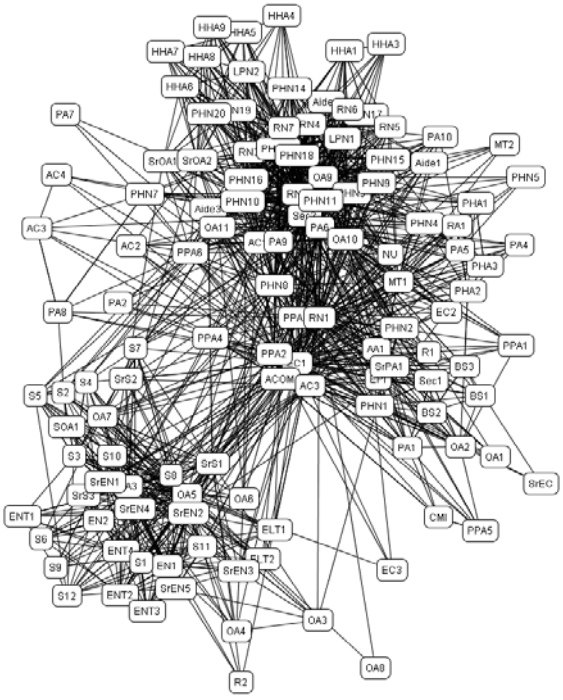
1. Full network



3. Staff with > 20 years experience removed



2. Senior staff removed



4. Supervisors/managers removed

Report on the Planned Merger of Two Divisions

Health department leadership asked for an analysis of a planned merger of the Communicable Disease Division (CDC) into the Public Health Nursing Division (PHN), which is currently composed of 4 programs, of which CDC would become the fifth. *ORA* reports were generated to compare the network profiles of PHN and CDC with the profile of the two divisions merged.

Centrality of Self-defined Roles

Centrality scores of self-defined roles in the PHN and CDC divisions and in the merged divisions were compared. Results displayed in Table 19 show overlap in the roles of the two divisions: 1) the most central roles of each division became the top two most central roles of the merged divisions and 2) the top 5 roles in the CDC and PHN divisions become the top 8 roles in the merged divisions.

Table 19 Comparison of centrality of ten self defined roles

PHN		CDC		Merged	
nurse*	0.529	comm dx invest*	0.357	nurse*	0.477
bioterrorism	0.098	health promotion	0.286	comm dx invest	0.123
comm. development	0.098	nurse	0.286	bioterrorism	0.108
counselor	0.078	counselor	0.214	counselor	0.108
public relations	0.078	educator	0.214	health promotion	0.092
comm dx invest.	0.059	epidemiologist	0.214	comm. development	0.077
environ	0.059	bioterrorism	0.143	educator	0.077
food inspector	0.059	hlth administrator	0.143	public relations	0.077
social worker	0.059	health officer	0.071	epidemiologist	0.062
dietician	0.039	health safety	0.071	environmental	0.046

* = most central role

Organizational Quality Report for the PHN/CDC Merger

Organizational quality of each division, and of the two divisions merged, is compared in Table 20. The merger does not affect the diversity of knowledge or resources, or the load of knowledge, but it does even out the resource load. Redundancies in access, assignment and knowledge are all increased. This markedly improves current redundancies in CDC, which are very low. Complexity and density of the CDC division are reduced in the merger. Shared situation awareness improves markedly, and the gap between average and minimum communication speed narrows slightly. These changes have more impact on the existing CDC network than they do on the PHN network.

Table 20 Comparison of quality measures for the divisional merger

Measure	PHN	CDC	MERGED
Diversity/Knowledge	0.971	0.971	0.971
Diversity/Resource	0.966	0.974	0.969
Load/Knowledge per agent	24	24	24
Load/Resource per agent	15	22	17
Redundancy/Access	16	6	22
Redundancy/Assignment	10	3	13
Redundancy/Knowledge	30	8	40
Overall Complexity	0.28	0.37	0.29
Social Density	0.34	0.57	0.32
Shared Situation Awareness	166	89	200
Communication Speed/Average	0.63	0.73	0.61
Communication Speed/Minimum	0.33	0.33	0.33

Key Actor Summary for the PHN/CDC Merger

Table 21 displays the top five individuals with important network connections in four categories within the CDC and PHN divisions currently and when merged. Key actors from the PHN division dominate in the merged division. A new key actor, SPHN3,

emerges in “Potentially Influential” and “Connects Groups” categories. Discord is possible when there is insufficient overlap of key actors in a merged division. The political consequences of the merger may be the loss of informal status for some CDC actors.

Table 21 Comparison of key actors

Position	PHN		CDC		Merged	
Emergent Leader						
1	0.302	D5	0.332	D6	0.319	SrPHA
2	0.280	SPHN2	0.331	SrPHA	0.289	D5
3	0.275	PHN6	0.314	SPHN1	0.275	PHN6
4	0.267	SPHN5	0.308	RN1	0.272	SPHN2
5	0.265	Sec2	0.241	PHA3	0.260	Sec2
Potentially Influential						
1	0.079	SPHN5	0.109	SrPHA	0.062	SPHN5
2	0.050	SPHN2	0.092	PA5	0.043	SPHN2
3	0.037	D5	0.061	RN1	0.040	SPHN3*
4	0.036	PHN18	0.036	SPHN1	0.035	SrPHA
5	0.026	Sec2	0.031	PHA3	0.031	PHN18
Connects Groups						
1	0.250	SPHN5	0.250	PA5	0.250	SPHN5
2	0.150	SPHN2	0.219	SrPHA	0.176	PA5
3	0.127	PHN18	0.128	RN1	0.168	SPHN3*
4	0.118	D5	0.083	PHA3	0.154	SPHN2
5	0.112	D7	0.078	SPHN1	0.134	SrPHA
Good Group Knowledge						
1	464	SPHN2	174	SrPHA	566	SPHN2
2	462	SPHN5	158	RN1	547	SPHN5
3	427	SPHN3	142	SPHN1	546	SPHN3
4	368	D5	126	D6	454	D5
5	367	PHN18	124	PA5	452	PHN18

Shaded cells = PHN staff,
Unshaded cells = CDC staff.
* new key actor

4.4 Summary of findings

In summary, the findings of the analysis show the following findings in response to research question #1: *What is the structure of information flow in the department communication network?*

1. The department is structured around a central core, with a major sub-group, composed of employees in environmental programs.
2. Diversity of knowledge and resources is very uneven and likely to be concentrated among a few employees.
3. Employees have highly similar knowledge, which could mean that their knowledge is more specialized than needed to do their work.
4. Programs have very low redundancies in resources and task capacity.
5. Complexity (density of the meta-matrix) of the organization is low, indicating limited interdependencies.
6. Density of the communication network is low in the agency overall, but is moderate to high in the programs, a possible sign of informational silos.
7. Shared situation awareness measures suggest that employees may be more aware of what is going on in the department overall, at least in their sub-area of expertise, than they are of what is going on in their program.
8. Information moves quickly in the programs, but not everyone gets it predictably.
9. Several programs show unnecessarily repetitive communication cycles.
10. Information is able to diffuse throughout the system efficiently.
11. Information is able to flow in efficient sequence among individuals.

12. The network shows presence of transitive groups, a positive indicator for collaboration and self organization.
13. Communication in some of the programs and in the department overall tends to center around single individuals or a small group.
14. There are just 11 employees holding the top five ranks in six strategic positions.
15. Potential loss of experienced staff in the department could result in wide variation in network centralization, as well as reduced connectivity, communication, and situation awareness.
16. Analysis of CDC and PHN networks produced statistics that support a planned merger of the two divisions, but with some loss of positional advantage for CDC staff.

4.5 Impact of the Research Findings on the Organization

After the final updates to the report were distributed, the leaders were asked to identify ways in which they expect to use the results, and to provide brief feedback on how they thought findings might have an impact. To guide their response, they were supplied with a list of items from the organizational impact portion of the information systems evaluation logic model described in Chapter 2, page 46 (Association of Public Health Laboratories & Public Health Informatics Institute, 2005). These items were: 1) managerial value; 2) changes to organizational processes; 3) redeployment of resources; 4) function changes; and 5) cross program support. Their suggestions were later examined in relation to three categories of communication and information use in intra-organizational networks (Farace et al., 1992) described in Chapter 2, p. 28. The

categories are: a) the scope of information received, including patterns of leadership and role distribution; b) the function of task coordination and information paths; and c) the structure of message transmission.

The following section provides feedback on the usefulness of the findings for information management and represents an answer to question #3a) *What is the value of network analysis for public health information managers?*

Managerial Value

Overall agency

The department's leaders were very interested in the appearance of an environmental sub-group. They thought this would be informative for public health leaders engaged in reorganization efforts at the national level. The graphic visualizations of the agency were termed "a good reflection of what exists." One graphical display of employee connectivity provoked this comment: "this is the kind of data I can bring to the county executive to acquire resources for information initiatives."

Key actors

The leaders expressed great interest in the influential actors in the agency. They quickly recognized the potential of these individuals to guide planning and reorganization. The department is currently engaged in an ongoing strategic planning process. They want to use the findings in this process. They decided five years ago to train the next generation of leaders and "this data can help." They specifically requested a list of the ten top

ranking agents (“bright lights in mid-level”) so more individuals could be tapped to participate in agency-wide initiatives. This addresses the scope and patterns in information distribution.

Experienced Staff Report

The department’s leaders questioned the value of removing whole blocks of agents in the model because this did not reflect the people who would take their place, and so was not a true reflection of connectivity. However, the effect that knowledge loss had on the network was of real concern, because the department has 26 employees with > 20 years experience, who are nearing retirement. They requested reports showing experienced staff removed at the divisional level to inform decisions on replacing these people. This addresses information use as a function of task coordination and communication.

Report on merger of CDC and PHN divisions

The department’s leaders found network profiles on the merger very useful. They saw positive indicators for the proposed merger. “Merging would increase awareness and reduce density—a good thing.” The profile of role centrality and improved redundancy confirmed their reasoning that both units will function better with a merger. The key actors report alerted them to possible implications for the “political” response of key CDC actors, because the effect of the merger will be more pronounced on this smaller division. This addresses scope of information use in patterns of leadership. It also addresses information functions in coordination of tasks, as well as overall structure of information flow.

The following feedback represents preliminary thinking from the health department's leaders on how they may apply the insights they have gained from the analysis in the future. This feedback answers research question # 3b. *How do department leaders expect to use the findings to make an impact on managing information?*

Changes to Organizational Processes

The leaders wished to expand/enhance links with community partners and responsibilities. They know that organizational effectiveness is also related to external information flows. They want to use the process of network analysis as a means for more community connections, and to create inter-organizational networks with other county health agencies and with state health agency. This suggestion addresses the scope and information individuals receive.

Redeployment of Resources

The department's leaders want to provide more communication tools as part of their infrastructure, and to test/train/utilize/evaluate them. They intend to institute mentoring relationships to ensure transfer of key expertise. For example, they suggested pairing junior staff with more experienced staff to mitigate the effects of staff turnover. Another priority for these leaders is to find a way to determine appropriate efficiencies and redundancies ("perfect for preparedness activities"). This suggestion addresses information function, which can be examined through coordination of tasks and communication pathways, and also addresses the structure of message transmission.

Function Changes

The leaders plan to use knowledge of the communication network for emergency readiness planning. They questioned how they could improve connectivity to create appropriate communication venues without increasing workload. They requested division reports in addition to the programs reports—both pieces of information were considered necessary to support change. Once these are in hand they will want the division directors to work with the insights they have gained during the year. This suggestion directly addresses information network function.

Cross Program Support

The leaders want to connect more *programs* internally by creating peer groups between programs. They also want to connect more *people* internally, also by creating peer groups. They intend to institute orientation to entire department for new staff (vs. a single program) to help with cross training. They will try matching staff for the year, to be in touch every month, and to have these individuals travel with their partner a few times a year to share information. This suggestion addresses information structure by exploring regularities in the transmission of messages, who talks to whom, and the overall flow of information.

CHAPTER 5 DISCUSSION

This chapter presents a discussion of the specific findings in relation to the research questions, including the significance of the study. A discussion of the limitations of the research method is presented, followed by implications of the study and a discussion of areas for future research.

5.1 Discussion of Results

In the section below the findings are discussed in the context of the concepts reviewed in Chapter 2, to answer research question # 2: *What relationships between information flow and performance are suggested by the model?*

The full network graph reveals the health department to be tightly connected to a more or less central core, with no isolated agents or weakly connected groups. The many agents at the periphery of the network are for the most part frontline staff, many of who work offsite in the two branch offices. A structure like this has been shown to be effective when the central core uses its tight connections as a means to coordinate learning, manage resources and integrate tasks for the network (Podolny & Baron, 1997). This visualization corresponds to the statistical findings on network centralization. The visual graph also shows one obvious sub-group, which is composed of employees of the environmental programs. This is a

logical sub-group for a public health agency. From a public health system perspective, what is of interest is that obvious sub grouping occurs among environmental programs versus other programs. This raises the question of whether this is a structure that might be found across public health agencies, and what the implication would be if it were.

Diversity and Redundancy

Diversity of knowledge and resources is very uneven. The department overall, and all the programs, have uniformly high scores for resource and knowledge diversity (> 0.9). This means that those resources and knowledge items that were measured (see Table 12, p.60) are concentrated in a few agents. This finding may point to pressing problems. The diversity measures describe the network in terms of resource and knowledge distribution. High diversity means there are probably underlying inequities in allocation, and work may suffer from over-dependence on the few individuals with most of the knowledge or resources (Magner *et al.*, 1996). In organizations with diversity profiles it is likely that some individuals or groups are likely to be over-tasked (Carley, 2005a).

The full network has very high *knowledge* redundancy, 95 of all 156 employees have the same knowledge. A high level of redundancy in an organization can be a sign of over-specialization (Lerner, 1986), if it means that many employees have knowledge they do not use or need for their assignment. Alternatively, it is possible that high overall knowledge redundancy is needed to perform specific

tasks (Moody & White, 2003; Sorenson, 2003; Southon *et al.*, 1999). High knowledge redundancy could indicate the department's need to respond locally to events, an inability to outsource tasks, or that a certain set of redundant knowledge is needed for cross coordination. At the program level, the elevated redundancy in knowledge suggests that programs tend to do similar things rather than collaborate; this could be a symptom of programmatic silos.

At the program level, resource and task redundancies are very low. These programs may not have sufficient redundancy to perform reliably if staff is absent or if agents leave or retire (Langlois & Garrouste, 1996). Organizational theory prescribes redundancy, in the form of overlap or duplication, to protect the organization from failed elements (Lerner, 1986). Sectors or departments that depend on failed components can also fail when a single crucial resource or link is absent. To ensure reliable performance, the health department might want to create more duplication and overlap. Landau recommends a pragmatic method: analyzing past performance and experiences to learn the redundancies needed to increase system reliability (Landau, 1969). Program directors and managers can define the types of breakdowns likely in their programs to help them frame their need for redundancy. The goal is to assure durability under stress by assigning units reserve functionality for specific failures. For example, applying contingency theory according to Galbraith's information processing model would emphasize parallelism in information channels to ensure redundant communication (Galbraith, 1974b).

Organizational theorists recognize a trade-off in the area of redundancy. Organizations high in redundancy are more capable of adaptation; but they are also more expensive to operate, and too much redundancy produces inefficiency (Cyert & March, 1963; Roberts, 1990). This health department needs to find ways to determine appropriate levels of redundancy. The department will need to look at the costs of redundancy, including the political cost of appearing wasteful (Lerner, 1986). This is better termed enlightened waste, because deliberate redundancies are more efficient in the long run (Landau, 1969)

Complexity and Density

Organizational complexity is defined as the amount of differentiation that exists within the different elements constituting the organization, for instance, the number of locations at which work is performed, the number of jobs or services performed, or the number of hierarchical ranks performing different tasks (Dooley, 2002).. In *ORA* this measure is operationalized as the density of the meta-matrix, or the number of links between agents, tasks, knowledge and resources compared to the total links possible. Complexity in the department and all the programs is below 0.5. There is no standard for public health organizational complexity, but these scores are low compared to other organizations (Carley, 2005b)

Organizational theorists describe a curvilinear relationship between overall complexity and performance (Roberts, 1990; Weick, 1979). Higher complexity results in increased coupling among sub-groups, technologies and processes. These interdependencies allow economies of scale and more cohesive structure (Coleman, 1990). As complexity increases, an organization performs better until a certain (undetermined) point at which the complexity becomes too great for individual employees or work units to manage. Performance begins to decline due to events such as missing information, inadequately informed decision making, delays in sequenced tasks, and so on. If complexity increases too far, the organization is prone to error cascades in across inter-dependent areas.

Another viewpoint from organizational theory tells us that when complexity is high (dense linkage between elements), and stability of the work environment is low (many changes in task problems) the optimal size of an organization is reduced, because when problems change quickly the organization can adapt better if there are fewer people who need to adjust (Cyert & March, 1963; Sorenson, 2003). When complexity is low (sparse linkage between elements) and stability is low (many changes) it is better to have many agents, because more people can solve problems faster (Carley & Hill, 2001; Cyert & March, 1963; March & Simon, 1958; Simon, 1979). This health department's complexity is low. The typical public health work environment is recognized to be unpredictable (Novick, 2001; B. J. Turnock, 1997), usually in the form of unplanned events (outbreaks, exposures, weather events, and so on). The findings therefore infer

that this health department needs more, rather than fewer, employees to optimize adaptability.

Clearly there are paradoxes in these views, and how an organization resolves these paradoxes defines performance (Roberts, 1990).To increase complexity the department's managers are faced with increasing interdependence, which typically calls for farming out parts of a problem while trying to maintain some information and resource connectedness among them (Thompson, 1967). Organization theory indicates that interdependence needs a hierarchy to manage well, but uncertainty in task problems requires decentralized management (March & Simon, 1958). The solution is that both structures are needed; and a strategy that is used by organizations requiring high reliability is to focus on training and use training to inform decentralized decisions (Roberts, 1990).

Social Density is the proportion of ties that exist compared to all that could exist. The full network structure in Figure 7 looks, and is (statistically) centralized. It also looks densely connected, but this is not the case. The many connections that radiate into the centralized core give the visual appearance of dense connectivity, but in fact density in the full network is low (0.149, or only 15% of all the ties that could be there).

As groups increase in size, density typically falls and it becomes more likely that differentiated and partitioned groups will emerge (Hanneman, 2001). Therefore,

the presence of subgroups in organizations is not unusual. This is seen in the full network diagram in which the central cluster is composed of two large subgroups: 1) environmental programs, and 2) all other programs.

Social density for the overall department is lower than at the program level, indicating less communication *between* programs than *within* programs. This is a sign that the programs are somewhat cut off from each other—evidence of the programmatic silos that are a recognized feature of public health organizational structures (Public Health Foundation, 2004a). Density within programs is relatively high (>0.5). Organizational units that have more dense networks can achieve a higher performance than those with sparse networks because increased density enhances the ability for teams to coordinate, thereby increasing productivity (Reagans & Zuckerman, 2001).

According to network theory, when networks are dense, agents are likely to receive the same or very similar information, because this information circulates among the same group of people (Burt, 1992; Granovetter, 1983). This means that information propagates faster, including rumors. There are fewer bottlenecks to information flow, but there can be a tendency for "group think," where a group's members strive for unanimity at the expense of realistically considering alternative courses of action (Festinger, 1954; Janis, 1972). Low complexity combined with high social density at the program level means that if error cascades occur, they may be due to a general group-think response rather than due

to the unavoidable coupling of tasks that is seen in organizations with high complexity (Reason, 1997).

Situation Awareness

Shared Situation Awareness across agents is a measure of organizational effectiveness. There have been too few cross-organizational studies of this measure to define a generally acceptable range, but higher numbers mean that more members of the organization understand what others are doing and share an understanding of the issues facing the organization (Graham, 2004). In this sense, higher numbers suggest sound organizational decision making, better coordination and better performance (Simon, 1979). High numbers also indicate good integration of the workforce, which enables seamless transitions in workload, or rapid recognition of errors and mitigation of unintended consequences (Weick & Sutcliffe, 2001). Scores for the full network are higher compared to the programs. This could mean that employees have a broad general understanding of administrative functions, and strong connectivity with others in their sub-area who are working in other programs, rather than deep knowledge of their particular program (Carley, 2005b). This interpretation makes sense in light of the tendency for public health practitioners to be generalists who apply their skills broadly.

Speed

The *Speed/Average and Speed/Minimum* reports in *ORA* reflect how rapidly information flows in the agency, measured by the number of paths needed to connect people. Fast communication is reflected by high average speed numbers. In the programs average speeds are above the mid-point (0.5), which is satisfactory (Carley, 2005a). However, *average* speed in all programs (except Administration) is at least twice as fast as *minimum* speed (see Table 16). Sizable gaps between average and minimum speeds suggest unpredictability or asymmetry in the flow of information, where employees get information at different times, with the result that some feel "out of the loop." Health departments are complex systems. Consistent with the principle of emergence in complex systems, unpredictable information flow causes paradoxical effects that can cloud meanings, roles and outcomes (Sawyer & Rosenbaum, 2000). The chief tenet of information processing theory is improving performance through reduction of uncertainty about task outcomes, environmental conditions, and other aspects of organizational life. For this reason, employees would benefit from strategies to create more predictable communication, where everyone got information closer to the same time.

Efficiency

The *efficiency* measure in *ORA* reflects the presence of redundant communication cycles that are not necessary to keep the network connected. Programs with scores below the mid-point (<0.5) exhibit unnecessarily repetitive communication

(see Table 16). Because this measure is an indicator for whether the right information is getting to the people who need it without going to those who don't, one way low scores on this measure can be interpreted is that there are too many bosses (Carley, 2005a). Too many bosses or not, transferring information is inefficient when agents spend time getting or giving information over and over. For example, there are opportunity costs. Instead of communicating repetitively, the department's managers need to consider how agents could be developing links that provide new knowledge, spend time cultivating relationships with other subunits, or processing incoming information from direct contacts (Hansen, 1999).

Global efficiency and local efficiency measures do not reflect communication cycles, but rather parallel and sequential paths for transporting information. They derive from graph theory, and reflect properties of small world networks (Latora & Marchiori, 2001). These measures reflect information diffusion. Large quantities of information are widely distributed across multiple agents within and among organizations, thus performance depends on this capacity (Carley, 2002b). The scores for both measures are well above the mid-point (0.61 – 0.90 for global; 0.85 – 0.96 for local)[3]. These results are positive for the agency and for the programs. These scores show that at the system (global) level, and at the individual agent (local) level there are adequate paths to move information

[3] In comparison, the global efficiency for the Boston bus system is 0.72 (meaning only 28% less effective than a direct road from one stop to another, because parallel paths are used), and local efficiency is 0.46 (because local efficiency only allows one sequential path, and accounts for possible errors, or missing paths).

effectively through the organization and programs, and also from employee to employee. This feature of the network could be important for initiatives to create cross program teams, and for developing system redundancy (Recall that information processing theory calls for parallel communication as a means to create redundancy.) However, once again, there is less efficient communication at the level of the full agency compared to the programs, further evidence of the silo phenomenon.

Transitivity

Transitivity is a measure of completed triads, in which if A communicates with B and B communicates with C, then C also communicates with A. This measure is an indicator of cooperation or collaboration between agents, where information can be shared. The concept is captured by paraphrasing a common adage: "it's who you know *and* what you know that gets things done." Organizational simulations show that triad formation precedes stability, and triads have implications for information diffusion, task consensus, and performance. Over time, as organizational structure stabilizes, more triads emerge and their longevity is shorter. Groups can form and reform, easily making for a flexible structure (Carley & Hill, 2001). Higher numbers on this measure indicate a more balanced group, less infighting, and less likelihood that people are excluded (Carley, 2005a). The health department has high transitivity, indicating a good potential to respond flexibly to conditions of uncertainty (Galbraith, 1974a). This is a goal of organizational design, and a positive indicator for performance. Scores within

each program are higher than for the full network, which is yet another suggestion that the programs are somewhat closed off from each other.

Centralization

Network Centralization is a measure of how tightly a graph is organized around its central point (Wasserman & Faust, 1994) It sums the differences between the score of the most central node in the graph and the scores of all other nodes, and presents this as a ratio to the sum of maximum possible differences. Network theorists interpret this as an indicator of how positional advantage is distributed. The score, 0.46, is indicative of centralization (only 46% of the difference in centrality among agents that *could be* is actually there). This means it is likely that a central group tends to have substantial power over the network (Hanneman, 2001). In the programs, some have centralized and others have distributed communication patterns. Centralization can lead to better performance because the central person (or group) integrates information, thus system energy is not wasted looking for leadership or for strategies to get work done (Scott, 2000). Further, centralized people often enjoy their jobs, produce a large volume of substantive communication, and are instrumental to information flow (Leavitt, 1951).

A drawback of centralized systems is that problems can become too complex for an individual or small group to handle. Highly central agents can become overwhelmed by communication, while the rest of the network wastes time

waiting for information or direction (Miller, 2001). The peripheral agents can experience dissatisfaction in their jobs because they are disconnected (Roberts, 1990). Managers in highly centralized networks also can lack adequately diverse viewpoints for making effective decisions (Mizruchi & Stearns, 2001). In such cases more distributed systems may perform better because the entire organization contributes to solving problems (Borgatti, 1997).

Key Actors in the Network

The key actors in the department are those that possess advantages due to their location in the network. The number and the nature of ties an agent has affects their power in the network (Hanneman, 2001). This is the notion of social capital, which represents the relational resources attainable by individual agents through networks of social relationships (Burt, 2000; Coleman, 1990; Tsai, 2000). Network theorists consider specific kinds of ties to be particularly influential in holding the organization together (Monge & Contractor, 2003). For example, individual agents with connections to a variety of networks rather than many connections within a single network are considered to be in a good position to innovate due to the variety of their connections (Granovetter, 1983; Hansen, 1999), while individuals who are strongly embedded by many connections in one network are considered in a strong position to affect cooperation and group work (Coleman, 1990). Informal networks among agents serve organizational goals by compensating for inadequacies in the formal network with links that bypass obstacles (Connors, *et al*., 1985).

In the health department there is a group of 11 people who dominate in all of the key positions that were measured (Table 15). The agent COM appears in all of these positions, which is not unexpected as this agent is the formal leader of the agency. However, COM is not the highest ranking agent in any of these measures, which suggests ability for delegation. This also implies that COM exerts power less through direct connections and more by using connections to the surrounding well connected people.

Ties between organizational units are created by powerful individuals, such as supervisors and directors who are involved in decisions about inter-unit activities (Schein, 1992). Nearly all of the prominent ranking agents in the key actor reports are in supervisory or management positions, and will need to be included in important agency initiatives. There is one strongly positioned agent that is not a manager. RN1, part of the main office field staff, shows up both as an informal leader and as a person with many direct and indirect connections to important people (eigenvector centrality). To improve network connectivity, RN1 is a good person for the agency's leadership to designate as a "go to" person on topics important to the ongoing work of the agency, and as a resource for field staff to get their opinions to the central leaders (Cross, *et al*., 2005).

The good group knowledge report in *ORA* is a measure of homophily (likeness) and proximity. The measure is based on network theory and social theories of

affiliation (Breiger, 1974; Davis, *et al*., 1941; Simmel, 1955). It uses two-mode network calculations (agent *and* attributes) to establish affiliations based on communication, location, and similar attributes (Wasserman & Faust, 1994). High-scoring agents have a lot in common with others and can be fairly effective people (Carley, 2005b). If you could interview only one person to gauge what is going on in the network it should be top-ranked SPHN2. Due to their positions, all five of these agents could be helpful to the department's leaders in interpreting the results of this network analysis. This measure introduces two new actors (SPHN5 and SPHN3) who are not among the most central agents. They are supervisors in the department's largest division, Public Health Nursing, which contributes to their good handle on what is going on in the department.

SrPHA is the highest ranking agent on four of the six measures. SrPHA is a strong informal leader (cognitive demand), who is the most highly connected agent in the network (degree centrality), and who is also the best connected to the other well connected people in the department (eigenvector centrality). SrPHA is also the most influential broker of information (betweeness centrality). This agent's involvement is crucial for spreading information through the network and key to finding out what is going on in the network. SrPHA's control over information flow can affect how others perceive news and information. This agent's position makes his/her support for agency-wide initiatives essential.

All the people who rank highly as boundary spanners (Connect Groups report) need to be on board when any changes are proposed in the department, to ensure the ideas are communicated to peripheral staff. AS1, an assistant in the environmental group scores highest in the "connects groups" category and also has a high betweeness score, meaning he receives a significant amount of the information that flows through the network. This agent is a "boundary spanner" who can efficiently link his group with less connected agents. This is the person to enlist to bring peripheral people into the group, and broker their buy-in for agency-wide projects. D3 also is in a position to connect groups, particularly with those in the environmental group, where he is a director. D3 appears only here and in none of the other top roles. Such brokers, if well respected, can help mitigate conflicts (Krackhardt, 1994). The role of a boundary spanner is also the only one in which RS1 appears. This person has a unique job in the department and is also a senior employee who is known to have strong opinions regarding the department's operating policies. RS1's participation in initiatives to improve the department's effectiveness will likely bring others on board who connect with RS1's point of view. Alternatively, the department's leaders could use 'structural leverage' by enlisting a close contact of RS1 to introduce an organizational initiative to RS1's circle (Krackhardt & Stearns, 1988).

The Status of Experienced Staff

Potential loss of experienced staff could result in wide variation in network centralization, as well as reduced connectivity, communication, and situation

awareness. When highly connected employees leave, organizations can experience knowledge drains based on what the departing person knows and how his or her relationships hold the entire network together (Cross, *et al*., 2005; Feeley & Barnett, 1996). Some actors are critical in maintaining or increasing the integration among groups and their departure can sever ties between groups (Brass, *et al.*, 2004). There are 32 senior and supervisory/management staff in the department, many with over 20 years of experience. Network statistics showed how loss of these agents decreases situation awareness, network complexity, and social density. Centralization of the network is doubled with the removal of senior staff but cut in half with removal of supervisors. Neither outcome is beneficial, which illustrates how important the experienced employees are both in distributing and controlling communication in the department.

The key issues with loss of experienced staff is losing their knowledge and leadership skill. The tacit knowledge held by experienced staff can be hard to formalize and communicate to others because it is complex, existing in the mental models and expertise gained over time and through personal insights. This knowledge is best transferred through means such as mentoring, teamwork, chat rooms, personal intranets, and opportunities for face-to-face conversations such as group dialogue or personal reflections on experiences and lessons learned (Goh, 2002). Another strategy is to leverage the relational load of key agents to maintain connectivity in the network when they leave (Cross, *et al.*, 2005). For example, agents in key positions (such as “boundary spanner” and “most influential”) need

to work with agents that rank highly on centrality and cognitive load to develop these links for themselves. Other management solutions, such as staggered retirements, might be used to allay the effects of anticipated staff loss. Managers need to be aware of contagion, a network phenomenon known to affect organizational turnover, resulting in clusters of similar people leaving simultaneously (Krackhardt & Porter, 1985).

Application of the Findings

The network analysis has revealed possible problems in the health department's information flow. These include the likelihood that sub-groups are controlling knowledge and resources; there may be overspecialization of knowledge; there is potential for significant knowledge loss through retirement; there is little back up for personnel turnover; and there are informational silos. Based on these findings the department needs greater redundancy and better cross program coordination. The department also has strengths that can contribute to effective performance, such as efficient communication paths and good social density in the programs.

The health department leaders have several ways in which they can take advantage of their knowledge of the existing network structure. According to information processing theory, organizations strive to improve performance through i) reducing the amount of information processed, or ii) increasing the ability to handle more information (Galbraith, 1974a; Rollag, 2000). Some techniques managers can use to reduce unnecessary information processing and

increase overall information flows are determine where a) efficiencies created by close ties (key actors) can be leveraged for better performance and b) where close ties are inhibiting performance, or burdening overly connected people.

Another area of concern is centralization in the network. In terms of member satisfaction, distributed networks offer participants greater feelings of self-determination and provide more socio-emotional gratification than do centralized nets (Connors *et al.*, 1985). The department's managers confirmed that many front line staff complain about being left out or neglected by "the main office." A strategy to address this is to connect more closely with peripheral agents to bring more ideas into the centralized group and to increase the job satisfaction of these members, so they feel that they are contributing. Agents on the periphery of a network can also be valuable as sources for new ideas because they are not constrained by the rigid patterns found in the core (Borgatti & Everett, 1999). If gaps in communication speed also are reduced, fewer people will feel left out, and this will produce more general contentment.

At the program level a question for the department's managers is what characteristics of the work environment benefit from either high or low centralization. For example, programs with mobile field staff might perform best with highly centralized structure. On the other hand, in some organizations greater centralization has been found to prevent a unit from exercising discretion in task resolution, and to reduce its chances of forming inter-unit ties (Tsai, 2002).

If centralization is perceived to be a problem in some programs department leadership might want to

1) help employees connect with each other directly to solve problems and thereby eliminate inefficiencies and bottlenecks resulting from excessive reliance on the central individuals or groups

2) target points where connectivity needs to be decreased as well as increased.

Such actions could increase effectiveness of central individuals over time and ensure that the agency is not overly influenced by small, insular groups of people (Cross *et al.*, 2005).

A potential hazard for the most central people in a network is that they can get overly consumed with demands from their colleagues and so become bottlenecks in the network. As the pressures for disseminating knowledge increase, central people can become insular and stop learning from as broad a personal network. Similar attitudes develop among employees when their roles are equivalent in an organization's structure (in the health department this may be the program directors, or nursing supervisors, or division coordinators) (Wasserman & Faust, 1994). While such similarity can facilitate transmission of tacit knowledge, simplify coordination and avoid conflict (Cross *et al.*, 2002), it also inhibits group diversity and promotes 'us vs. them' thinking that keeps peripheral agents out (Krackhardt & Stearns, 1988). Coaching, mentoring, or career development efforts to help these influential people keep their networks diversified can have a

positive impact on the individual and the group as a whole (Davenport & Prusak, 1998).

Another strategy is bridging informational silos by creating awareness of expertise distributed in the network (Cross *et al*., 2005). In the classic information silo, the focus is inward and all communication is vertical. Managers in the silo serve as information gatekeepers, making coordination and communication among departments difficult to achieve. Organizations that maintain silos can lose effectiveness because knowledge becomes stuck in one area or silo (Nonaka, 1994). Breaking down informational hierarchies in the organization enables knowledge transfer (Bartlett & Ghoshal, 1998). The issue is how to structure the organization so that the gains of parallel information can be had while balancing it with the need to coordinate information in light of how the agency's activities interact (Chang & Harrington, 2004). A technique to accomplish this is through horizontal communication flows. For example, creating cross-functional teams and encouraging teamwork through assigning tasks that require cross-functional collaboration will force individuals and groups away from the silo mentality and toward communicating horizontally (Goh, 2002). Integration has been shown to lead to interdependencies in many organizational settings, thus strategies to improve horizontal communication flows are likely to increase organizational complexity, which also has potential for improving performance (Sorenson, 2003).

The people in the key actor roles can be invaluable in this process. They need to be included in all cross program briefings and positioned on cross functional teams to help build strong ties throughout the agency. Strong ties are associated with reciprocal arrangements in which advice and help flow in both directions (Marsden & Campbell, 1984). This is the concept of embeddedness, which refers to the process by which social relations create cohesive groups and shape organizational action (Granovetter, 1985; Mizruchi & Stearns, 2001; Moody & White, 2003). Embedded ties have three features: trust, fine-grained information transfer, and joint problem solving arrangements (Uzzi, 1996). Embeddedness increases an organization's access to resources and strengthens its ability to adapt to unforeseen problems. Embedded ties perform unique functions, not only increasing the transfer of information, but also making it interpretable and valuable (ibid). Embeddedness is a condition of shared situation awareness, which can be achieved via rehearsal (mental or actual) and cross-training (Graham, 2004).

For agents to be adaptable they need a combination of situation awareness and redundant access to knowledge and resources. This is another area where the health department likely will benefit from regular within and cross-program briefings because these strategies allow personnel to build up their transactive memory (knowledge of who knows who and who knows what) to cope with novel situations (Carley, 2005b; Hollingshead, 2001; Stasser, 1995). Transactive memory structures are the organizing schemes that connect knowledge held by

individuals to knowledge held by others (Wegner, 1987). When group members need information, but cannot recall it themselves or mistrust their own memories, transactive memory facilitates turning to each other for help. Group training has been shown to develop transactive memory (Moreland & Myaskovsky, 2000), and there is a positive relationship between transactive memory system development and group performance (Austin, 2003).

5.2 Significance

In the section below, the significance of network analysis as a research method for public health is discussed.

The Public Health Department

The health department's leaders perceive the results of this analysis to be a useful guide for strategic planning. They produced a set of potential applications of the findings that are within the capacity of public leadership to initiate, in that they conformed to a logical model for public health information system evaluation: changes to organizational processes; redeployment of resources; function changes; and cross program support (see page 98). Significantly, their ideas equally address three categories of communication and information use in intra-organizational networks: scope of information and group structures, functional coordination of tasks and communication; and structure, or overall flow, of information through the organization (Farace et al., 1992). Their reaction

addressing both domains is evidence of the utility the method has for managing information in public health.

The planned merger between CDC and PHN divisions

A specific example of the utility is found in the analysis of a planned merger between the CDC and PHN divisions. Studies of multi unit organizations show that two units are likely to form a tie when their resources are strategically related or complementary, as a way to leverage internal resources and knowledge (Tsai, 2000). The network profile of the CDC and PHN divisions showed interdependent communication networks and similarities in employee roles. In the merger the most central roles of each division were retained. Redundancies improved, resources were more evenly distributed, and shared situation awareness improved. For CDC there was a reduction in density (from 0.57 to 0.32). This was interpreted positively because the department's leaders view social density in the CDC unit as sub-optimal. Thus the network analysis produced useful information to support merging these.

However, the impact of the merger is greater on the small CDC division. Employees in key positions are less well positioned in the merged division. Informal networks emerge not only from the flow of work, but also as a result of attractions of similar others, and are the outcome of status jockeying between workers and managers for status among peers and subordinates (Flap, Bulder, & Beate, 1998). This finding has obvious utility for managers. They can address

the political implications of the merger before hidden dynamics among employees seeking to protect their status undermine benefits for performance (Kahn, Cross, & Parker, 2003).

Public Health Organizations

Organizational network analysis has been primarily used in private sector organizations. This research serves as a case study for application of the method in a public health agency. Unlike private sector organizations, the structure of a local health department is not completely malleable because it is determined by state and local law and is under the control of local government. This study provides evidence that network findings can be usefully applied to a public sector agency

Rainey argues that organizational issues in the public sector are not at opposite poles to private sector concerns to the degree once believed. Public agency effectiveness is highest where organizational design, task design and leadership are combined to produce worthwhile public service (Rainey, 2000). There is increasing public sector awareness that autonomy to manage mission and tasks tends to enhance performance, and increasing recognition that leadership can shape a culture of innovation adaptiveness (General Accounting Office, 2003; Gore, 1993, Government Performance and Results Act, 1993). The skills that public managers need for coping with the constraints of their roles can be improved by accurate surveillance of the task environment. It gives them insight

to respond to public sector work issues with established strategies like shared leadership and teams, utilization of technology, and development of human resources.

Communication networks are known to have a strong effect on organizational performance (Mohrman *et al.*, 2003), and this effect operates on a logic of exchange that is different from the incentive-based logic of markets (Uzzi, 1996). Public sector agencies relate performance to mission, not economic profit. Provan and Milward argue that organizational network analysis is a legitimate and effective evaluation method for public sector organizations in the absence of financial success criteria used in the for profit world (Provan & Milward, 2001). Network analysis examines performance from a relational, not an economic, perspective, a suitable metric for evaluation of a public sector organization. The cognitive accuracy derived from knowing the structure and the central people in a network is political knowledge (Krackhardt, 1990), something with which public agency managers are familiar. Network insights that inform management strategies are as valuable to public sector managers as they are to private sector managers (O'Toole, 1997). Network insights can help public health managers understand and direct information flows in the agency, and supply evidence for planning to improve performance. The usefulness the findings had for the leaders of the health department studied here is evidence of this.

Public Health Nursing

Public health nurses are the largest occupational group employed by governmental public health agencies, and public health nursing is typically the largest program or division in a local health agency (Gebbie, 2002). That is the case, for example, in the health department studied here. Network analysis targets information management as a means to better organizational performance. The information network is a key aspect of public health agency structural capacity, upon which public health nurses depend to do their work. The method will affect public health nursing practice and performance through insights on how the scope, function and structure of the information network are managed in the agency.

Public Health Informatics

Organizational network analysis is a means to build knowledge about how information is used in public health. It can be used in planning stages to design information interventions based on empirical evidence of communication patterns, or to differentiate and clarify the roles of systems users. It can identify network patterns or influential leaders in the communication structure who may be crucial to successful execution of information initiatives. Anderson observed significant effects after network analysis was used to identify key leaders in a clinical setting, who then facilitated implementation of a clinical information system (Anderson, 2002). Similar effects could be expected in the public health setting.

Sequential network analyses can document the evolution and refinement of information management projects by documenting changes in communication patterns over time. In addition, network analysis presents an opportunity for informaticians and public health practitioners to build collaborative knowledge on how information is used that could be applied to improve public health systems.

Public Health System

On a public health systems level, there is potential for the method to contribute as well. Performance measurement is difficult in public health due to the wide variation in structure and jurisdictional mandates in individual agencies. By examining a variety of agency structures in relation to those agencies that have established high performance (through National Public Health Performance Standards Program or other techniques), organizational network analysis could prove a valuable resource for identifying a range of preferred structures.

5.3 Limitations

This section presents a discussion of the methodological limitations of the study.

Network Analysis

There are limitations to network analysis as a research tool. The analysis represents only one aspect of the complex organizational landscape (Cross & Parker, 2004). In particular, network patterns do not assess the culture of organizations. The work atmosphere and attitudes of management and staff

contribute to trust and safety in organizations and can affect performance as much as patterns of information exchange (Podolny & Baron, 1997; Spector & Jones, 2004; Thoms, Dose, & Scott, 2002). Kahn and colleagues argue that network analysis reveals the symptoms of organizational issues rather than the issues themselves. Stakeholders must be aware that network analysis is a means of organizational diagnosis and change. This viewpoint holds that there are rational behaviors in groups that seek better performance, but there are also defensive behaviors that seek to retain power, ward off stress, or limit perceived threats from others. These forces operate beneath the surface in group relationships, and may be irrational. The authors claim that network analysis needs to expand and address multiple layers of interaction such as hidden dynamics that may undermine effective organizational development. The value of this approach is that change agents can gain collective agreement on problems in the network, and bring to the surface issues on how they work together in order to make suitable choices for improvement (Kahn, *et al.*, 2003).

The chief difficulties associated with intra-organizational network research include problems of access to organizations and incomparability of research findings (Flap, *et al.*, 1998). There are significant difficulties collecting data; it is labor intensive and time consuming for both researcher to coordinate data collection amongst many subjects, and for subjects to accurately capture relations, especially in large networks (Newman, 2003). Each network is unique and must be interpreted in context (although baselines for some measures can be

constructed by comparing similar types of organizations). For public health organizations, baselines have yet to be established that incorporate appropriate elements of public health work.

Network relational data contain inherent dependencies that do not exist in traditional attribute data, and which invalidate the assumption of independent observations (Monge & Contractor, 2003). A limitation of network analysis has been the inability to test hypotheses statistically, since auto correlation violates the assumption of independence required by classical statistical tests (Krackhardt, 2002). Recently this issue has been addressed by Mantel's Test for space-time interaction, using a Monte Carlo method to permute elements of one matrix while holding another constant (Borgatti, 2000). This advanced technique is beyond the scope of this project.

Finally, network analysis is complicated to execute. The results are complex and difficult both to interpret and to communicate (Kilduff & Tsai, 2003). It is an inherently difficult and sophisticated process, with many layers of meaning (Kahn, Cross, & Parker, 2003). Organizations typically cannot conduct a network analysis without the assistance of an expert, and the costs inherent to expert consultation. In addition, because information structures evolve over time they cannot be re-engineered quickly or without cost, with the result that some findings may have limited utility in some settings (Langlois & Garrouste, 1996)

Reliability

Network models are criticized for being static and unable to reflect adjustments in network conditions to ongoing workplace contingencies (Wasserman & Faust, 1994). This study is a cross-sectional study that reflects the network at one point in time. Issues such as work atmosphere were not examined in this study. Network conditions may have changed during the time between analysis and interpretation of findings. Therefore caution must be used when applying findings.

The means used to elicit network connections affect data reliability. Studies on the consistency and dependability of network measurement have found that using a free recall technique to query respondents about their ties performs less well than recognition techniques that list possible network connections (Hlebec & Ferligoj, 2002). Accordingly, a complete list of all agency personnel was used to gather data for this study. To further aide recognition, the list was contextualized by grouping personnel according to division and program, and by providing their titles.

Survey collection of network data has implications for reliability. Surveys are time consuming. Measurement error is a threat if respondents rush through survey questions or forget, or inaccurately state, the nature of their network relations. Observation, interviews, and log tracking (e.g. email logs) can improve precision, but these methods are difficult and carry the cost of excessive researcher time and/or respondent burden. These techniques were not used in this study because

precedence has shown that despite this potential for error, informants are generally considered to be “fairly reliable” judges of their network affiliations (Kumbasar, *et al.*, 1994).

Non-response bias is a threat when there is incomplete data. In a full network analysis this means any response rate less than 100%. A missing answer on a question does not mean absence of a tie. Information obtained from both parties about mutual interaction contributes to reliability of the data (De Lange, *et al*., 2004). In this study, two-way questions were used to capture how agents “give information” and “get information.” Network measures are robust under small amounts of missing data. For example, missing 5% of ties yields correlations between true and observed centrality at >.90 (Borgatti, *et al*., 2004). The response rate in this study was 93%. Data is missing so the conclusions of this study are subject to uncertainty (Costenbader & Valente, 2003).

It is possible that the culture of the public health workplace, in which a high premium is placed on cooperation, consultation and collaboration, influenced the respondents’ perceptions of the network. Respondents have “positive distortion” for reporting if they exaggerate their relationships, and many of their ties will actually be weak interactions that are unlikely to be reported by others, i.e. unlikely to be reciprocated (Feld & Carter, 2002). Due to a public health “norm,” employees may have tended to list that they work with lots of people. To address the issue of overstated connectivity, the data sets were merged and only agents providing affirmative responses to all 4 network questions were considered

linked. However, expansiveness bias in reporting may be masking the actual degree of centralization in this network (it may be higher).

Validity

Validity, the extent to which network measures accurately capture the characteristics of the true network, has not been well studied. Internal validity in network analysis has been defined as error free code (Borgatti, *et al*., 2004). Significant efforts were made to insure accurate data collection, entry and conversion in this study. These efforts are described in Chapter 3. Still of concern is whether it is simple information or richer forms of knowledge (e.g., a complex technology) that flows through the ties between agents, and this has not been well studied (Hansen, 1999). One possible reason for the overstated connectivity that was found may have been because "information" was interpreted broadly. The health department's leaders felt that a good deal of information flow in the network was related to administrative matters, such as time cards and paychecks. Precise directions to survey respondents to indicate only communication links directly related to public health work (e.g. who provides you with information to get your work done?) might yield differences in the network profile.

The data collection instruments may present a threat to the validity of this study's findings. Content validity is the principal guide for formulating survey questions regarding specific network relationships (De Lange, *et al.*, 2004; Wasserman &

Faust, 1994). The two surveys used in this study can be considered valid for measuring the relations, and the knowledge, tasks, and resources of public health workers only to the extent that the survey items are representative of those elements.

In the network survey, questions to measures relationships between employees were derived from standard questions, and were customized with expert consultation. The NYMC survey questions were based upon public health worker informatics competencies and benchmarking questions that have been used in prior research (Lee, *et al*., 2003; O'Carroll, 2002). It is possible that these survey items do not accurately capture true dimensions of public health knowledge, resources, and tasks in public health. When preliminary results of the network analysis were presented to the department's leadership they indicated that tasks derived from NYMC survey did not reflect public health jobs that can be substituted for one another. Thus task redundancy scores in this study likely are not completely accurate. In contrast, the self-rated job function, also an item from the NYMC survey, *was* a very useful node set in the task matrix, so the actual validity of the survey items for network analysis is unclear.

There is a threat to content validity if survey questions do not capture important information flows. To address this issue, a final question asking respondents to write in specific barriers they experience in accessing and using information was

included to reduce this threat. These qualitative data were not included here, but were contained in a formal report to the health department.

Another concern for content validity is the way matrix variables were operationalized. For example, the results show that knowledge is not evenly distributed. Knowledge diversity is a function of knowledge representation in the "agent x knowledge matrix." Among the knowledge items in that matrix were education and experience. These variables were additive across six levels. Every person with a high school education received a 1 and five 0's; everyone with an associate degree received two 1's, and four 0's; and so on. Not surprisingly, the handful of employees with doctorates hold considerable knowledge, as do employees with >20 years of experience. By way of contrast, the dominant knowledge in the department (total degree centrality) is education level 1 and public health experience level 1, because everyone has those knowledge items. This seems to be reasonable for face validity, but may or may not be a true reflection of knowledge in the department.

Few network models need more than face validation, which can be determined by asking the question "is it a reasonable representation of reality?" (Chang & Harrington, 2004). The multiple results that point to information silos, which are a known feature of public health organizations, contribute validity to the analysis as an accurate reflection of reality. Comments from the department's leaders are evidence of face validity. Their remarks regarding graphical representations of the data include: "a good reflection of what exists," "shows all the links that

should be there," and "depicts nuts and bolts of the department, plus programs that are more peripheral." In response to network statistics at the program level the leaders remarked that data "makes sense." In response to key actor statistics they indicated "if [these links] weren't there I'd be worried" and "surprised about some [links] but not about others because of position and personality."

External validity is not an entirely accurate term to use regarding network analysis because it implies generalizability (Marsden, 1990). Networks are unique and a single network analysis is not generalizable. It is more useful to consider the robustness of findings using qualitative and/or quantitative methods (Borgatti, *et al.*, 2004). Validity of network data can be tested by correlation of the network findings with observed data. Triangulation techniques, which check data using multiple methods such as observation, interviews, or collection of records, are used but have the drawback of being time consuming, and risk being intrusive in the workplace (Schrieber & Carley, 2003). Of crucial importance is sufficient attention to how the model reflects reality through careful review of the results with stakeholders (Chang & Harrington, 2004). This ensures results that are interpreted in the right context given the organizational structure and operations (Scott, 2000). Iterative, collaborative interpretation was used to improve the robustness of this study's findings. Interpretation was adjusted on two occasions in response to the contributions from the department's leadership: 1) after preliminary data presentation, and 2) after presentation of the completed analysis.

5.4 Implications

This study is based on the interaction of three concepts: organizational network analysis, information use, and performance (see conceptual model in Chapter 1, page 11). The findings have implications in all three areas.

Organizational Network Analysis

As a research method, network analysis has potential for public health. But because it has not been applied in public health organizations, the technique may need adaptation, and new measures may be required. Public health agencies may have characteristics that require singular interpretation of findings, since they may not be comparable to organizations where organizational network analysis has been traditionally used.

The purpose of a network model is to organize theoretical beliefs with empirical observations about a system, by identifying important system aspects (Loerch, 2004). For instance, this study presents evidence of information silos in several measures. While silos are likely to be present this may also be a reflection of some necessary aspect of public health work. The goal of network analysis is to relate the model to reality and in the process gain insight that may lead to useful modifications (Chang & Harrington, 2004). New measures, or new interpretations for existing measures, need to be developed, that can present an accurate model of where silos may complement or detract from public health work.

Practically, for an analysis program like *ORA*, not only could new measures be incorporated, but special reports could be developed. Instead of selecting and assembling measures from pre existing reports designed to serve the needs of "typical" organizations (as was done in this study), measures specific to public health could be presented as pre-structured reports that could be used directly by public health information managers. Output could include range and general interpretations of measures. Within that framework there also needs to be guidelines regarding which level of data is best for interpretation with which level of staff. Findings will do no good if they provoke negative comparisons or anxiety regarding network models and their implications for performance. As it exists now, organizational network analysis is too complex to be used directly. Ways need to be found to make the technique and the results more accessible, if the method is to achieve its potential to support information management in public health.

Information Use

The findings imply that the department has issues with centralized communication, concentrated access to resources, extremely low redundancies, and low complexity with limited interdependencies. There is also evidence of informational silos that could negatively affect performance. These findings suggest several areas in which information should be restructured. Perhaps most important is to create appropriate levels of redundancy. Redundant information,

by reducing “noise” in the system, has implications for organizational reliability and adaptability (Atlan, 1972; Langlois & Garrouste, 1996). Information-processing capabilities are crucial to development of adequate redundancy because they create channels for duplication of information (Kampfner, 1999). A strategy derived from information processing theory calls for developing parallel information channels that overlap in functional areas of the organization, a process that could also be used to reduce informational silos (Galbraith, 1974a).

The findings also suggest that the department should find ways to increase organizational complexity. Many scholars studying complexity in organizations have observed interdependencies among elements of organizational design, such as allocation of decisions, incentives and information flows (Flap et al., 1998). There is a relationship between redundancies, interdependency and organizational complexity. Self organization in systems increases complexity and redundancy by creating interdependencies (VonFoerster, 1960). This is the idea behind the transitivity measure in *ORA*, where communication triads are used to gauge the self-organization of the system. The department scores well on this measure, implying there is structural potential for increasing redundancy.

Appropriate levels of redundancy are a function of ordered, and self-organized, duplication and overlap (Lerner, 1986). One way redundancy can be created is with ordered information. This makes sense, because public health information is known to be fragmented and therefore a source of less efficient performance. The

department's managers can look for ways to aggregate information, improve access, and identify information gaps that are stressing cooperative working relationships.

There are also implications in the costs of redundancy, which include the political cost of appearing wasteful. This implies that the department's leaders may need to educate their public stakeholders on the specific ways redundant information flows will contribute to the department's reliability (Lerner, 1986).

Performance

Network structure is entwined with performance. This implies that the environmental sub-group found by this study may have an affect on the department's performance. It is also possible that this type of sub-group occurs frequently in public health agencies that provide environmental services, suggesting possible system wide implications for this structure. Is functionality of the full network compromised by this structure, or is this a necessary division for a public health agency to perform efficiently? Only further study of public health agency networks can provide the baseline comparison data to answer performance questions like this.

Another implication for performance is how network structure is perceived. The respondents in this study exhibited expansiveness bias in their view of their network connections. In general, respondents to network surveys will tend to

over report ties to high status individuals (Brewer, 2000) and see themselves as more central than others do (Kumbasar *et al.*, 1994). However, in this study respondents had a tendency to over report their connectivity across the board, not just with central people. They indicated connections that were distributed among many agents, rather than overstating their connections to central people. It is possible that this network is more centralized. The level of group situation awareness, small number of employees in key positions, and diversity scores indicating resource concentration all support this suspicion. This implies that these public health workers view their communication network inaccurately. Public health's collaborative work culture may contribute to this tendency. This has implications for transactive memory because employees' cognition of the network determines their interactions, and groups can take advantage of the knowledge of its members only to the extent that they can accurately map who knows what and who knows who (Borgatti & Foster, 2003).

Accurate perception of the agent network also translates into an accurate perception of power in the network. Organizational performance is a function of information sharing and the process of searching for and combining information (Carley, 2002a). When employees know who to go to, or understand who has the power, the chances of organizational success are increased (Krackhardt & Hanson, 1993). The network model produced by this analysis has implications for performance if it can help employees develop an accurate "mental model" of the network.

5.5 Areas for Future Research

Refinement of the data collection instrument is essential for developing network analysis as an aide for public health information management. In addition to developing survey items that accurately capture public health knowledge, resources, and tasks, it is also necessary to establish the range of resources and knowledge needed to perform specific public health tasks. These parameters are needed to allow further calculations of quality and performance. There are many measures of network efficiency in *ORA* that can deliver insights for public health managers, but the surveys used in this study did not capture the data required to calculate these measures. For example, when there is high diversity in resources or knowledge, congruency should be checked, as some agents may not have the resources or knowledge needed to complete their work. Another example is agents with a high task load. In this case, variance in workload should be assessed. High variance would suggest that some organizational members may be pulling the load for the rest, implying that the group may be less satisfied and less productive than if workload were more evenly distributed. This would help managers design tasks more effectively or provide additional support where it is needed. For the current study, data were not available to construct the 'task x knowledge' or 'task x resource' matrices required to calculate such measures.

To determine what resources and knowledge are needed to perform tasks, a minimum set of public health tasks, those likely to be performed in most to all

health agencies, needs to be established.[4] Once a set of tasks is determined, the general knowledge and resources for each of these could be stipulated. Expert opinion and focus groups with public health practitioners are methods that could achieve this.

More network studies of health departments are needed. A baseline needs to be established for measures like organizational complexity and optimum levels of redundancy by analyzing agencies with a known level of performance.

Longitudinal studies of health departments could contribute to understanding the factors that contribute to performance in public health organizations. Studying network change is critical because cross-sectional analysis of networks usually leaves causal relations ambiguous (Brass, *et al*., 2004). Elements such as staff education and training, changes in technology, or staff turnover, when examined longitudinally across public health departments could yield insights into how network structural elements affect performance and how social structure and organizational capabilities co-evolve (Tsai, 2000).

There is a phrase often repeated when public health agency structure is under discussion—*if you have seen one health department you have seen one health department*. This truism stems from the fact that each health agency's structure

[4] e.g.. facility/food service inspection; re-inspection; process new case of: lead poisoning, TB, STD, animal bite, etc; follow existing case of same; pest control inspection; extermination; poison control counseling; early intervention service planning; processing vital records, licenses, fine collection; case investigation; contract approval, and so on…plus routine office tasks like data entry, document and report preparation, etc.

has evolved uniquely as part of state and local government. The health department studied here demonstrates a structural feature—environmental programs form a distinct subgroup. More network studies might determine if this structure is typical of agencies that provide environmental services. Positional analyses using block models could be compared to validate a theory that general structural patterns exist across health departments (Wasserman & Faust, 1994). These might be correlated with resource, knowledge and task requirements to produce empirically driven recommendations for agency structure.

In conclusion, an organizational network analysis demonstrated utility for public health leaders in one local health department. These leaders intend to use insights achieved through the analysis to plan strategies for improving agency performance. The technique has potential to aid public health information management. Additional research is needed to refine network analysis methods for the public health domain.

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APPENDICES

APPENDIX A

Institutional Review Board Documentation of Status

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APPENDIX B

Network Survey Instrument

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County Department of Health
Organizational Network Analysis Survey

This is the second of two surveys administered as part of an organizational analysis being conducted by researchers from the New York Academy of Medicine and Columbia University. The goal of the research is to explore information use and communication flow in the department, and hopefully to identify ways to improve information use in routine work so the department can be more effective.

Please provide your input by answering the questions below. This should take about 15 to 25 minutes. Please note that your answers are confidential. Results that identify you by name will be kept within the Columbia/New York Academy of Medicine research team that is administering the questionnaire. Outside of that group only aggregated data will be released, that will not identify you by name.

If you choose to participate in this survey, you acknowledge your understanding that you will not have access to the data collected, and that the data is to assist the Department and its management staff in identifying ways to improve information use in routine work.

1. Please provide the following information about yourself

Name_____

Worksite_____

To share information from the New York Medical College *phip* survey that you just completed please enter the ID number you used below

Birth Month Birth Day Last 4 Digits of SS#

___ ___ ___ ___ ___ ___ ___ ___

2. What are the main barriers that you face in accessing information that you need to do your job?

_____

_____

_____

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3. On the list below please place a check mark next to the organizations you communicate with in you routine work. If you communicate with an agency or group not listed, please add it at the end of the list

Organization	Check
National	
American Cancer Society	
American Heart Association	
American Lyme Disease Foundation	
American Red Cross	
CDC	
HRSA	
GlaxoSmithKline	
NACCHO	
United Way	
NYState	
Child Abuse Prevention Center	
Cornell Cooperative Extension	
Health Research, Inc.	
Mental Health Association	
NYS – Office of Mental Retardation	
NYS Troopers	
NYSACHO	
NYSDEC	
NYSDOH – fiscal	
NYSDOH – Local Health Division	
NYSDOH – MARO	
NYSDOH AIDS Institute	
NYSDOH Arthropod-Borne Disease Program	
NYSDOH Bureau of Communicable Diseases	
NYSDOH Bureau of Community Sanitation	
NYSDOH Bureau of Radiation Protection	
NYSDOH Bureau of STD Control	
NYSDOH Bureau of Tuberculosis Control	
NYSDOH Bureau of Water Supply Protection	
NYSDOH Division of Chronic Disease Prevention	
NYSDOH Division of Family Health	
NYSDOH Immunization Program	
NYSDOH Office of Children and Family Services	
SPARCS	
State University of New York – New Paltz	
State University of New York – New Paltz Library	
Dutchess County	
Community Alert Network, Inc. (CAN)	
Dutchess County Dept. of Mental Hygiene	
Dutchess County Dept. of Social Services	
Dutchess Community College	
Dutchess County Board of Health	
Dutchess County Comptroller	
Dutchess County Council on Alcoholism	
Dutchess County Dept. of Central Services	

Organization	Check
Dutchess County Continued	
Dutchess County Dept. of Personnel	
Dutchess County Dept. of Planning	
Dutchess County Dept. of Probation	
Dutchess County Dept. of Public Works	
Dutchess County Dept. of Risk Management	
Dutchess County District Attorney Office	
Dutchess County Executive Office	
Dutchess County Legislature	
Dutchess County Medical Society	
Dutchess County OCIS	
Dutchess County Office for the Aging	
Dutchess County Sheriff	
Dutchess County Youth Bureau	
Emergency Medical Services	
Family Partnership Center	
Family Services, Inc.	
Smokefree Dutchess Coalition	
Local	
Alamo Ambulance	
Beacon Health Resource Center	
Byrnes Message Bureau	
Children's Medical Group	
Churches	
Hudson River HealthCare, Inc.	
Hudson Valley Pharmaceutical Society	
Institute of Eco System Studies	
Marist College	
Marist College Library	
Mid-Hudson Family Health Institute	
Mid-Hudson Interpreter Services	
Mid-Hudson Library System	
Normet	
NYMC	
NYMC Library	
Other local Health Departments	
Poughkeepsie Journal Newspaper or other media	
Schools	
St. Francis Hospital	
St. Francis Hospital Medical Library	
Vassar Brothers Medical Center	
Vassar Brothers Medical Center Library	
Vassar College	
Vassar College Library	
Other	
Other	

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4. Please list up to 5 people outside the department of health who are important in terms of providing you with information to do your work or helping you think about complex problems posed by your work. These may or may not be people that you communicate with on a regular basis. (example: associates or colleagues in other organizations, friends, family, etc.)

PERSON	RELATIONSHIP

5. From the list of health department employees below please answer the following questions. If the answer to any question is "0" you may leave that box blank.

5A Do you receive work related information from each person listed below?

0 = No (leave blank)
1 = Yes

5B. To whom do you give work related information?

0 = No (leave blank)
1 = Yes

5C. Who is important in terms of helping you think about complex problems posed by your work? These may or may not be people that you communicate with on a regular basis.

0 = No, I do not discuss work issues with this person (leave blank)
1 = Yes, I discuss work issues with this person

5D. I understand what knowledge and skills this person has. This does not mean I have these skills or knowledge, but I understand what skill and knowledge capacity they possess.

0 = I do not understand this person's knowledge and skills (leave blank)
1 = I understand this person's knowledge and skills

`

NAME	TITLE	Question 5A	Question 5B	Question 5C	Question 5D
		Get info	Give info	Discuss issues	Understand skills
COMMISSIONER'S OFFICE					
Last name, First name	Commissioner				
Last name, First name	Confidential Admin. Assistant				
Last name, First name	Clinical Physician				
Last name, First name	Office Assistant				
PUBLIC HEALTH INFORMATION OFFICE					
Last name, First name	Director				
Last name, First name	Secretary				
Last name, First name	Program Assistant				
Last name, First name	Office Assistant				
Last name, First name	Ryan White Contract Coordinator				
Health Planning and Education					
Last name, First name	Director				
Last name, First name	Epidemiologist				
Last name, First name	Emergency Response Staff				
Last name, First name	Principal Program Assistant				
Last name, First name	Biostatistician				
Last name, First name	Biostatistician				
Last name, First name	Biostatistician				
Last name, First name	Senior PH Education Coordinator				
Last name, First name	PH Education Coordinator				
Last name, First name	PH Education Coordinator				
Last name, First name	Public Health Nurse				
Last name, First name	Public Health Nurse				
Last name, First name	PH Nutritionist				
Last name, First name	GIS Technician				
ADMINISTRATION AND FISCAL DIVISION					
Last name, First name	Assistant Commissioner				
Last name, First name	Senior Accountant				
Last name, First name	Receptionist				
Last name, First name	Principal Program Assistant				
Last name, First name	Principal Program Assistant				
Last name, First name	Account Clerk				
Last name, First name	Account Clerk				
Last name, First name	Senior Program Assistant				
Last name, First name	Principal Program Assistant				
Last name, First name	Account Clerk				
ENVIRONMENTAL WATER LABORATORY					
Last name, First name	Env. Lab Director				
Last name, First name	Env. Lab Technician				
Last name, First name	Env. Lab Technician				

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NAME	TITLE	Question 5A	Question 5B	Question 5C	Question 5D
		Get info	Give info	Discuss issues	Understand skills
ENVIRONMENT HEALTH SERVICES					
Last name, First name	Director				
Last name, First name	Supervising Office Assistant				
Last name, First name	Program Assistant				
Last name, First name	Office Assistant				
Last name, First name	Program Assistant				
Last name, First name	Office Assistant				
Last name, First name	Receptionist				
Last name, First name	Radiological Specialist				
Last name, First name	Senior PH Sanitarian				
Last name, First name	Senior PH Sanitarian				
Last name, First name	Supervising PH Engineer				
Last name, First name	Office Assistant				
Last name, First name	Senior PH Sanitarian				
Last name, First name	Senior PH Engineer				
Last name, First name	Senior PH Engineer				
Engineering Office					
Last name, First name	Senior PH Engineer				
Last name, First name	Senior PH Engineer				
Last name, First name	Senior PH Engineer				
Last name, First name	PH Engineer				
Last name, First name	PH Engineer				
Last name, First name	Senior PH Sanitarian				
Last name, First name	PH Engineering Technician				
Last name, First name	PH Engineering Technician				
Last name, First name	PH Engineering Technician				
Last name, First name	PH Engineering Technician				
Last name, First name	PH Sanitarian				
Core Environmental Health Services					
Last name, First name	Associate PH Sanitarian				
Last name, First name	Senior PH Sanitarian				
Last name, First name	Office Assistant				
Last name, First name	PH Sanitarian				
Last name, First name	PH Sanitarian				
Last name, First name	PH Sanitarian				
Last name, First name	PH Sanitarian				
Last name, First name	Senior PH Sanitarian				
Last name, First name	Office Assistant				
Last name, First name	PH Sanitarian				
Last name, First name	PH Sanitarian				
Last name, First name	PH Sanitarian				
Last name, First name	Senior PH Sanitarian				
Last name, First name	Office Assistant				
Last name, First name	PH Sanitarian				
Last name, First name	PH Sanitarian				
Last name, First name	PH Sanitarian				
Last name, First name	PH Sanitarian				
Last name, First name	PH Education Coordinator				

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NAME	TITLE	Question 5A	Question 5B	Question 5C	Question 5D
		Get info	Give info	Discuss issues	Understand skills
OFFICE OF THE MEDICAL EXAMINER					
Last name, First name	Chief Medical Examiner				
Last name, First name	Principal Program Assistant				
Last name, First name	Chief Medical Investigator				
PUBLIC HEALTH NURSING & CLINICAL PREVENTIVE SERVICES					
Last name, First name	Director				
Last name, First name	Secretary				
Communicable Disease Control Division					
Last name, First name	Director				
Last name, First name	Program Assistant				
Last name, First name	Senior PH Advisor				
Last name, First name	PH Advisor				
Last name, First name	PH Advisor				
Last name, First name	PH Advisor				
Last name, First name	Program Assistant				
Last name, First name	Supervising PH Nurse				
Last name, First name	Office Assistant				
Last name, First name	PH Nurse				
Last name, First name	PH Nurse				
Last name, First name	PH Nurse				
Last name, First name	Case Manager Aide				
Last name, First name	Registered Nurse				
Clinical Services & Research					
Last name, First name	Director				
Last name, First name	Program Assistant				
Last name, First name	PH Nurse				
Last name, First name	Clinical Research Assistant				
Clinical Laboratory					
Last name, First name	Director				
Last name, First name	Medical Technologist				
Last name, First name	Medical Technologist				
Last name, First name	Medical Technologist				
Children With Special Needs Unit					
Last name, First name	Program Coordinator				
Last name, First name	PH Nurse				
Last name, First name	Principal Program Assistant				
Last name, First name	Principal Account Clerk				
Last name, First name	Program Assistant				
Last name, First name	Account Clerk				
Last name, First name	Account Clerk				
Last name, First name	Program Assistant				

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NAME	TITLE	Question 5A	Question 5B	Question 5C	Question 5D
		Get info	Give info	Discuss issues	Understand skills
Public Health Nursing Division					
Vacant	Assistant Director				
Preventive Health Services					
Last name, First name	Supervising PH Nurse				
Last name, First name	Program Assistant				
Last name, First name	PH Nurse				
Immunizations					
Last name, First name	PH Nurse				
Last name, First name	Registered Nurse				
Last name, First name	Registered Nurse				
Last name, First name	Registered Nurse				
Last name, First name	Case Manager Aide				
Last name, First name	Case Manager Aide				
Family Health					
Last name, First name	Supervising PH Nurse				
Last name, First name	Program Assistant				
Last name, First name	Office Assistant				
Last name, First name	PH Nurse				
Last name, First name	PH Nurse				
Last name, First name	PH Nurse				
Last name, First name	PH Nurse				
Last name, First name	PH Nurse				
Last name, First name	PH Nurse				
Home Care Unit					
Last name, First name	Supervising PH Nurse				
Last name, First name	Office Assistant				
Last name, First name	PH Nurse				
Last name, First name	PH Nurse				
Last name, First name	Registered Nurse				
Last name, First name	Registered Nurse				
Last name, First name	Licensed Practical Nurse				
Last name, First name	Home Health Aide				
Last name, First name	Home Health Aide				
Last name, First name	Home Health Aide				
Last name, First name	Supervising PH Nurse				
Last name, First name	Senior Office Assistant				
Last name, First name	Senior Office Assistant				
Last name, First name	PH Nurse				
Last name, First name	PH Nurse				
Last name, First name	PH Nurse				
Last name, First name	Registered Nurse				
Last name, First name	Licensed Practical Nurse				
Last name, First name	Home Health Aide				
Last name, First name	Home Health Aide				
Last name, First name	Home Health Aide				
Last name, First name	Home Health Aide				
Last name, First name	Home Health Aide				
Last name, First name	Home Health Aide				

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APPENDIX C

Relational Data Dictionary

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ONA Data Dictionary

County Department of Health
7/2005

>>>NODE TYPE AGENT>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

ID	TITLE	ProgName
COM	Commissioner	COMMISSIONER
AA1	Confidential Admin. Assistant	COMMISSIONER
PHYS	Clinical Physician	COMMISSIONER
OA1	Office Assistant 1	COMMISSIONER
D1	Director-Public Information Office	PH INFORMATION
Sec1	Secretary 1	PH INFORMATION
PA1	Program Assistant 1	PH INFORMATION
OA2	Office Assistant 2	PH INFORMATION
RW1	Ryan White Contract Coord	PH INFORMATION
D2	Director-Health Planning & Edu	HEALTH PLANNING & EDU
EPI	Epidemiologist	HEALTH PLANNING & EDU
PPA1	Principal Program Assistant	HEALTH PLANNING & EDU
BS1	Biostatistician 1	HEALTH PLANNING & EDU
BS2	Biostatistician 2	HEALTH PLANNING & EDU
BS3	Biostatistician 3	HEALTH PLANNING & EDU
SrEC	Senior PH Education Coord	HEALTH PLANNING & EDU
EC1	PH Education Coordinator 1	HEALTH PLANNING & EDU
EC2	PH Education Coordinator 2	HEALTH PLANNING & EDU
PHN1	Public Health Nurse 1	HEALTH PLANNING & EDU
PHN2	Public Health Nurse 2	HEALTH PLANNING & EDU
NU	PH Nutritionist	HEALTH PLANNING & EDU
GIS	GIS Technician	HEALTH PLANNING & EDU
ACOM	Assistant Commissioner	ADMINISTRATION & FISCAL
SrA	Senior Accountant	ADMINISTRATION & FISCAL
R1	Receptionist 1	ADMINISTRATION & FISCAL
PPA2	Principal Program Assistant 2	ADMINISTRATION & FISCAL
PPA3	Principal Program Assistant 3	ADMINISTRATION & FISCAL
AC1	Account Clerk 1	ADMINISTRATION & FISCAL
AC2	Account Clerk 2	ADMINISTRATION & FISCAL
SrPA1	Senior Program Assistant 1	ADMINISTRATION & FISCAL
PPA4	Principal Program Assistant 4	ADMINISTRATION & FISCAL
AC3	Account Clerk 3	ADMINISTRATION & FISCAL
D3	Director-Environmental Water Lab	ENV WATER LAB
ELT1	Env. Lab Technician 1	ENV WATER LAB
ELT2	Env. Lab Technician 2	ENV WATER LAB
D4	Director-Environmental Health Serv	ENV HEALTH SERVICES
SOA1	Supervising Office Assistant	ENV HEALTH SERVICES
PA2	Program Assistant 2	ENV HEALTH SERVICES
OA3	Office Assistant 3	ENV HEALTH SERVICES
PA3	Program Assistant 3	ENV HEALTH SERVICES
OA4	Office Assistant 4	ENV HEALTH SERVICES
R2	Receptionist 2	ENV HEALTH SERVICES
RS1	Radiological Specialist 1	ENV HEALTH SERVICES
SrS1	Senior PH Sanitarian 1	ENV HEALTH SERVICES
SrS2	Senior PH Sanitarian 2	ENV HEALTH SERVICES
SEN1	Supervising PH Engineer 1	ENV HEALTH SERVICES
OA5	Office Assistant 5	ENV HEALTH SERVICES
SrS3	Senior PH Sanitarian 3	ENV HEALTH SERVICES
SrEN1	Senior PH Engineer 1	ENV HEALTH SERVICES

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SrEN2	Senior PH Engineer 2	ENV HEALTH SERVICES
SrEN3	Senior PH Engineer 3	ENGINEERING
SrEN4	Senior PH Engineer 4	ENGINEERING
SrEN5	Senior PH Engineer 5	ENGINEERING
EN1	PH Engineer 1	ENGINEERING
EN2	PH Engineer 2	ENGINEERING
SrS4	Senior PH Sanitarian 4	ENGINEERING
ENT1	PH Engineering Technician 1	ENGINEERING
ENT2	PH Engineering Technician 2	ENGINEERING
ENT3	PH Engineering Technician 3	ENGINEERING
ENT4	PH Engineering Technician 4	ENGINEERING
S1	PH Sanitarian 1	ENGINEERING
AS1	Associate PH Sanitarian 1	CORE ENV HEALTH
SrS5	Senior PH Sanitarian 5	CORE ENV HEALTH
OA6	Office Assistant 6	CORE ENV HEALTH
S2	PH Sanitarian 2	CORE ENV HEALTH
S3	PH Sanitarian 3	CORE ENV HEALTH
S4	PH Sanitarian 4	CORE ENV HEALTH
S5	PH Sanitarian 5	CORE ENV HEALTH
SrS6	Senior PH Sanitarian 6	CORE ENV HEALTH
OA7	Office Assistant 7	CORE ENV HEALTH
S6	PH Sanitarian 6	CORE ENV HEALTH
S7	PH Sanitarian 7	CORE ENV HEALTH
S8	PH Sanitarian 8	CORE ENV HEALTH
SrS7	Senior PH Sanitarian 7	CORE ENV HEALTH
OA8	Office Assistant 8	CORE ENV HEALTH
S9	PH Sanitarian 9	CORE ENV HEALTH
S10	PH Sanitarian 10	CORE ENV HEALTH
S11	PH Sanitarian 11	CORE ENV HEALTH
S12	PH Sanitarian 12	CORE ENV HEALTH
EC3	PH Education Coordinator 3	CORE ENV HEALTH
CMX	Chief Medical Examiner	MEDICAL EXAMINER
PPA5	Principal Program Assistant 5	MEDICAL EXAMINER
CMI	Chief Medical Investigator	MEDICAL EXAMINER
D5	Director-PH Nrsng & Clin Prev Serv	PH NURSING & CLINICAL
Sec2	Secretary 2	PH NURSING & CLINICAL
D6	Director-Communicable Disease Con	COMMUNICABLE DISEASE
PA4	Program Assistant 4	COMMUNICABLE DISEASE
SrPHA	Senior PH Advisor	COMMUNICABLE DISEASE
PHA1	PH Advisor 1	COMMUNICABLE DISEASE
PHA2	PH Advisor 2	COMMUNICABLE DISEASE
PHA3	PH Advisor 3	COMMUNICABLE DISEASE
PA5	Program Assistant 5	COMMUNICABLE DISEASE
SPHN1	Supervising PH Nurse 1	COMMUNICABLE DISEASE
OA9	Office Assistant 9	COMMUNICABLE DISEASE
PHN3	PH Nurse 3	COMMUNICABLE DISEASE
PHN4	PH Nurse 4	COMMUNICABLE DISEASE
PHN5	PH Nurse 5	COMMUNICABLE DISEASE
Aide1	Case Manager Aide 1	COMMUNICABLE DISEASE
RN1	Registered Nurse 1	COMMUNICABLE DISEASE
D7	Director-Clinical Serv & Research	CLINICAL & RESEARCH
PA6	Program Assistant 6	CLINICAL & RESEARCH
PHN6	PH Nurse 6	CLINICAL & RESEARCH
RA1	Clinical Research Assistant 1	CLINICAL & RESEARCH
D8	Director-Clinical Laboratory	CLINICAL LABORATORY
MT1	Medical Technologist 1	CLINICAL LABORATORY
MT2	Medical Technologist 2	CLINICAL LABORATORY

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PC1	Program Coordinator 1	CHILDREN SPECIAL NEEDS
PHN7	PH Nurse 7	CHILDREN SPECIAL NEEDS
PPA6	Principal Program Assistant 6	CHILDREN SPECIAL NEEDS
PAC1	Principal Account Clerk 1	CHILDREN SPECIAL NEEDS
PA7	Program Assistant 7	CHILDREN SPECIAL NEEDS
AC4	Account Clerk 4	CHILDREN SPECIAL NEEDS
AC5	Account Clerk 5	CHILDREN SPECIAL NEEDS
PA8	Program Assistant 8	CHILDREN SPECIAL NEEDS
AD1	Assistant Director 1	PH NURSING DIVISION
SPHN2	Supervising PH Nurse 2	PREVENTIVE HEALTH SERV
PA9	Program Assistant 9	PREVENTIVE HEALTH SERV
PHN8	PH Nurse 8	PREVENTIVE HEALTH SERV
PHN9	PH Nurse 9	IMMUNIZATIONS
RN2	Registered Nurse 2	IMMUNIZATIONS
RN3	Registered Nurse 3	IMMUNIZATIONS
RN4	Registered Nurse 4	IMMUNIZATIONS
Aide2	Case Manager Aide 2	IMMUNIZATIONS
Aide3	Case Manager Aide 3	IMMUNIZATIONS
SPHN3	Supervising PH Nurse 3	FAMILY HEALTH
PA10	Program Assistant 10	FAMILY HEALTH
OA10	Office Assistant 10	FAMILY HEALTH
PHN10	PH Nurse 10	FAMILY HEALTH
PHN11	PH Nurse 11	FAMILY HEALTH
PHN13	PH Nurse 13	FAMILY HEALTH
PHN14	PH Nurse 14	FAMILY HEALTH
PHN15	PH Nurse 15	FAMILY HEALTH
SPHN4	Supervising PH Nurse 4	HOME CARE UNIT
OA11	Office Assistant 11	HOME CARE UNIT
PHN16	PH Nurse 16	HOME CARE UNIT
PHN17	PH Nurse 17	HOME CARE UNIT
RN5	Registered Nurse 5	HOME CARE UNIT
RN6	Registered Nurse 6	HOME CARE UNIT
LPN1	Licensed Practical Nurse 1	HOME CARE UNIT
HHA1	Home Health Aide 1	HOME CARE UNIT
HHA2	Home Health Aide 2	HOME CARE UNIT
HHA3	Home Health Aide 3	HOME CARE UNIT
SPHN5	Supervising PH Nurse 5	HOME CARE UNIT
SrOA1	Senior Office Assistant 1	HOME CARE UNIT
SrOA2	Senior Office Assistant 2	HOME CARE UNIT
PHN18	PH Nurse 18	HOME CARE UNIT
PHN19	PH Nurse 19	HOME CARE UNIT
PHN20	PH Nurse 20	HOME CARE UNIT
RN7	Registered Nurse 7	HOME CARE UNIT
LPN2	Licensed Practical Nurse 2	HOME CARE UNIT
HHA4	Home Health Aide 4	HOME CARE UNIT
HHA5	Home Health Aide 5	HOME CARE UNIT
HHA6	Home Health Aide 6	HOME CARE UNIT
HHA7	Home Health Aide 7	HOME CARE UNIT
HHA8	Home Health Aide 8	HOME CARE UNIT
HHA9	Home Health Aide 9	HOME CARE UNIT

```
>>>NODETYPE KNOWLEDGE>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
Lvledu  level of education
            0    Missing data
            1    Less than high school
            2    High school or eqv
            3    Associate or 2 year degree
```

```
            4    Bachelor's degree
            5    Master's degree
            6    Doctorate (MD, Phd, EdD)

If lvledu = 1 than code
lvledu 1 = 1
lvledu 2 = 0
lvledu 3 = 0
lvledu 4 = 0
lvledu 5 = 0
lvledu 6 = 0

If lvledu = 2 than code
lvledu 1 = 1
lvledu 2 = 1
lvledu 3 = 0
lvledu 4 = 0
lvledu 5 = 0
lvledu 6 = 0

If lvledu = 3 than code
lvledu 1 = 1
lvledu 2 = 1
lvledu 3 = 1
lvledu 4 = 0
lvledu 5 = 0
lvledu 6 = 0

If lvledu = 4 than code
lvledu 1 = 1
lvledu 2 = 1
lvledu 3 = 1
lvledu 4 = 1
lvledu 5 = 0
lvledu 6 = 0

If lvledu = 5 than code
lvledu 1 = 1
lvledu 2 = 1
lvledu 3 = 1
lvledu 4 = 1
lvledu 5 = 1
lvledu 6 = 0

If lvledu = 6 than code
lvledu 1 = 1
lvledu 2 = 1
lvledu 3 = 1
lvledu 4 = 1
lvledu 5 = 1
lvledu 6 = 1


ExpPHhlth   experience in PH
            1    Less than 1 year
            2    1-5 yrs
            3    6-10 yrs
```

`

```
            4    11-15 yrs
            5    16-20 yrs
            6    Over 21 yrs)

If ExpPHlth = 1 than code
ExpPHlth 1 = 1
ExpPHlth 2 = 0
ExpPHlth 3 = 0
ExpPHlth 4 = 0
ExpPHlth 5 = 0
ExpPHlth 6 = 0

If ExpPHlth = 2 than code
ExpPHlth 1 = 1
ExpPHlth 2 = 1
ExpPHlth 3 = 0
ExpPHlth 4 = 0
ExpPHlth 5 = 0
ExpPHlth 6 = 0

If ExpPHlth = 3 than code
ExpPHlth 1 = 1
ExpPHlth 2 = 1
ExpPHlth 3 = 1
ExpPHlth 4 = 0
ExpPHlth 5 = 0
ExpPHlth 6 = 0

If ExpPHlth = 4 than code
ExpPHlth 1 = 1
ExpPHlth 2 = 1
ExpPHlth 3 = 1
ExpPHlth 4 = 1
ExpPHlth 5 = 0
ExpPHlth 6 = 0

If ExpPHlth = 5 than code
ExpPHlth 1 = 1
ExpPHlth 2 = 1
ExpPHlth 3 = 1
ExpPHlth 4 = 1
ExpPHlth 5 = 1
ExpPHlth 6 = 0

If ExpPHlth = 6 than code
ExpPHlth 1 = 1
ExpPHlth 2 = 1
ExpPHlth 3 = 1
ExpPHlth 4 = 1
ExpPHlth 5 = 1
ExpPHlth 6 = 1

otherlangs       languages
                        0    No
                        1    Yes
```

`

```
Skill Proficiency       0     not aware
                        1     aware  TO PROFICIENT

EvlP01      evaluate data integrity

IntP02      interpret data on risks and benefits

CollP03     collect & summarize info

MedP04      Use media and technology to communicate

PreP05      present info for professional and lay audience
ImpP06      Implement public health assessment
RetP07      Retrieve & evaluate scientific evidence
UtiP08      Utilize technology tools to locate info
UseP09      Use browser software
OnlneP10    Use online search engines
IdPubP11    identify specialized search engines eg PubMed
DtaP12      assess validity of data retrieved online
ITprP13     use IT to promote PH
DsgP14      design website
ITP15       Use IT to broadcast health info to various audiences
IdsP16      Identify info sources
FinP17      find data online
ComP18      combine and use data from multiple sources
NetP19      describe fundamentals of a computer network
WWWP20      describe at a basic level the internet & WWW
SecPCP21    describe at basic level PC security
NewITP22    describe new info technologies pert. to PH
DstLP23     name technologies for delivering distance learning
MonP24      monitor informatics and info sys developments
efforts pert. to PH
ISmptP25    identify major info system development likely to impact PH
ScanP26     regularly scan literature for developments in IT pert. to
PH


>>>NODETYPE TASK>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

joblevel
            1    Front line Staff
            2    Senior Level staff
            3    Supervisory and mgmt staff
            4    Clerical/support

If job level = 1 then code
job level 4 = 1
job level 3 = 0
job level 2 = 0
job level 1 = 1

If job level = 2 then code
job level 4 = 1
job level 3 = 1
job level 2 = 1
job level 1 = 1
```

`

If job level = 3 then code
job level 4 = 1
job level 3 = 1
job level 2 = 0
job level 1 = 1

If job level = 4 then code
job level 4 = 1
job level 3 = 0
job level 2 = 0
job level 1 = 0

Skill Relevance 0 not relevant or somewhat relevant
1 relevant or highly relevant

EvlP01 evaluate data integrity

IntP02 interpret data on risks and benefits

CollP03 collect & summarize info

MedP04 Use media and technology to communicate

PreP05 present info for professional and lay audience
ImpP06 Implement public health assessment
RetP07 Retrieve & evaluate scientific evidence
UtiP08 Utilize technology tools to locate info
UseP09 Use browser software
OnlneP10 Use online search engines
IdPubP11 identify specialized search engines eg PubMed
DtaP12 assess validity of data retrieved online
ITprP13 use IT to promote PH
DsgP14 design website
ITP15 Use IT to broadcast health info to various audiences
IdsP16 Identify info sources
FinP17 find data online
ComP18 combine and use data from multiple sources
NetP19 describe fundamentals of a computer network
WWWP20 describe at a basic level the internet & WWW
SecPCP21 describe at basic level PC security
NewITP22 describe new info technologies pert. to PH
DstLP23 name technologies for delivering distance learning
MonP24 monitor informatics and info systems development efforts pert. to PH
ISmptP25 identify major info system development likely to impact PH
ScanP26 regularly scan literature for developments in IT pert. to PH

Individual's self identified job functions (0-No;1-Yes)
AnimalCtrl animal control
Bioter bioterrorism
CommDevt community development
CommDisInv communicable diseases investigator
Counselor counselor
DentOral dental services
Dietician dietician
Educator educator
Environ environmental

`

Epidem	epidemiologist
FoodInsp	food inspector
HlthAdmPDir	health admin program director
HlthAdminreg	health admin regional
HealthEd/Prom	health education
HealthOff	health officer
Healthsafety	health safety
Lab tech	lab technician
Nurse	nurse
NursDir	nursing director
Nursepract	nurse practitioner
Pestctrl	pest control
Physician	physician
Rel	public relations
ResearchSci	research scientist
Sanitationeng	sanitation engineer
SocialWrkr	social worker
Other	_____
usepcwork	use PC at work

Individual's JOB TITLE (0-No;1-Yes)

AA	administrative assistant
AC	account clerk
ACOMjob	assistant commissioner
AD	assistant director
Aide	case manager aide
AS	associate public health sanitarian
BS	biostatistician
CMIjob	chief medical investigator
CMXjob	chief medical examiner
COMjob	commissioner
D	director
EC	education coordinator
ELT	environmental lab technical
EN	public health engineer
ENT	public health engineering technician
EPIjob	epidemiologist
ERSjob	emergency response staff
GISjob	GIS technician
HHA	home health aide
LPN	licensed practical nurse
MT	medical technologist
NUjob	public health nutritionist
OA	office assistant
PA	program assistant
PAC	principal account clerk
PC	program coordinator
PHA	public health advisor
PHN	public health nurse
PHYSjob	physician
R	receptionist
RA	clinical research assistant
RN	registered nurse
RS	radiological specilist
RW	Ryan White coordinator
S	sanitarian

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Sec               secretary
SENjob            supervising public health engineer
SOA               supervising office assistant
SPHN              supervising public health nurse
SrAjob            senior accountant
SrECjob           senior education coordinator
SrENjob           Senior public health engineer
SrOA              senior office assistant
SrPA              senior program assistant
SrPHA             senior public health advisor
SrS               senior sanitarian

Communication w/ outside organizations (0-No;1-Yes)
NATIONAL
NORG1 American Cancer Society
NORG2 American Heart Association
NORG3 American Lyme Disease Foundation
NORG4 American Red Cross
NORG5 CDC
NORG6 HRSA
NORG7 GlaxoSmithKline
NORG8 NACCHO
NORG9 United Way

STATE
SOrg1       Child Abuse Prevention Center
SOrg2       Cooperative Extension
SOrg3       Health Research, Inc.
SOrg4       Mental Health Association
SOrg5       S – Office of Mental Retardation
SOrg6       S Troopers
SOrg7       SACHO
SOrg8       SDEC
SOrg9       SDOH – fiscal
SOrg10      SDOH – Local Health Division
SOrg11      SDOH – MARO
SOrg12      SDOH AIDS Institute
SOrg13      SDOH Arthropod-Borne Disease Program
SOrg14      SDOH Bureau of Communicable Diseases
SOrg15      SDOH Bureau of Community Sanitation
SOrg16      SDOH Bureau of Radiation Protection
SOrg17      SDOH Bureau of STD Control
SOrg18      SDOH Bureau of Tuberculosis Control
SOrg19      SDOH Bureau of Water Supply Protection
SOrg20      SDOH Division of Chronic Disease Prevention
SOrg21      SDOH Division of Family Health
SOrg22      SDOH Immunization Program
SOrg23      SDOH Office of Children and Family Services
SOrg24      SPARCS
SOrg25      State University
SOrg26      State University Library
SOrg27      Community Alert Network, Inc

COUNTY
DOrg1       County Dept. of Mental Hygiene
DOrg2       County Dept. of Social Services
DOrg3       Community College
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DOrg4       County Board of Health
DOrg5       County Comptroller
DOrg6       County Council on Alcoholism
DOrg7       County Dept. of Central Services
DOrg8       County Dept. of Personnel
DOrg9       County Dept. of Planning
DOrg10      County Dept. of Probation
DOrg11      County Dept. of Public Works
DOrg12      County Dept. of Risk Management
DOrg13      County District Attorney Office
DOrg14      County Executive Office
DOrg15      County Legislature
DOrg16      County Medical Society
DOrg17      County OCIS
DOrg18      County Office for the Aging
DOrg19      County Sheriff
DOrg20      County Youth Bureau
DOrg21      Emergency Medical Services
DOrg22      Family Partnership Center
DOrg23      Family Services, Inc.
DOrg24      Smokefree Dutchess Coalition

LOCAL
LOrg1       Ambulance
LOrg2       Health Resource Center
LOrg3       Byrnes Message Bureau
LOrg4       Children's Medical Group
LOrg5       Churches
LOrg6       River HealthCare, Inc.
LOrg7       Valley Pharmaceutical Society
LOrg8       Institute of Eco System Studies
LOrg9       College
LOrg10      College Library
LOrg11      Family Health Institute
LOrg12      Interpreter Services
LOrg13      Library System
LOrg14      Normet
LOrg15      NYMC
LOrg16      NYMC Library
LOrg17      Other local Health Departments
LOrg18      Newspaper or other media
LOrg19      Schools
LOrg20      Hospital
LOrg21      Hospital Medical Library
LOrg22      Medical Center
LOrg23      Medical Center Library
LOrg24      College
LOrg25      College Library


>>>NODETYPE RESOURCE>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

Category of information needed on regular basis
            0 seldom or never
            1 daily, weekly or monthly

dirinfor    directory/contact info
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grantsinfo	grants information/proposal requests
dtacityr	health data statistics city/local level
dtacountyr	health data statistics county level
dtastater	health data statistics state level
dtanationr	health data statistics national level
dtalegr	legislative data
mgtinfor	management information
modelr	model program/inervention information
publitr	published medical literature
intlcommr	internal commo (memos, etc)
intldocsr	internal documents, reports, etc
pcinfor	info about your computer
v2r	other information
pers	personal contacts
conf	conferences, meetings
intlmem	internal memos, manuals, documents
massmda	mass media
books	personal or department
jnls	personal or department
libs	libraries
statfed	state/fed reports
teledir	telephone directories
v4	other print resources 1
v5	other print resources 2
intldb	internal databases
ahrq	agency for healthcare research and quality website
cdcwond	cdc wonder website
censusbur	census bureau website
cdcontrol	center for disease control website
epa	environmental protection agency website
fda	food and drug administration website
medline	medline online
han	health alerlt network
hin	health information network
hpn	health provider network
nchs	national center for health statistics
nih	national institutes of health
nysdoh	nys dept of health
osha	occupational safety and health administration website
otherdb	other database
internet	internet search
email	email
maillist	mailing listserves
elbullbd	e-bulletin boards
v7	other electronic resource 1
v8	other electronic resource 2

Program resources by assignment (0-No;1-Yes)

c	commisioner's office
phi	public health information office
hpe	health planning and education
afd	adminstration and fiscal division
ewl	environmental water lab
ehs	environmental health services
eo	engineering office
ceh	core environmental health servuces
ome	office of medical examiner

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phncps      public health nursing and clinical preventive services
cdc         communicable disease control
csr         clinical services and research
cl          clinical lab
csn         children w/ special needs unit
phnd        public health nursing division
phs         preventive health services
imm         immunizations
fhs         family health services
hhu         home health unit

Persons outside work with whom discuss work issues
Q4-1              0     not 1 person indicated
                  1     at least 1 person indicated
Q4-2              0     not 2 persons indicated
                  1     at least 2 persons indicated
Q4-3              0     not 3 persons indicated
                  1     at least 3 persons indicated
Q4-4              0     not 4 persons indicated
                  1     at least 4 persons indicated
Q4-5              0     not 5 persons indicated
                  1     at least 5 persons indicated


>>>ATTRIBUTE DATA >>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>

NAME        text        Last name, first name

Seq#        number            individual's numerical sequence as listed
on paper survey (this can be deleted after data entry)

Title             text        official job title

ID          text        network identifier (initials of title and # if
more than one person holds the title)

ProgName    text        title of program or office

ProgCode#   number            code for program or office
                        1     Commissioner's office
                        2     Public Health Information Office
                        3     Health Planning and Education
                        4     Administration and Fiscal
                        5     Environmental Water Laboratory
                        6     Environmental Health Services
                        7     Engineering
                        8     Core Environmental Health
                        9     Medical Examiner
                        10    Public Health Nursing and Clinical
Services
                        11    Communicable Disease Control
                        12    Clinical Services and Research
                        13    Clinical Laboratory
                        14    Children with Special Needs
                        15    Public Health Nursing Division
                        16    Preventive Health Services
                        17    Immunizations
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                        18    Family Health Services
                        19    Home Care Unit
SiteCode    text        abbreviation of work site
                        POK   ------
                        BEA   ------
                        MIL   ------
Site#       number            code for work site
                        1     ------
                        2     ------
                        3     ------

NYMC ID#    number      8 digit anonymous code each individual used on
NYMC survey (for data linking)
JOBLEVEL        number        self identified job level from NYMC
survey
                        0    Missing data
                        1    Front line Staff
                        2    Senior Level staff
                        3    Supervisory and mgmt staff
                        4    Clerical/support

lvledu            number            level of education
                        0    missing data
                        1    Less than high school
                        2    High school or eqv
                        3    Associate or 2 year degree
                        4    Bachelor's degree
                        5    Master's degree
                        6    Doctorate (MD, Phd, EdD))

gender            number            Male
                        1 = male
                        0 = not male
                                  Female
                        1 = female
                        0 = not female

ExpPHhlth         number            experience in PH
                        1    Less than 1 year
                        2    1-5 yrs
                        3    6-10 yrs
                        4    11-15 yrs
                        5    16-20 yrs
                        6    Over 21 yrs)

lvlcexp           number            level of expertise as a computer
user
                        0    Missing data
                        0    Beginner
                        1    Intermediate
                        1    Advanced
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