Using Modeling and Simulation to Improve Oral Health Services Delivery in Hampton Roads, Virginia

Mohammad J. Alzahrani
Old Dominion University

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USING MODELING AND SIMULATION TO IMPROVE

ORAL HEALTH SERVICES DELIVERY

IN HAMPTON ROADS, VIRGINIA

by

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A Dissertation Submitted to the Faculty of
Old Dominion University in Partial Fulfillment of the
Requirement for the Degree of

DOCTORAL OF PHILOSOPHY

HEALTH SERVICES RESEARCH

OLD DOMINION UNIVERSITY
August 2011

Approved by:

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ABSTRACT

USING MODELING AND SIMULATION TO IMPROVE ORAL HEALTH SERVICES DELIVERY IN HAMPTON ROADS, VIRGINIA

Mohammad J. Alzahrani
Old Dominion University, 2011
Director: Dr. Holly Gaff

The purpose of this study is to examine the system performance in delivering oral health services in a public health district based on the Conceptual Framework to Measure Performance of the Public Health System (PHS). Using modeling and simulation, a predictive model based on the conceptual framework dimensions: mission, structural capacity, processes, and outcomes was developed to predict the performance of public health district in delivering oral health services.

This is a retrospective longitudinal study. The main objective of this study is to use a modeling and simulation approach to predict the performance of public health district dental clinic in delivering oral health services. Specifically, the following performance metrics were examined: average number of patients' visits per day at a public health district dental clinic; average number of diagnostic and preventive dental services delivered by the dentist or the dental hygienist per day at a public health district dental clinic; average number of corrective services provided by the dentist per day at a public health district dental clinic; and average total dental services. The scenarios, based on the existing structural capacities and the number of personnel, were modeled and simulated using Rockwell Automation Software, Arena® version 13.5.
Purposeful sampling consisted of five public health district dental clinics of Hampton Roads for the fiscal years, 2005-2010. For the purpose of this study the following five public health district dental clinics were chosen: Norfolk, Virginia Beach, Hampton, Peninsula, and Western Tidewater. Norfolk Health District operates two sites: Little Creek and Park Place. Virginia Beach District operates two sites: Birdneck and Pembroke. Western Tidewater Health District operates two sites: Isle of Wight and Southampton.

Data analysis revealed that adding a new healthcare provider (a dental hygienist) to the system has a statistically significant influence in delivering oral health services at all public health districts' dental clinics in the following performance metrics: number of patients' visits per day, diagnosis and preventive services, corrective services, and total number of dental services (p < 0.05).
This dissertation is dedicated to my parents and family.
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CHAPTER I

INTRODUCTION

This dissertation is a retrospective longitudinal study to examine the system performance in delivering oral health services in a public health setting based on the Conceptual Framework to Measure Performance of the Public Health System (PHS). This first chapter of this dissertation presents the problem statement, purpose of the study, an overview of modeling and simulation, modeling and simulation in health care discipline, the significance of the study, definitions of terms, research questions, and hypotheses. The chapter concludes by describing the theoretical framework.

Problem Statement

This research seeks to address issues that affect the delivery of oral health care in the public dental health settings. The results of this study will determine what variables in the dental practice setting influence oral health care delivery and to what extent. Results of this study will contribute to the knowledge gap among oral health providers regarding the significance of modeling and simulation techniques in improving oral health care delivery.

Oral diseases, such as dental caries and periodontal diseases, are infectious diseases and become difficult to manage and treat when they advance to severe stages (Centers for Disease Control and Prevention, 2007). In its early stages, oral cancer may go unnoticed because it is usually painless and, frequently, does not demonstrate physical changes that are obvious to many individuals.
Oral health experts agree that most oral diseases can be prevented and treated with low-cost procedures and less traumatic intervention if diagnosed and treated in their early stages (Gilbert et al., 2002; Milgrom et al., 1998). The consequences of untreated oral diseases can lead to pain, tooth loss and increased expenses (Centers for Disease Control and Prevention, 2007). Preventive oral health services include many procedures such as regular oral and dental checkup, scaling and root debridement, dental sealants, fluoride therapy, and regular periodontal maintenance treatment.

Untreated oral diseases may impact an individual’s self-esteem and total overall health. Advanced stages of oral infections have been indirectly linked with some diseases such as cardiovascular diseases, negative pregnancy outcomes (low birth-weight, premature births) and diabetes (Genco, Offenbacher, & Beck, 2002; Grossi & Genco, 1998; Kardeşler, Buduneli, Cetinkalp, & Kinane, 2010; Soskolne & Klinger, 2001).

While oral cancer receives less attention than other forms of cancer, it remains an important health problem with substantial costs to society. Late stage diagnosis is occurring because there is a lack of public awareness coupled with the lack of a screening protocol established in the public dental setting. There are relatively few studies about the cost of oral cancer in general, or the costs and cost-effectiveness of various treatment modalities. More emphasis on economic data is clearly warranted in this time of mounting concerns over healthcare costs..

Approximately 35,000 Americans are diagnosed each year with oral cancer, and early detection, usually during a regular dental check-up at general practices, is critical to successful treatment of this disease. If a premalignant lesion is detected and treated, the lesion may not progress to a malignant state. Early detection of premalignant (stage 0-
IV) lesions is the principal determining factor outlining prognosis, treatment, and cost induced for the individual diagnosed with oral cancer. When found early, oral cancers have an 80-90% survival rate (La Vecchia et al., 1997; Patton, Epstein, & Kerr, 2008; Sciubba, 2001). Unfortunately, the death rate associated with oral cancer is about 45% at five years from diagnosis because it is routinely discovered in a late stage (IV) (La Vecchia, et al., 1997; Sciubba, 2001). Often it is diagnosed when the cancer has metastasized to another location (stage IV), usually to the lymph nodes of the neck (Greene F.L. et al., 2010). Prognosis at this stage of discovery is significantly worse than when it is caught in a localized intra-oral area due to the lymph system acting as a vehicle to aid in the metastasis mission of the cancer cells (Greene F.L., et al., 2010; Sciubba, 2001).

There are relatively few studies describing the cost of oral cancer in general, or of the costs and cost-effectiveness of various patient treatment options. The estimated means of the cost of surgical treatment of oral cancer, external beam radiation therapy, and external beam radiation therapy with brachytherapy were $30,476, $22,906, and $19,502, respectively. The approximate societal cost of head and neck cancer is $2 billion in the U.S. compared to $1.3 million in Germany. Furthermore, the estimated mean of the cost of head and neck cancer care per-patient is $25,936 in the U.S. compared to $9,398 for Greek oral cancer patients (Hunink M.G. et al., 2001).

More than 91% of adults (20 years or older) have experienced coronal caries. Approximately 23% of this population has untreated dental caries. More than 18% of the population has root caries. Furthermore, more than 90% of adults over 60 years have experienced dental caries. One forth of adults over the age of 60 has lost all of their teeth.
as a result of having tooth decay. Severe periodontal diseases affect 5 to 15% of adults in the United States (Centers for Disease Control and Prevention, 2007).

According to the U.S. Census Bureau report released in September 2010, the number of people who have no insurance has increased from 46.3 million, 15.4% of the population, in 2008 to 50.7 million, 16.7% of the population, in 2010. In 2009, more than 10% of children (7.5 million) who are under 18 years old have no health insurance (US Census Bureau, 2010). Research reports that there are more than 45% of Americans (108 million) who have no dental insurance (National Health Interview Survey, 1995).

In 2000, the Surgeon General recognized that national oral health care needs more attention. According to this report, the lack of access to oral health care was identified and recognized by different legislative parties such as lawmakers, professional organizations, interest groups and public health departments as a big concern (Surgeon General Report, 2000).

Modeling and simulation will enable the author to modify the changeable variables, such as adding a new oral health provider (dental hygienists) without impacting the quality of care. In addition, using modeling and simulation methodology will enable public health districts dental clinics to serve their clients effectively and efficiently with the best use of information, and organizational, physical, human and fiscal resources, without compromising the quality of care.

Purpose of the Study

The purpose of this study is to examine the system performance in delivering oral health services in a public health district based on the Conceptual Framework to Measure
Performance of the Public Health System (PHS). Using modeling and simulation, a predictive model based on the conceptual framework dimensions: mission, structural capacity, processes, and outcomes was developed to predict the performance of a public health district in delivering oral health services.

Modeling and Simulation

Simulation is an applied methodology that can describe the behavior of a system using either a mathematical model or a symbolic model (Fishwick, 1995). Also, simulation can be defined as the imitation of the operation of a real-world process or system over a period of time (Banks, 1998). Modeling and simulation are the overall processes of developing a model and then simulating that model to gather data concerning performance of a system (Sokolowski & Banks, 2010).

Modeling and simulation can be applied through multiple cyclic phases. These phases are: developing computer simulation based on a real model or theoretical system, coding phase, executing the model through the simulation process, and analyzing the output and obtaining insights. Each phase depends on a different set of supporting technologies. The figure below illustrates these phases (Sokolowski & Banks, 2010).
Modeling and Simulation in Healthcare

Many healthcare providers are adapting new technologies to enhance their ability to serve their clients with the best use of resources and time. Modeling and simulation methodology has been used in different healthcare settings such as hospital management, emergency departments, surgery rooms, pediatric clinics and public and private dental practices. Modeling and simulation is an ideal approach when investigating different systems with many options. Simulation requires minimal cost and personnel training and limited risk to clients (Barnes, Quiason, Benson, & McGuiness, 1997). Specifically, modeling and simulation has been used to improve patients’ waiting time in emergency departments (Kolker, 2008).

Modeling and simulation has been used in different educational institutions such as medical schools, dental schools, nursing schools and applied health sciences schools.
Operations research principles such as queuing theory and process model simulation have been applied in the modeling and simulation field to study patient flow (Kolker, 2008).

Modeling and simulation is a new approach to be used in public oral health services settings. Researchers at Old Dominion University used modeling and simulation to develop a dental clinic layout using design of experiment (D.O.E) statistical analysis method to create the required data which is based on different parameters such as number of hygienists, number of x-ray units, and reception room capacity. Six-sigma methodology and Process Model™ software were used to simulate the dental clinic design. The authors also used utility function to compare cost based design with performance-based design. In addition, the researchers used multi-criteria analysis when they included the cost in their model. This study was a thesis study which mainly depended on theoretical data(Ghate, 2008).

**Significance of the Study**

This study is the first to use M&S to examine PHS performance to deliver oral health services in public health settings. Many dental practice’s productions are complicated combinations of parameters such as information, organizational, physical, human and fiscal resources. Using simulation would be the reasonable approach when the system under investigation produces outcomes that are complicated, stochastic (involving probability), and dynamic. Non-linear production makes simulation models an appropriate methodology to study and improve the delivery of oral healthcare service outcomes in the public health setting. Using modeling and simulation is less expensive than conducting research with many different variables.
Using modeling and simulation with a well-structured model will provide reliable data, an accurate process outline, and decrease the gap between modeling simulation and process application (ElHaik & AlAomar, 2006).

Healthcare administrators are concentrating on identifying the areas where the healthcare delivery system needs the most appropriate approach to address the problem of delivering oral healthcare and to meet the need of uninsured individuals (Virginia Interface Center for Public Policy, 2007).

As the public, policymakers, and healthcare providers consider oral health to be less important than other health needs, barriers continue to exist. Oral diseases are still prevalent, and there are fewer dentists graduating from dental school to provide essential oral healthcare services compared to the increased number of population (Bentley, 2007). Most oral diseases have no symptoms until reaching advanced stages. Therefore, many individuals may not use oral health care services until they suffer pain. The Centers for Disease Control and Prevention (CDC) state that a large percentage of Americans suffer from untreated oral diseases such as dental caries, periodontal diseases and oral cancer. This segment of the population can be characterized as low socioeconomic status (SES), uninsured and underinsured individuals, certain ethnicities and individuals with low educational level. Oral health experts agree that most oral diseases can be prevented and treated with less traumatic intervention if diagnosed and treated in their early stages (Gilbert, et al., 2002; Milgrom, et al., 1998).

As long as public policymakers and medical providers less appreciate oral health services, barriers will continue to exist to prevent many patients from receiving essential oral health services. Additionally, there are still many factors limiting some patients
from receiving essential oral healthcare such as transportation costs and accessibility, low
dental insurance reimbursement to providers, lack of dental insurance, low
socioeconomic status, and low level of education and knowledge about how oral health
may affect whole body health (Manski & Magder, 1998).

The American Dental Association emphasizes that everyone in the United States
should have comprehensive oral healthcare since there is a strong relationship between
oral health and general health. The ADA reports that the uninsured population is
increasing which makes access to oral healthcare more critical to those who have no
dental insurances (American Dental Association, 2009). There are many factors that
might predict utilization of oral health services such as access to oral health care, levels
of knowledge about oral health, ethnicity/race, age, and socioeconomic status (SES)

The greatest benefit potential of this study will be to institutions of community
health, public health educators, the public and community at large and future patients
seeking oral healthcare at public health settings. The dissemination of the results of this
study through publications and professional presentations will allow academic
institutions and public health educators to evaluate public health setting procedures and
criteria and possibility identify those criteria most likely to optimize oral healthcare
service's delivery.
Definitions of Terms

The following terms were defined for the purpose of this study:

1. **Structural capacities**: are the cumulative resources necessary to enable the public health services system to function properly to deliver oral health services such as information, organizational, physical, human, and fiscal resources. Specifically, this study is focusing on human and physical resources.

2. **Processes**: are the collective services (i.e. assessment, diagnosis, planning, implementing, evaluation, and documentation) that identify, and address oral health problems for indigent preschool and school aged children. In more details, these processes may include: oral examination and treatment plan, x-rays, medical and dental history, restorative dentistry, dental sealant, endodontic, space maintenance, scaling, prophylaxis and oral hygiene instructions and a topical fluoride treatment (Norfolk Department of Public Health).

3. **Oral Health Services Outcomes**: are defined as the performance metrics for delivering oral health care services at a public health district's dental clinic. For the purpose of this study, these metrics include the following: the average number of clinical hours worked per month of the dentist in delivering oral health care services (i.e. diagnosis, preventive, corrective) at a public health district dental clinic; the average number of patients' visits per day at a public health district dental clinic; the average number of diagnostic and preventive dental services delivered by the dentist or the dental hygienist each day at a public health district dental clinic and the average number of corrective services provided by the dentist each day at a public health district dental clinic.
4. **Corrective services**: according to the Virginia Department of Health (VDH) performance metrics, corrective services include restorative, endodontic, periodontic, removable prosthodontic, fixed prosthodontic, oral surgery, and orthodontic services performed by a dentist.

5. **Diagnostic and Preventive services**: include many procedures such as oral examination and treatment plan, intra and extra-oral radiographs, medical and dental history, regular oral and dental checkup, prophylaxis, scaling, dental sealants, topical fluoride treatment, and oral hygiene instructions

**Research Questions**

The purpose of this study was to use modeling and simulation to develop a predictive model based on the conceptual framework dimensions to predict the performance of public health districts in delivering oral health services. Modeling and simulation is an ideal approach when investigating different systems with many options. Simulation requires minimal cost and personnel training and presents limited risk to patients (Barnes, et al., 1997). The study uses 6-year longitudinal data obtained from VDH for the five health districts under investigation to answer the research questions. The following specific research questions will be answered for each of the five health districts:

1. To what extent do the public health system conceptual framework dimensions (mission, structural capacity, processes, and outcomes) explain the variance among the five health districts' performance in delivering oral health services over a six-year period?
2. To what extent does employing a dental hygienist affect oral health services delivery at a public health district dental clinic? The following specific oral health services’ outcomes will be investigated:

a. the average number of patient visits per day at a public health district dental clinic.

b. the average number of diagnostic and preventive dental services delivered by the dentist or the dental hygienist per day at a public health district dental clinic.

c. the average number of corrective services provided by the dentist per day at a public health district dental clinic.

d. the average number of total services provided by the dentist per day at a public health district dental clinic.

**Hypotheses**

The following hypotheses will be evaluated for all sites of the five public health district dental clinics under investigation and will be tested at the 0.05 level of significance.

**Hypothesis One**

The public health system conceptual framework dimensions: mission, structural capacity, processes, and outcomes have no effect in explaining the variance among the five health districts’ performance in delivering oral health services over a six-year period.

**Hypothesis Two**

Employing a dental hygienist has no effect on oral health services’ delivery at a public health district dental clinic.
2.a. $H_0$: There will be no difference between a public health district dental clinic which employs a dental hygienist compared to a public health district dental clinic with no dental hygienist in the average number of patients' visits per day.

$H_A$: The average number of patients' visits per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist.

2. b. $H_0$: There will be no difference between a public health district dental clinic which employs a dental hygienist compared to a public health district dental clinic with no dental hygienist in the average number of diagnostic and preventive services delivered per day.

$H_A$: The average number of diagnostic and preventive services delivered per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist.

2.c. $H_0$: There will be no difference between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist in the average number of corrective services provided by the dentist per day.

$H_A$: The corrective services provided by the dentist per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist.
2.d. \( H_0 \): There will be no difference between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist in the average number of total dental services per day.

\( H_A \): The average number of total dental services per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist.
Theoretical Foundation

Handler (2001) stated “to provide a science base for the study of public health system performance, it is necessary to articulate a conceptual framework that explicates the various components of the public health system and the relationships between them” (Handler, Issel, & Turnock, 2001). The conceptual framework used in this study was developed based on the work of Donabedian, (1980) and Handler, et al., (2001). This conceptual framework links the mission, structural capacity, processes, and outcomes of the public health system.

This model was used to measure public health system performance and the extent to which the organization achieves its mission. In the public health system, there should be an interaction and feedback loops between these components. This framework can be used at multiple levels to measure public health system performance. It can be applied at the national public health system, state public health system and local or community public health systems (Handler, et al., 2001) (Figure 2).
Figure 2: Public Health System Performance Conceptual Framework.

Note: adapted from Handler et al., 2001.
CHAPTER II

REVIEW OF THE LITERATURE

This chapter reviews studies of public health services, oral health care services, and oral diseases such as epidemiology of dental caries, epidemiology of periodontal diseases, and epidemiology of oral cancer. Furthermore, literature related to preventive dental hygiene services, dental insurance, and using modeling and simulation in health care were reviewed.

Public Health Services

Mays et al. (2009) stated that studying the dimensions of the public health systems such as structure, processes, and impact (outcome) may prove that delivering health services to the public can be improved. This group of researchers emphasized that continued research on public health delivery systems may address the need for evidence of the importance of improving and assuring the quality of investigation on public health delivery systems. They conducted a review study to examine published studies on topics related to public health systems between 1990 and 2007. They studied public health organization structure, financing, staffing, and service delivering. They found that most public health systems are significantly different in their organizational, financial, and personnel characteristics which have impacted the effectiveness and efficiency of public health service's delivery. Specifically, they found that financial resources and staffing are the most vital factors influencing service delivery and outcomes. In their study, they focused on organizational structural characteristics. Organizational structure consists of system boundaries and size, organizational and inter-organizational structures, financing,
and workforce characteristics. Their findings indicated that there are huge gaps and uncertainties in the mechanisms through which public health systems deliver health services to the public. They recommended conducting further research to evaluate the rapid changes occurring in delivery system structure and staffing (Mays et al., 2009).

According to Donabedian's framework, public health systems consist of three main dimensions: structure, process, and outcome. Originally, this framework was developed to study medical care delivery systems (Donabedian, 1980).

In order to determine whether the public health system accomplishes its mission, it is necessary to measure each dimension of the system and its relationship with others. Public health system should operate and interact with other dimension to lead to desired outcomes. Feedback loops should exist between all different dimensions (Handler, et al., 2001).

In this study, the following dimensions were studied: structural capacities, processes, and outcomes. These dimensions were based on the Framework to Measure Performance of the Public Health System. Public health mission and purpose includes the system philosophy, goals, and core functions. Structural capacity includes: information resources, organizational resources, physical resources, human resources, and fiscal resources (Handler, et al., 2001).

**Ten Essential Public Health Services**

According to Public Health Functions Steering Committee (1994), the ten essential public health services are: monitor health status to identify and solve community health problems; diagnose and investigate health problems and health hazards in the
community; inform, educate, and empower people about health issues; mobilize community partnerships and action to identify and solve health problems; develop policies and plans that support individual and community health efforts; enforce laws and regulations that protect health insurance and safety; link people to needed personal health services and assure the provision of health care when otherwise unavailable; assure a competent public and personal health care workforce; evaluate effectiveness, accessibility, and quality of personal and population-based health services; and research for new insights and innovative solutions to health problems. The three core public health functions and the ten essential public health services are illustrated in the following table and figure (Table 1), (Figure 3).

Table 1: Ten Essential Public Health Services.

<table>
<thead>
<tr>
<th>#</th>
<th>Service</th>
<th>#</th>
<th>Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Monitor health status to identify and solve community health problems.</td>
<td>6</td>
<td>Enforce laws and regulations that protect health insurance and safety.</td>
</tr>
<tr>
<td>2</td>
<td>Diagnose and investigate health problems and health hazards in the community.</td>
<td>7</td>
<td>Link people to needed personal health services and assure the provision of health care when otherwise unavailable.</td>
</tr>
<tr>
<td>3</td>
<td>Inform, educate, and empower people about health issues.</td>
<td>8</td>
<td>Assure a competent public and personal health care workforce</td>
</tr>
<tr>
<td>4</td>
<td>Mobilize community partnerships and action to identify and solve health problems.</td>
<td>9</td>
<td>Evaluate effectiveness, accessibility, and quality of personal and population-based health services.</td>
</tr>
<tr>
<td>5</td>
<td>Develop policies and plans that support individual and community health efforts.</td>
<td>10</td>
<td>Research for new insights and innovative solutions to health problems.</td>
</tr>
</tbody>
</table>

Note. Source: A consensus list developed by federal health agencies in partnership with major national public health organizations, adopted by the Public Health Functions Steering Committee, 1994.
Figure 3: The three core public health functions.


The Ten Essential Public Health Services in the Context of Oral Health Services

The following ten essential public health services and their activities are described in the context of the role of oral health services (American Association for Community Dental Programs, 2006).
Essential Public Health Service 1: Monitor health status to identify community health problems.

1. Obtain and share data that provides information on the community's oral health (e.g. prevalence of early childhood caries and dental caries, untreated caries, oral cancer rates).

2. Determine access to oral health care for the uninsured or underinsured, and determine community capacity to meet oral health needs.

3. Analyze data to identify trends and population oral health risks (e.g., poverty levels, undocumented immigrants, lack of water fluoridation, adverse pregnancy outcomes, cardiovascular disease).

4. Review national, regional, and state oral health data for comparison and planning purposes.

5. Conduct efforts or contribute oral health expertise to community health assessments to develop a comprehensive picture of the public's oral health (e.g., Title V needs assessment) and to educate.

6. Integrate oral health data with other health-assessment and data-collection efforts conducted by the public health system (e.g., Youth Risk Behavior Survey).

7. Develop relationships with oral health professionals and others in the community who have information on diseases and other conditions relevant to public health, and facilitate information exchanges (e.g., among Head Start programs, community health centers, schools, nursing homes, and hospital emergency units).

Essential Public Health Service 2: Diagnose and investigate identified health problems and health hazards in the community.
1. Identify oral health problems and environmental hazards to general health (e.g., improper fluoride levels, amalgam disposal).

2. Track trends and behaviors that identify emerging oral health problems (e.g., diabetes mellitus, obesity, lack of dental insurance, inadequate Medicaid/State Children's Health Insurance Program (SCHIP) coverage, insufficient number of oral health professional participating in Medicaid/SCHIP).

3. Participate in Local Public Health Association (LPHA) planning for emergency preparedness.

4. Identify and advocate for changes in social and economic conditions that adversely affect the public's oral health.

5. Maintain access to laboratory expertise and capacity to help monitor and report on community and environmental health status (e.g., water plant operations, private well monitoring).

**Essential Public Health Service 3: Inform, educate and empower people about health issues.**

1. Share oral health and related information with individuals, community groups, agencies, and the general public to improve understanding of the issues affecting public health (e.g., social, economic, educational, and environmental issues).

2. Provide information that is appropriate for the cultures and literacy levels of various audiences to help individuals understand the decisions they can make to promote their own oral health and the actions agencies can take to promote oral health.

3. Conduct health-promotion activities to improve the oral health status of the community (e.g., tobacco-cessation activities, oral-cancer-detection activities).
4. Mobilize the community to advocate for policies and activities that will improve the public’s oral health (e.g., community water fluoridation policies).

5. Work with the media to convey information of oral health significance (e.g., relationship between diet and oral health).

**Essential Public Health Service 4: Mobilize community partnerships to identify and solve health problems.**

1. Contribute oral health expertise to a comprehensive planning process that engages the community in identifying, prioritizing, and solving their public health problems and establishing oral-health-related goals.

2. Support and/or implement strategies that address identified oral health problems through the development and maintenance of partnerships of public and private organizations, government agencies, businesses, schools, and the media.

3. Develop partnerships to generate interest in and support for improved community oral health status.

4. Identify potential advocates and organizations that represent populations effected by oral health problems and disparities (e.g., Head Start participants, individuals with developmental disabilities, families who are homeless, senior citizens).

5. Develop advocates (i.e., “champions”) to support the development of community oral health programs.

**Essential Public Health Service 5: Develop policies and plans that support individual and community health efforts.**

1. Serve as a primary oral health resource to guide federal, state, and local elected and appointed officials to establish and maintain sound public health and oral health policies,
practices, and capacity (e.g., fluoridation, oral services in Medicaid/Medicare, state dental practice acts, MCH block grant, tobacco policy, comprehensive school health programs, oral health services for high-risk populations).

2. Provide oral health expertise to policy development efforts to improve physical, social, and environmental conditions in the community that adversely affect public health (e.g., school A Model Framework for Community Oral Health Programs 4 lunch programs/beverage contracts, long-term care and correctional facilities, tobacco-free public places).

3. Engage in LPHA strategic planning to develop a vision, mission, and guiding principles for the agency that is responsive to the community’s oral health needs.

4. Develop community oral health vision and mission statements and guiding principles that reflect the community’s oral health needs.

**Essential Public Health Service 6: Enforce laws and regulations that protect health and ensure safety.**

1. Monitor laws, ordinances, regulations, and policies that impact oral health, and take steps to ensure their enforcement to maintain or improve oral health in the community (e.g., Medicaid/Early and Periodic Screening, Diagnosis and Treatment requirements; Head Start program performance standards; nursing home oral examination requirements; fluoridation laws; blood-borne pathogen standards).

2. Educate policymakers on gaps in public health law, ordinances, regulations, and policies needed to protect the public’s oral health (e.g., adult Medicaid oral services).

3. Inform and educate individuals and organizations about the purpose, meaning, and benefit of public health laws, ordinances, regulations, and policies that impact oral health.
4. Determine whether modifying, repealing, or developing new laws, regulations, ordinances, or policies is needed to maintain or improve the community’s oral health, and take appropriate steps to effect change.

5. Monitor and respond to proposed legislation, regulation, ordinances, and policies that may impact community oral health.

**Essential Public Health Service 7: Link people to needed personal health services, and ensure the provision of health care when otherwise unavailable.**

1. Lead or join efforts to increase access to comprehensive culturally competent oral health care that includes health promotion, prevention, and treatment services.

2. Partner with the community to establish systems and programs to meet oral health treatment needs (e.g., for individuals with special health care needs, for families who are homeless).

3. Partner with the community to identify and establish systems and programs that include preventive services (e.g., school-based/linked dental sealant and fluoride programs, mouth guard programs, early-childhood-caries-prevention programs).

4. Link individuals to appropriate oral health services (e.g., using care coordination mechanisms, patient navigators).

**Essential Public Health Service 8: Ensure a competent public health and personal health care work force.**

1. Ensure appropriate presence of community oral health programs in the LPHA and state organizational structure and decision-making processes.

2. Apply appropriate public health competencies to the recruitment, training, and development of the community oral health director and work force.
3. Assess the dental public health competencies of community oral health program staff, and promote these competencies through training, continuing education, and leadership development activities.

4. Provide expertise in developing and implementing public health curricula through partnerships with academia (e.g., public health/dental/medical/allied health students.).

5. Provide educational experiences in community oral health for the future oral health work force.

6. Recruit, train, develop, and retain a diverse and culturally competent oral health work force.

7. Promote the use of effective oral health practices among all professionals and agencies engaged in public health interventions.

8. Promote the use of effective preventive services among oral health professionals and other health professionals in the community.

9. Provide the community oral health program work force with access to the training and resources needed to develop and maintain its competency.

10. Identify and provides strategies for addressing public- and private-sector shortages in the oral health care work force (e.g., dental health professional shortage area designations, utilization of National Health Service Corps, loan repayment mechanisms).

11. Identify and address barriers to the utilization of oral health services (e.g., transportation, financial, health literacy, language).

**Essential Public Health Service 9: Assess effectiveness, accessibility and quality of personal and population-based health services.**
1. Evaluate the effectiveness of strategies implemented through the comprehensive health planning process to achieve the identified goals for the community oral health program.

2. Evaluate the effectiveness and quality of all community oral health programs and activities against evidence-based criteria, and use the information to improve performance and outcomes (e.g., community oral health programs, community health centers).

3. Review the effectiveness of oral health interventions provided by other health professionals (e.g., physicians, nurses) and agencies (e.g., Head Start, maternal and child health, WIC).

**Essential Public Health Service 10: Research for new insights and innovative solutions to health problems.**

1. Use current data and research findings to develop evidence-based community oral health programs.

2. Collaborate with researchers to actively involve the community in oral health research.

3. Develop research activities in a collaborative fashion so as to provide mutual benefit to all parties.

4. Provide data and expertise to support research that benefits the community's oral health.

5. Involve the community in developing, conducting, and disseminating research.

6. Ensure confidentiality and safety for community members participating in research.

7. Contribute to the evidence base of community oral health programs and the identification of best practices by sharing results of research and program evaluations.
Oral Healthcare Services

In 2000, the Surgeon General acknowledged the national oral health care crisis. According to this report, the lack of access to oral health care was identified and acknowledged by lawmakers, professional organizations, advocacy groups, public health professionals, and concerned individuals.

Healthy People 2020 Oral Health and Health Communication Objectives states "(HP 2020) is to increase the proportion of children and adults who use the oral health care system each year" (U.S. Department of Health and Human Services, 2010).

Chronic oral diseases such as dental caries and periodontal diseases become difficult to manage, treat and afford if not diagnosed and treated early. The consequences of untreated oral diseases can lead to pain, tooth loss and undefeatable expenses (Centers for Disease Control and Prevention, 2007). Virginia leads the nation in its provision of free clinics and community-based healthcare centers that provide low cost services, with 53 free clinics operating a total of 67 sites and 73 community centers statewide (Virginia Interface Center for Public Policy, 2007). In addition, there are 35 public health districts in Virginia administered by Virginia Department of Public Health (Virginia Department of Health, 2010).

Furthermore, Virginia ranks 11th nationally when total dentists are counted to be 4,395, compared to the US weighted average of 3,420 (Virginia Interface Center for Public Policy, 2007). Therefore, there is room for health services researchers to participate in improving Virginia’s oral healthcare delivery system to be one of the most effective and efficient system. According to the National Conference of State
Legislatures (2008), still serious disparities exist in the delivery of oral health care across the country, especially for low-income populations.

**Oral Diseases**

There are relatively few studies of the cost of the consequences of untreated oral diseases in general, or of the costs and effectiveness of various dental treatment outcomes. In this time of increased concerns over healthcare costs, more emphasis on effective and efficient delivery of health care is clearly warranted. Modeling and simulation was used in this study as an analytic method for decision makers to maximize the health benefits, best use existing resources, and to minimize the consequences of untreated oral diseases to the population.

This research will narrow the profound gap that exists in investigating the performance of public health departments in delivering oral health services. Further, by addressing this issue, this study will contribute to the scientific knowledge among public health providers regarding the importance of oral healthcare delivery leading to an improved quality of life among Americans.

According to the Surgeon General (2000), untreated infectious oral diseases have indirect link to some systematic diseases such as cardiovascular diseases and stroke, premature low-weight infants and diabetes. Dental caries is a serious problem for many uninsured individuals, especially with an increasing number of older adults who have retained most of their permanent teeth (Surgeon General Report, 2000).
Epidemiology of Dental Caries

More than 91% of adults have experienced coronal caries. Approximately 23% of this population still has untreated dental caries. More than 18% of the population has the less common dental caries (root caries). Furthermore, more than 90% of adults over 60 years have experienced dental caries. One forth of adults over the age of 60 has lost all of their teeth as a result of having tooth decay. Severe periodontal diseases affect 5 to 15% of adults in the United States (Centers for Disease Control and Prevention, 2007).

Epidemiology of Periodontal Diseases

Periodontal disease refers to a number of inflammatory diseases affecting the periodontium, that is the tissues that surround and support the teeth. Periodontal disease can affect one tooth or many teeth. Disease begins when the bacteria in dental plaque (the sticky, colorless film that constantly forms on teeth) causes the gums to become inflamed (American Academy of Periodontology, 2009). Periodontal diseases are classified according to the severity of the disease. The two major stages are gingivitis and periodontitis. Gingivitis is a milder and reversible form of periodontal disease that only affects the gums. Gingivitis may lead to more serious, destructive forms of periodontal disease called periodontitis which affects the supporting bone (American Dental Association, 2009).

According to Surgeon General 2000, an estimated 80% of American adults currently have some form of the periodontal disease. Furthermore, approximately 23% of 65 to 74-year-olds have severe periodontal disease. In general, men are more prone than women to have more severe disease. It has been documented that at all ages people at the
lowest socio-economic status (SES) have more severe periodontal disease (Surgeon General Report, 2000).

It is very difficult to find out the exact expenditure related to periodontal diseases treatment. According to ADA, $27.5 billion, (6.4% of the total health bill) was spent on dental care in the United States (ADA, 1987). Of that amount, approximately 1%, or $275 million, was spent directly to treat periodontal disease. Another large proportion was spent on prevention via routine prophylaxis and on prosthetic replacement of teeth lost due to the periodontal disease. If the estimated 25 million Americans with periodontal disease who receive no treatment were to be treated, the estimated cost would be over $7 billion for periodontal treatment alone (Antczak-Bouckoms & Weinstein, 1987).

**Epidemiology of Oral Cancer**

In its early stages, oral cancer may go unnoticed because it is usually painless and frequently does not demonstrate physical changes that are obvious to many individuals. Approximately 35,000 Americans are diagnosed each year with oral cancer, and early detection, usually during a regular dental check-up, is critical to successful treatment of this disease.

Oral cancer has been identified as a significant public health threat in the United States and is designated as a priority in several oral health initiatives such as *Oral Health in America: (A Report of the Surgeon General 2000 and Healthy People 2010)*.

The term oral cancer refers to the largest group of cancers in the head and neck region, including cancer of the lips, tongue, salivary glands, floor of the mouth, pharynx
(throat), hypopharynx (bottom of the throat) and oropharynx (soft palate, base of tongue, tonsils). Approximately 35,000 new cases of oral cancer are diagnosed each year in the United States, of which only half of those diagnosed will be alive in 5 year (Ries et al., 2007; NIDCR, 2009). More than 7,500 people will die this year of oral cancer, with mortality rate of one person per hour each day in the United States (Ries, et al., 2007; Shiboski, Shiboski, & Silverman, 2000). The death rate for oral cancer is higher than cervical cancer, stomach cancer, brain cancer, skin cancer (malignant melanoma), cancer of the testes and Hodgkin’s lymphoma (Ries, et al., 2007; Shiboski, et al., 2000).

There are several disparities that exist in oral cancer including racial and gender disparities. Oral cancer is especially high in the male African-American population, accounting higher incidence rates of the disease than men in any other racial/ethnic group or than women from all racial/ethnic groups; the same is true for mortality rates (Ries, et al., 2007). Although, more prevalent in males, the incidence of oral cancer in women has increased significantly, largely due to an increase in risk factors (smoking) among women. In 1950, the male to female ratio was 6:1; by 2002 it increased to a 2:1 ratio (Ries, et al., 2007). Of greatest importance, there has been nearly a five-fold increase in the incidence rates among patients under the age of 40, many with no known risk factors for the disease and who comprise 25% of all oral cancer patients (Dahlstrom et al., 2008; Shiboski, et al., 2000). This significant change indicates that all individuals are susceptible to oral cancer and must be screened in the dental setting, regardless of risk or behavioral factors.

In its early stages, oral cancer may go unnoticed because it is usually painless and frequently does not demonstrate physical changes that are obvious to many individuals.
Dental providers at public health settings are challenged with implementing effective screening protocols that utilize technology and innovation that may help detect oral cancer at an early (premalignant) stage (Patton, et al., 2008). The most common system used to describe the extent of oral cancers is the system of the American Joint Committee on Cancer (Greene et al., 2010). This staging and grouping system is a way for doctors to describe and summarize how far a patient's cancer has spread.

Early detection of premalignant (stage 0-IV) lesions is the principal determining factor outlining prognosis, treatment, and cost induced for the individual diagnosed with oral cancer (La Vecchia, et al., 1997; Patton, et al., 2008; Sciubba, 2001). When found early, oral cancer patients have an 80-90% survival rate (La Vecchia, et al., 1997; Sciubba, 2001).

While oral cancer receives less attention than other forms of cancer, it remains an important health problem with substantial costs to the whole society. Late stage diagnosis is occurring because there is a lack of public awareness coupled with the lack of a screening protocol established in the dental clinics at the public health settings. Unfortunately, the death rate associated with oral cancer is about 45% at five years from diagnosis because it is routinely discovered in a late stage (IV) (La Vecchia, et al., 1997; Sciubba, 2001). Often it is diagnosed when the cancer has metastasized to another location (stage IV), usually to the lymph nodes of the neck (Greene, et al., 2010). Prognosis at this stage of discovery is significantly worse than when it is caught in a localized intra-oral area due to the lymph system acting as a vehicle to aid in the metastasis mission of the cancer cells (Greene, et al., 2010; Sciubba, 2001).
Preventive Dental Hygiene Services

American Academy Periodontology (AAP) treatment guidelines stress that periodontal health should be achieved in the least invasive and most cost-effective manner. This is often accomplished through non-surgical periodontal treatment, including scaling and root planning, followed by adjunctive therapy such as local delivery antimicrobials and host modulation, as needed on a case-by-case basis.

The major etiological factor of periodontal diseases is the accumulation of dental biofilm (bacterial plaque) subgingivally. Therefore the aim of nonsurgical periodontal therapy (performed by a dental hygienist) is to remove supra- and sub-gingival microbial plaque to treat periodontal inflammation. Regardless the changing epidemiological profiles of periodontal diseases, rigorous studies are needed to explore the effectiveness and health consequences of preventive dental hygiene services (Maupomé, Gullion, Peters, & Little, 2007). There are many preventive approaches to improve oral health such as dental sealant, prophylaxis, fluoridated water, topical fluoride treatment, use of antimicrobial agents, and regular dental hygiene visits.

There are different periodontal treatments approaches such as surgical treatment, nonsurgical treatment alone, and nonsurgical treatment with antimicrobial agents. One goal for any oral health intervention is to maximize the healthy life of each tooth. Many recent reports and studies support the implementation of preventive dental services and regular periodontal maintenance in public health settings. This will shift the focus from traditional restorative procedures to preventive procedures. In theory, preventive dental hygiene services can reduce costs. There is evidence that preventive dental care can reduce the need for further restorative and emergency dental treatment (M. F. Savage,

Dental Clinic Team Members

A dental hygienist is a member of a dental profession team who performs scaling and root planning (SRP) procedures which may reduce the probing pockets depths (PPD) and gain in the attachment clinical level (CAL) (Antczak-Bouckoms & Weinstein, 1987). SRP is a careful cleaning of the root surfaces to remove plaque and calculus (tartar) from deep periodontal pockets and remove bacterial toxins. The World Health Organization (WHO) Global Goals for Oral Health are: the expansion of oral disease prevention, health promotion knowledge and practices in communities (Monajem, 2006). WHO calls dental hygienists as part of primary health care, as the “best poised” to help accelerate the integration of oral health with primary care, particularly in the light of the compelling evidence confirming the cost-effectiveness of the care delivered by intermediate providers such as dental hygienists (Monajem, 2006).

Furthermore, Klock reported that traditional dental care such as restorative treatment was more expensive than preventive dental treatment (Klock, 1980). Many studies reported that there is a lack of social and cultural awareness of how the preventive dental care can benefit from preventive programs.
Dental Insurance

The Center of Disease Control and Prevention states that a large percentage of Americans who suffer from untreated oral disease are individuals of low income, minorities and those without dental insurance (CDC). There are many barriers to oral healthcare such as lack of resources (insurance or money), availability of care, limited appreciation for the importance of oral health, and little information about publicly funded programs (Bentley, 2007).

Researchers at Old Dominion University used Aday-Andersen Behavioral Model dimensions (Predisposing, Enabling, and Need variables) to determine the relative contributions of this framework in predicting utilization of oral health services during the past year. The authors used logistic regression to analyze data on 2,885 adults from the 2001 – 2002 U.S. National Health and Nutrition Examination Survey (NHANES). Predictor variables included Predisposing variables (gender and ethnicity), Enabling variables (household income, dental insurance, and years of education), and Oral Health Need (self-rated pain). They found 68% of sample adults had utilized oral health services in the past year. The logistic regression model was statistically significant (P < .05) with approximately 14% of the variance in dental service use in the past year explained by the Aday-Andersen Behavioral Model dimensions. Significantly greater likelihood of dental service use was found with regard to Enabling variables [(higher education (OR = 2.183), presence of dental insurance (OR = 1.389), and higher incomes (OR = 1.000)], Predisposing variables [being black (OR = 0.752) or male (OR = 0.830)], or Need [self-reported pain (OR = 0.611)]. Enabling dimension variables were more highly predictive of dental service use (11.7% of variance explained) compared to
predisposing and need variables (1% and 1.3% respectively). Interestingly, dental insurance (Enabling variable) was more predictive of dental service use than Need variables (i.e. oral pain) (Alzahrani & Neff, 2010).

According to the National Health Interview Survey (NHIS), more than 45% of Americans (108 million) have no dental insurance (NHIS 1995). Uninsured individuals per state and per Virginian regions are illustrated in the figures below (Figure 4 and Figure 5) (Council on Virginia's Future, 2010).

Figure 4: Uninsured by State From 1999-2006.

Figure 5: Percent Uninsured, By region, 2000.


Population of Virginia and Hampton Roads

According to the U.S. Census Bureau in 2010, the population density estimate of Virginia is 202 persons per square mile (Table 2) (US Census Bureau, 2010). The below map shows the population density for Virginia by counties in 2000 (Figure 6) (US Census Bureau, 2000).

Table 2: Population Density of Virginia, 2010.

<table>
<thead>
<tr>
<th>State or Region</th>
<th>191</th>
<th>192</th>
<th>193</th>
<th>1940</th>
<th>1950</th>
<th>196</th>
<th>197</th>
<th>198</th>
<th>199</th>
<th>200</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>People/sq. mile</td>
<td>2.06</td>
<td>2.30</td>
<td>2.4</td>
<td>2,677</td>
<td>3.31</td>
<td>3.96</td>
<td>4.64</td>
<td>5.34</td>
<td>6.18</td>
<td>7.07</td>
<td>8.00</td>
</tr>
<tr>
<td>Rank</td>
<td>1,61</td>
<td>9.18</td>
<td>21.</td>
<td>773</td>
<td>8.68</td>
<td>6.94</td>
<td>8.49</td>
<td>6.81</td>
<td>7.35</td>
<td>8.51</td>
<td>1.02</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>7</td>
<td>85</td>
<td>0</td>
<td>9</td>
<td>4</td>
<td>8</td>
<td>8</td>
<td>5</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>People/ sq. mile</td>
<td>52.2</td>
<td>58.5</td>
<td>61.</td>
<td>67.8</td>
<td>84.0</td>
<td>100.</td>
<td>117.</td>
<td>135.</td>
<td>156.</td>
<td>179.</td>
<td>202.</td>
</tr>
<tr>
<td>Rank</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td>4</td>
<td>7</td>
<td>2</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Source: U.S. Census Bureau, 2010.
Figure 6: Population Density of Virginia.

Census 2000: Virginia Profile
Population Density by Census Tract

Note: Source: U.S. Census Bureau, 2000.

The following table shows the change of percentage of the population of Hampton Roads (8.3%) compared to Virginia (14.4) and the United States population changes (13.2%) between years 1990 and 2000 (Table 3).

<table>
<thead>
<tr>
<th></th>
<th>Population</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>1,454,185</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>1,574,801</td>
<td>8.3%</td>
</tr>
<tr>
<td>Hampton Roads Population</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Virginia Population</td>
<td>6,187,358</td>
<td>14.4%</td>
</tr>
<tr>
<td>US Population</td>
<td>248,709,873</td>
<td>13.2%</td>
</tr>
</tbody>
</table>

Note: Source: U.S. Census Bureau, 2010.
According to Hampton Roads Planning District Commission, 50.7% of Hampton Roads population are female and approximately 30% of the population are 19 years old or less (Figure 7).

**Figure 7: Hampton Roads Population (Sex and Age).**

Note: Source: U.S. Census Bureau, 2010.

In summary, determining what influences the delivery of oral health services has been a persistent goal among many public health providers. For many years studies have attempted to accurately identify the variables which influence the delivery of oral health services in public health settings. Numerous studies have been conducted that attempted to establish the best variables impacting the delivery of oral health services. Research indicates that studying the dimensions of the public health systems such as structure, process, and outcome may prove that delivering oral health services to the public can be improved. The most prolific of these studies focused on structural capacities such as physical, human, information, organizational, and fiscal resources. Research shows that the evaluation of public health performance in delivering oral health care services must be continued.
CHAPTER III

METHODOLOGY

The purpose of this study is to examine the system performance in delivering oral health services in a public health setting based on the Conceptual Framework to Measure Performance of the Public Health System (PHS). Using modeling and simulation, a predictive model based on the conceptual framework dimensions: mission, structural capacity, processes, and outcomes will be developed to predict the performance of public health department in delivering oral health services.

Modeling and simulation methodology enabled the author to modify the changeable variables such as adding a new oral health provider (dental hygienist) without impacting the quality of care. In addition, using modeling and simulation methodology will enable public health districts dental clinics to serve their clients effectively and efficiently with the best use of information, organizational, physical, human and fiscal resources, with no compromising the quality of care.

Using modeling and simulation with a well-structured model provided a reliable input data, an accurate process outline, and decrease the gap between modeling simulation and process applications (ElHaik & AlAomar, 2006).

This third chapter of this dissertation presents the research design, modeling and simulation methodology phases: problem formulation, simulation model building, and experimental design and analysis.
Research Design

This is a retrospective longitudinal study. Independent and dependent variables under investigation were categorized based on a comprehensive conceptual framework, Public Health System Performance Framework (PHS) dimensions. Independent variables are human resources and processes. The ultimate dependent variable in this study is the oral health services delivery as measured by the average number of patients' visits per day, the average number of diagnostic and preventive dental services per day, the average number of corrective services and the average number of total dental services per day.

The variables under investigation were chosen based on their prevalence as traditionally collected data on VDH monthly dental activity summary report; the evidence in the literature regarding their importance to administrators, academicians and institutions in measuring performance; the reported conflicting results of studies found in the literature; and the special interest of the faculty at this institution.

Modeling and Simulation Methodology

This section presents the five phases of the simulation methodology that were followed to build the simulation model of a dental clinic at a public health district (Rossetti, 2010). These phases were used as a guiding framework to build and run the simulation model (Figure 8).

1. Phase 1: Problem Formulation
2. Phase 2: Simulation Model Building
3. Phase 3: Experimental Design and analysis
4. Phase 4: Evaluate and Iterate (part of chapter 4)
5. Phase 5: Documentation and Reporting Results (part of chapter 4)
Figure 8: General Simulation Modeling Methodology.

**PHASE 1: PROBLEM FORMULATION**
- Objectives of the study
- Problem Definition
- System Description
- Performance metrics
- Conceptual Model
- Assumptions and Limitations

**PHASE 2: MODEL BUILDING**
- Model Building
- Data Collection
- Coding
- Verified?
- Validated?
- YES
- NO

**PHASE 3: SCENARIOS AND ANALYSIS**
- Scenarios
- Production Runs and Analysis

**PHASE 4: EVALUATION AND ITERATE**
- "More Runs?"
- NO

**PHASE 5: RESULTS AND ANALYSIS**

Note. Adapted from Rossetti, 2010
Phase 1: Problem Formulation

This phase covered the following: objectives of the study, problem definition, system description and selection, establishing performance metrics, building conceptual model, and documenting modeling assumptions and limitations (Figure 9).

Figure 9: Phase 1, Problem Formulation

1. Objective of the study

The objective of this study was to examine the system performance in delivering oral health services in a public health district dental clinic based on the Conceptual Framework to Measure Performance of the Public Health System (PHS). Using modeling and simulation, a predictive model based on the conceptual framework dimensions: structural capacity, processes, and outcomes was developed to predict the performance of public health district dental clinic in delivering oral health services.
2. **Problem definition**

Oral diseases such as dental caries and periodontal diseases are infectious diseases and become difficult to manage and treat when they advance to severe stages (CDC, 2003). In its early stages, oral cancer may go unnoticed because it is usually painless and frequently does not demonstrate physical changes that are obvious to many individuals.

Most oral health experts agree that most oral diseases can be prevented and treated with low-cost procedures and less traumatic intervention if diagnosed and treated in their early stages (Gilbert, et al., 2002; Milgrom, et al., 1998). Preventive oral health services include many procedures such as regular oral and dental checkup, scaling and root planning, applying dental sealants (for children), fluoride treatment, and regular periodontal maintenance treatment. The consequences of untreated oral diseases can lead to pain, tooth loss and undefeatable expenses (CDC, 2007).

Untreated oral diseases may impact on an individual’s self-esteem and total overall health. Advanced stages of oral infections have been indirectly linked with some diseases such as cardiovascular diseases, pregnancy outcomes (low birth-weight, premature births) and diabetes (Genco, et al., 2002; Grossi & Genco, 1998; Kardeşler, et al., 2010; Soskolne & Klinger, 2001).

Approximately 35,000 Americans are diagnosed each year with oral cancer, and early detection, usually during a regular dental check-up at general practices, is critical to successful treatment of this disease (Ries, et al., 2007). If a premalignant lesion is detected and treated, the lesion may not progress to a
malignant state. Early detection of premalignant (stage 0-IV) lesions is the principal determining factor outlining prognosis, treatment, and cost induced for the individual diagnosed with oral cancer. When found early, oral cancers have an 80-90% survival rate (La Vecchia, et al., 1997; Patton, et al., 2008; Sciubba, 2001). There are relatively few studies describing the cost of oral cancer in general, or of the costs and cost-effectiveness of various patient treatment options. In this time of mounting concerns over healthcare costs, more emphasis on economic data is clearly warranted.

More than 91% of adults (20 years or older) have experienced coronal caries. Approximately 23% of this population has untreated dental caries. More than 18% of the population has root caries (CDC, 2007). Furthermore, more than 90% of adults over 60 years have experienced dental caries. One forth of adults over the age of 60 has lost all of their teeth as a result of having tooth decay. Severe periodontal diseases affect 5 to 15% of adults in the United States (CDC, 2007).

According to the U.S. Census Bureau report that released in September 2010, the number of people who has no insurance has increased from 46.3 million, 15.4% of the population, in 2008 to 50.7 million, 16.7% of the population, in 2010. In 2009, more than 10% of children (7.5 million) who are under 18 years old have no health insurance (US Census Bureau, 2010). According to the National Health Interview Survey (NHIS), more than 45% of Americans (108 million) have no dental insurance (NHIS 1995).
In 2000, the Surgeon General recognized that the national oral health care needs more attention. According to this report, the lack of access to oral health care was identified and recognized by different legislative parties such as lawmakers, some professional organizations, interested groups and public health departments as a big concern (Surgeon General Report, 2000).

Modeling and simulation will enable the author to modify the changeable variables such as adding new personnel; adding a dental hygienist, a dental assistant or a secretary without impacting the quality of care. In addition, using modeling and simulation methodology will enable dental practices to serve their clients effectively and efficiently with the best use of information, organizational, physical, human and fiscal resources, with no compromising the quality of care.

This research seeks to address issues that affect the delivery of oral health care in public dental health settings. The results of this study will determine what variables in the dental practice settings influence oral health care delivery and to what extent. Results of this study will narrow the knowledge gap among oral health providers regarding the importance of modeling and simulation technique leading to improve oral health care delivery. Furthermore, the results of this research study will be shared with the decision-makers at VDH and our hope is that it will be useful for their future planning and development purposes.

3. System description

According to Schmidt and Taylor (1970), a system can be defined as a collection of entities (e.g. people, machines, clinics) that act and interact together toward the accomplishment of some logical end (Schmidt, 1970). A discrete system is one
for which the state variables change instantaneously at separated points in time (Law, 2007). For example, the number of patients in the clinic changes only when a patient arrives or when a patient finishes treatment (being served) and departs.

The state of a system can be defined as a collection of variables necessary to describe a system at a particular time (Law, 2007). The number of busy dentists, the number of patients in the clinic and the time of treatment are some examples of the state of our system.

In this study, the system under investigation is a public health district dental clinic which consists of a dentist, a dental hygienist, a dental assistant, a receptionist and patients. The system includes a real structural capacities and personnel parameters such as number of dental chairs, radiographs units, dentists, dental assistants and receptionists. The current dental team operating the dental clinics at the public health districts does not include a dental hygienist. Public health district dental clinic opens five days a week from 9 AM to 5 PM, totally 40 hours per week. The detailed structural capacities and personnel number are presented in details under structural capacities and personnel for each district in (Table 5).

A dental clinic at a public health district involves different activities such as checking-in, registration, diagnosis, preventive and corrective dental services. If this is the first visit for the patient, the patient will move to see dental assistant who will document the medical and dental history of the patient, and take necessary radiographs. Also, the dental assistant will perform prophylaxis, supra-
gingival scaling, and topical fluoride treatment. Then, the dentist will see the patient to perform the necessary preventive services if needed.

The patients seeking dental treatment at a public health dental clinic can be categorized as first visit patients, recare patients and returning patients. First time visit patients mean the first visit of the patient in the fiscal year (July 1- June 30). If the patient comes back for 6-month regular check-up, he/she considers as a recare patient not as a new patient. Returning patients include those who have not finished their dental care plan.

If the patient is returning patient (who has not finished the dental care plan), the patient will advance directly to the dentist after checking-in to perform the planned corrective services. Finally, the patient will be dismissed after checking out and scheduling the next appointment with the receptionist. If there is a dental hygienist among the dental team, she will perform all diagnosis and preventive services instead of the dentist. So, the dentist will have more time to perform essential corrective services for patients.

There are different radiographs kinds depending on the patient's diagnostic needs such as intraoral radiographs: full mouth radiographs series, bitewings, occlusal and periapicals; and extra-oral radiographs such as panoramic.

Part of data accuracy verification, the researcher contacted all the dental clinics' directors at the public health districts under investigation to verify the accuracy of the obtained essential information about the structural capacities and the number of personnel (Appendix D).
3.1 Study Sample and Setting

Purposeful sample consists of five public health district dental clinics of Hampton Roads for the fiscal years, 2005-2010.

For the purpose of this study the following five public health district dental clinics were chosen: Norfolk, Virginia Beach, Hampton, Peninsula, and Western Tidewater. Norfolk Health District operates two sites: Little Creek and Park Place. Virginia Beach District operates two sites: Birdneck and Pembroke. Western Tidewater Health District operates two sites: Isle of Wight and Southampton (Figure 10) (Virginia Department of Health, 2010).

Figure 10: Virginia Health Districts and Locations.

These districts have been chosen because they provide primary oral healthcare services. All districts report their performances and the number of patients every three months to the VDH.

3.2 Structural capacities and personnel of the districts

The data essential for this study were obtained from VDH and from the five districts' dental directors for the fiscal years, 2005, 2006, 2007, 2008, 2009, and 2010. Before starting this study, essential forms received from VDH were completed and signed by the researcher to obtain the necessary data. Data were analyzed for the six-year period of time, 2005-2010. The districts' directors were contacted to verify information about the structural capacities and the personnel of districts under investigation. Based on datasets and the responses of the districts' director, the structural capacity and the personnel of Norfolk, Virginia Beach, Peninsula, and Western Tidewater were described below and summarized in (Table 4).

Table 4: Health Districts and dental clinics locations

<table>
<thead>
<tr>
<th>Number</th>
<th>Districts</th>
<th>Cities and Locations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Norfolk</td>
<td>Little Creek</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Park Place</td>
</tr>
<tr>
<td>2.</td>
<td>Virginia Beach</td>
<td>Birdneck</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pembroke</td>
</tr>
<tr>
<td>3.</td>
<td>Hampton</td>
<td>Hampton</td>
</tr>
<tr>
<td>4.</td>
<td>Peninsula</td>
<td>Newport News</td>
</tr>
<tr>
<td>5.</td>
<td>Western Tidewater</td>
<td>Isle of Wight</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Southampton</td>
</tr>
</tbody>
</table>
Norfolk Health District, Dental Clinic

1. Structural Capacity

Norfolk health district has two sites: Little Creek and Park Place. There are four dental chairs at each site. At the Little Creek site, there are two intraoral radiographs units and one extra-oral panoramic radiographs unit. At the Park Place site, there are four intraoral radiographs units and one extra-oral panoramic radiographs unit. The dental clinic at Park Place is shared with the American Red Cross who has installed some of the radiographs units and chairs.

2. Personnel

Norfolk Health District Dental Clinic has one dentist and two dental assistants who are full time. There is no dental hygienist or secretary. Currently, they share administrative services with other departments at the health district.

Virginia Beach Health District, Dental Clinic

1. Structural Capacity

Virginia Beach Health District Dental Clinic operates two sites: Pembroke and Birdneck. At Pembroke site, there are three dental chairs, two intraoral radiographs units, and one extra-oral panoramic radiographs unit. At the Birdneck site, there is a two chair clinic in a trailer at Birdneck elementary school.

2. Personnel

Virginia Beach Health District Dental Clinic at Pembroke site has one dentist, two dental assistants, no hygienist and one receptionist. Birdneck site opens only on Mondays. It is staffed by a part-time dentist and temporary dental assistant plus one of the main clinic dental assistant who handles administrative tasks and
assists as needed. At Birdneck site, there is no dental hygienist or secretary. Clinic does not operate if dentist is absent.

Hampton Health District, Dental Clinic

Hampton district’s dental program was ended in 2009. The following structural capacities and personnel are as before ending the program.

1. Structural Capacity

Hampton health district operated one site. There were three dental chairs, 3 intraoral radiographs units, and no extra-oral panoramic radiographs unit.

2. Personnel

Hampton health district had one dentist, one dental assistants, no hygienist and no receptionist.

Peninsula Health District, Dental Clinic

1. Structural Capacity

Peninsula health district has five dental chairs, two intraoral radiographs units, and one extra-oral panoramic radiographs unit.

2. Personnel

Peninsula health district has two dentists, two dental assistants, and one secretary. There is no dental hygienist.
Western Tidewater Health District, Dental Clinic

1. **Structural Capacity**

Western Tidewater Health District Dental Clinic operates two sites: Isle of Wight County and Southampton County. At each site, there are two dental chairs, and two intraoral radiographs units.

2. **Personnel**

Western Tidewater Health District Dental Clinic has one dentist, no hygienist and one dental assistant. There are two part time secretaries who do the billing and eligibility. They work about twenty hours a week. The full time employees work forty hours per week (Table 5).

<table>
<thead>
<tr>
<th>Districts and Locations</th>
<th>Structural Capacity</th>
<th>Personnel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dental Chair</td>
<td>Intraoral x-ray</td>
</tr>
<tr>
<td><strong>Norfolk</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Little Creek</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Park Place</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><strong>Virginia Beach</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pembroke</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Birdneck</td>
<td>2 (Trailer)</td>
<td>0</td>
</tr>
<tr>
<td><strong>Hampton Peninsula</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Newport</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Newport News</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td><strong>Western Tidewater</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isle of Wight</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Southampton</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>
The following section describes the duties done by the current dental team at a public health dental clinic: receptionist, dental assistant and dentist on a daily basis for both new or recare patients and returning patients.

**Patient Categories and Oral Healthcare Providers (no dental hygienist)**

I. First visit patients:

This includes diagnosis and preventive services such as medical history review with parent, exam and charting, radiographs if appropriate, prophylaxis, topical fluoride therapy, and oral hygiene instructions. On average, this kind of dental visit may take 35-45 minutes.

**Receptionist:**

Receptionist certifies income or Medicaid status, checks all forms for completion (health questionnaire, clinic policy statement, Health Information Portability and Accountability Act, HIPAA, consent form) and puts chart together. These procedures take approximately 25 minutes with 10-15 minutes for each additional family member. In case there is no receptionist, the dental assistant will conduct all these duties.

**Dental Assistant:**

Dental assistant may performs the following dental procedures: taking radiographs, performing oral prophylaxis, applying topical fluoride and providing oral hygiene instructions.

**Dentist:**

Dentist performs medical history review, dental history review, develop dental care plan, dental diagnosis and discuss that with the patients and their parents.
II. Returning patients (second visit)

Receptionist:

The patient will check-in with the receptionist. Usually, there is no forms to be updated in the second visit (return patient). This procedure takes about 5 minutes. The patient will advance directly to the dentist to perform the corrective services that have been planned in the first visit.

Dental Assistant: assists with different duties such as instruments, materials and suction. Also, sometimes the dental assistant may help with patient management.

Dentist:

The dentist will perform the corrective services such as restorative procedures, extraction or combination. In more details, the dentist will review medical history, anesthetize patient (wait 5 minutes), apply rubber dam for fillings or crowns, do fillings or crowns, post operative instructions to parent and patient, and dismiss the patient. This may take 35-45 minutes.

III. Recare visits (6-month regular check-up):

Receptionist:

For six month check-up patients: the receptionist will recertify income status and update health history for about 30 minutes.

Dental Assistant:
Dental assistant may perform the following dental procedures: taking radiographs if needed, performing oral prophylaxis, applying topical fluoride and providing oral hygiene instructions.

Dentist:
The dentist will review the medical and dental history with the patient and the parent, perform dental exam, and chart new findings.

**Adding dental hygienist to the Oral Healthcare Providers**

**Dental Hygienist**

A dental hygienist performs dental hygiene diagnosis, planning, and implementing the dental hygiene care. In more detail, the dental hygienist will perform different dental services such as medical and dental history, intra and extra-oral exam and charting, radiographs if appropriate, prophylaxis, scaling, dental sealants, topical fluoride treatment, and oral hygiene instructions.

4. **Establishing performance metrics**

The data essential for this study obtained from VDH and have been verified for accuracy by the dental directors of the five health districts under investigation for the fiscal years, 2005, 2006, 2007, 2008, 2009, and 2010. These datasets were used to collect the parameters needed to build the simulation model necessary for this research.

By using these datasets, researcher placed specific questions which would be used to measure the performance of oral healthcare services delivery at public health districts' dental clinics.

These datasets contain the following performance metrics:
a. the average number of patients' visits per day at a public health district dental clinic.

b. the average number of diagnostic and preventive dental services delivered by the dentist or the dental hygienist per day at a public health district dental clinic.

c. the average number of corrective services provided by the dentist per day at a public health district dental clinic.

d. the average number of total dental services per day at a public health district dental clinic.

5. Building conceptual model

In this step, the real world system concepts were represented into a logical representation. Conceptual model represents the basic concepts and behavior of our real system, a public health district dental clinic.

The system under investigation was a dental clinic at a public health district which operates with one dentist, one dental assistant, and one receptionist. It opens five days a week from 9 AM to 5 PM. The following flow chart represents the logical representation of the simulation model. The first patient flow chart does not contain a dental hygienist (Figure 11 and 12).
Figure 11: Flowchart of Patients' Visits at a Dental Clinic (No Dental Hygienist Included)

Check-in procedures for new and recare patients \(\rightarrow\) Dentist: dental assessment, diagnosis, planning and implementing dental treatment

Receptionist: Check-in. Is this a new patient visit?

YES \(\rightarrow\) Dental assistant: taking radiographs (if needed), prophylaxis, fluoride therapy and oral health instructions

NO \(\rightarrow\) Check-in procedures for patients who returning to complete the dental care

Patient checks out, schedules a follow-up (if needed) or 6-month recare appointment

Figure 12: Proposed Flowchart of Patients' Visits at a Dental Clinic (with Dental Hygienist)

Check-in procedures for new and recare patients \(\rightarrow\) Dental hygienist: assessment, dental hygiene diagnosis, planning, and implementing dental hygiene care

Receptionist: Check-in. Is this a new patient visit?

YES \(\rightarrow\) Dentist and dental assistant: assessment, dental diagnosis, planning and implementing corrective dental treatment

NO \(\rightarrow\) Check-in procedures for patients who returning to complete the dental care

Patient checks out, schedules a follow-up (if needed) or 6-month recare appointment
6. Documenting simulation modeling assumptions and limitations

For the purpose of this study the following assumptions were made:

a. The comprehensive conceptual framework, Public Health System Performance Framework (PHS) dimensions: physical resources and processes have a direct relationship on the outcome variable in this study, oral health services delivery.

b. The increased number of patients seen by the dentist is an indicator of improvement in the oral health services delivered by the public health district dental clinic.

c. The received dataset from VDH have complete data including:

   i. the average number of clinical hours worked per month of the dentist in delivering oral health care services (i.e. diagnosis, preventive, corrective) at a public health district dental clinic.

   ii. the average number of patients' visits per day at a public health district dental clinic.

   iii. the average number of diagnostic and preventive dental services delivered by the dentist or the dental hygienist per day at a public health district dental clinic.

   iv. the average number of corrective services provided by the dentist per day at a public health district dental clinic.

d. The received data verifications from the dental clinics' directors of Norfolk, Virginia Beach, Peninsula, and Western Tidewater (Appendix D) have complete data about:

i. Structural capacities: number of dental chairs, and intra and extra oral radiographs units.

ii. Personnel number: number of dentists, dental hygienists, dental assistant and receptionists.

iii. Daily dental duties performed by the dental team and their estimated time.

e. The received dataset from VDH have been verified for accuracy and confirmed to be accurate.

f. The researcher entered the data in Arena Input Analyzer, Arena, and Arena Output Analyzer in a consistent manner to ensure reliable and accurate data entry.

g. Patients will be patients of record of one district only. For example, patients who are residing in Norfolk will not be seen at another health district.
Phase 2: Simulation Model Building

This phase covered the following activities: data collection procedures, model building, coding, and validating (Figure 13).

Figure 13: Phase 2, Model Building

1. Data Collection Procedures

This research requires access to a non-sensitive material. The sample of this study was the following five public health district dental clinics in Hampton Roads, VA: Norfolk, Virginia Beach, Hampton, Peninsula, and Western Tidewater for six fiscal years: 2005, 2006, 2007, 2008, 2009, and 2010.

All data were anonymously coded and were treated in aggregative form. The research team was not able to link names to the sensitive information of the patients. Confidentiality was maintained throughout the study. No member of the research team was involved in the data collection at the time when the data may be linked with an identifier. No patients' names or social security numbers were
used in this study. In addition, all subsequent treatment of the collected data was in anonymous format. The potential benefits of this study outweigh the possible risks.

All researchers are under obligation to protect private information about human subjects. Additionally, all members of the research team had completed the Human Participants Protection Education for Research Team sponsored by the National Institutes of Health (NIH).

The researcher sent a cover letter to VDH to explain the purpose and the benefits of this study and to request permission for access oral health services data via the public health districts' databases in order to build the most effective simulation model and conduct the research (Appendix A). Official forms were received from Quality Assurance Manager, Division of Dental Health, at Richmond to be signed by the researcher and to be sent back to him before releasing data. These official forms were DH 1214 Data Use Disclaimer Form and DH 1214 Data Request Form (Appendix B and C).

The Director of Division of Dental Health at VDH gave permission to the researchers to have access to the dataset of the sample and to contact dental clinics' directors to verify the accuracy of the data sets (Appendix D).

The researcher obtained information regarding the mission statement, goals, structural capacities, personnel and the outcomes of the five districts of public health in the Hampton Roads area from the VDH.
After obtaining the approval from VDH, the researcher contacted the five districts of public health in the Hampton Roads area, dental clinics directors to verify the data accuracy.

The datasets that obtained from VDH were received as Microsoft Excel® Spreadsheets for the six-year period of time, 2005-2010, and were categorized by the fiscal year (Appendix E). The researcher performed further data organizing to make data more relevant to the purpose of this study.

2. Model Building

The main objective of this study was to use the modeling and simulation approach to developed a simulating model to predict the performance of public health district dental clinic in delivering oral health services. Specifically, the following performance metrics were examined: the average number of patients' visits per day at a public health district dental clinic, the average number of diagnostic and preventive dental services delivered by the dentist or the dental hygienist per day at a public health district dental clinic, the average number of corrective services provided by the dentist per day at a public health district dental clinic and the average total dental services.

The following scenarios based on the existing structural capacities and personnel were modeled and simulated using Rockwell Automation software, Arena ® version 13.5.

3. Model Translation to Arena (Coding)

In this step the conceptual model was translated to Arena model, including timing and all different dental procedures (Figure 14).
4. Verification, Validation and Testing (VV&T)

Model Verification is "substantiating that the model is transformed from one form into another, as intended, with sufficient accuracy. Model verification deals with building the model right. The accuracy of transforming a problem formulation into a model specification or the accuracy of converting a model representation from a micro flowchart form into an executable computer program is evaluated in model verification" (Balci, 1998, p. 41).

Model Validation is "substantiating that the model, within its domain of applicability, behaves with satisfactory accuracy consistent with the M&S objectives. Model validation deals with building the right model" (Balci, 1998, p. 41).
In order to develop a more accurate and representative model, verification, validation, and testing are essential procedures. In the diagram below, dashed lines indicate how the process move from one phase to the next. The solid lines indicate the verification, validation, and testing procedures. This diagram shows that VV&T activities are not connected when moving from one phase to the next, rather it shows that these activities are integrated throughout the M&S process (Balci, 1998).

As part of verification procedures and before running the model, the researchers checked for the programming errors. Run/Check Model was selected from the menu option in Arena software. If any errors found, a window listing them will pop up on the flowchart view of the model. Find button located at the bottom of the flowchart view may be selected to find the programming errors. The other approach that may be used is to debug Arena models by selecting the Run/Run Control menu options: Command, Breakpoints, Watch, Break on Module, and Highlight Active Module (Elam, Anderson, Lamphere, & Wilkins, 2010). In addition, all the programming codes were verified and confirmed by an expert in the engineering management who is a member of this dissertation committee. The Model was validated by evaluating the conceptual model by all public health district dental clinic directors in Hampton Roads and by experts at Old Dominion University, College of Health Sciences, Dental Hygiene School.
Figure 15: Validation and Verification Process

Adapted from (Balci, 1998)
Note: Dashed arrow = process to move to next, Solid arrow = Verification and Validation assessment.
Phase 3: Scenarios and Analysis

This phase covered the following steps: scenarios design, statistical tests (Figure 16).

Figure 16: Phase 3, Scenarios and analysis

3.1 Scenarios Design:

Based on the research questions and the hypotheses, the researchers developed two scenarios for each site. The first scenario was the current status of the personnel at a public health district dental clinic with no dental hygienist. The second scenario was by adding a new oral health care provider (a dental hygienist) to the model to determine the impact of this addition on the performance metrics. Four hypotheses were developed for each site. In total, there were 32 hypotheses formulated and tested in this study, see Table 6 below.

Paired t-test was conducted to determine whether or not the differences between scenario one (as is) and scenario two (adding a dental hygienist) is statistically significant
at p-value equals or less than 5%. There are four hypotheses and eight different scenarios for each district (Table 6).

Table 6: Scenarios, Hypotheses and Statistical Tests

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Variable</th>
<th>Metric</th>
<th>Operational Definition</th>
<th>Statistical Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>HYPOTHESIS ONE</td>
<td>One</td>
<td>As is, No addition</td>
<td>The average number of patients' visits per day</td>
<td>The number of patients' visits per day at a public health district dental clinic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dental hygienist</td>
<td>HYPOTHESIS TWO</td>
<td>The number of diagnostic and preventive dental services delivered by the dentist or the dental hygienist per day at a public health district dental clinic</td>
</tr>
<tr>
<td></td>
<td>Three</td>
<td>As is</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Four</td>
<td>Dental hygienist</td>
<td>HYPOTHESIS THREE</td>
<td>The number of corrective services provided by the dentist per day at a public health district dental clinic</td>
</tr>
<tr>
<td></td>
<td>Five</td>
<td>As is</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Six</td>
<td>Dental hygienist</td>
<td>HYPOTHESIS FOUR</td>
<td>The total number of all dental services including diagnostic, preventive and corrective services provided at a public health district dental clinic.</td>
</tr>
<tr>
<td></td>
<td>Seven</td>
<td>As is</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Eight</td>
<td>Dental hygienist</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.2 Statistical Tests

3.2.1 Descriptive statistics

Data were received as Microsoft Excel® spreadsheets for all the five public health dental clinics under investigation for six-year period of time (2005-2010). Demographic information such as gender was collected and analyzed for each site. In addition, types of visits either recare/first visits or return visits were collected and analyzed in this study. Depending on the level of the measurement, descriptive analyses such as measures of central tendency (mean, mode, and median) and measures of dispersion (variances, standard deviation) were computed for independent and dependent variables. These variables include: the average number of patients' visits per day at a public health district dental clinic, the average number of diagnostic and preventive dental services delivered by the dentist or the dental hygienist per day at a public health district dental clinic, the average number of corrective services provided by the dentist per day at a public health district dental clinic and the average of total dental services per day. Researchers placed specific questions to measure the performance of oral healthcare services delivery at a public health district dental clinic. In all cases of analysis, a p-value of less than or equal to 0.05 was used to determine significance level (Table 7).
Table 7: Descriptive Statistics

<table>
<thead>
<tr>
<th>Variables</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dental services</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diagnosis and preventive services per day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrective services per day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total services per day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patient status</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patients' visits per day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3.2.2 Statistical tests: paired t-test, repeated measures analysis of variance (ANOVA) and 95% confidence interval

This study was to build a predictive simulation model to predict the performance of a public health district dental clinic in delivering oral health services. The data essential for this study were obtained from VDH and have been verified for accuracy by the dental directors of the five health districts under investigation for the fiscal years, 2005, 2006, 2007, 2008, 2009, and 2010. These datasets were received as Microsoft Excel® Spreadsheets for the six-year period of time. These datasets were used to collect the parameters essential to build the simulation model necessary for this research. Rockwell Automation software, Arena®, version 13.5, was used to build the simulation model essential for this study.

Based on the research questions, the researchers developed four hypotheses for each public health district dental clinic site. A new oral health provider (dental hygienist) was added to the model to determine the impact of this addition on the performance metrics. Paired T-test was conducted to determine whether or not the differences between scenario one (as is) and scenario two
(adding a dental hygienist) is statistically significant at p-value equals or less than 5%.

Arena Input Analyzer and Output Analyzer are two additional tools associated with Arena software. Arena Input Analyzer is used to determine an appropriate statistical distributions for raw data such as interarrival rate, number of patients' visits rate, diagnosis, preventive and corrective services process time. The researcher can use these statistical distribution directly in Arena model. On the other hand, Arena Output Analyzer is used to analyze the results obtained from running Arena model. Output Analyzer provides different output analyses such as plots, correlograms, histograms, confidence intervals, comparing means and one-way analysis of variance (one-way ANOVA) (Takus & Profozich, 1997).

In addition, the following statistical analyses were determined: desired confidence level, desired confidence interval, goodness-of-fit tests for theoretical distributions (i.e. Chi-Square test, Komogorov-Smirnov (K-S) goodness-of-fit hypothesis test, and square errors criteria). Statistical Package for Social Sciences (SPSS, Version 18) was used to compute paired t-test and repeated measures analysis of variance (ANOVA). Paired t-test can be calculated by the following equation:

\[
t_{\text{paired}} = \frac{\bar{x}_1 - \bar{x}_2 - 0}{\sqrt{\frac{\sum D^2 - (\sum D)^2}{N(N-1)}}}
\]

Where \( \alpha \)-level is 5 %, degrees of freedom is computed as \( d.f = N-1 \).05, and critical value comes from the t-table.
Protection of Human Subjects

Prior to the initiation of this study, a proposal was submitted for IRB approval for the protection of human subjects through Old Dominion University, College of Health Sciences, Human Subjects Committee. The study was approved as exempt research.

1. **Subject Population**: This research requires access to a non-sensitive material. The sample of this study will be five public health district dental clinics in Hampton Roads.

2. **Potential Risks**: all data will be anonymously coded and will be in aggregative form. The research team will not be able to link names to the sensitive information of the patients. All researchers will be under obligation to protect private information about human subjects. Additionally, all members of the research team will have to complete the Human Participants Protection Education for Research Team sponsored by the National Institutes of Health (NIH).

3. **Consent Procedures**: This research presents minimal risk of harm. The director of Division of Dental Health at VDH were contacted to give permission to the researchers to have access to the dataset.

4. **Confidentiality**: will be maintained throughout the study. No member of the research team will be involved in the data collection at the time when the data may be linked with an identifier. No patients' names or social security numbers will be used in this study.

5. **Potential Benefits**: The greatest benefit potential of this study will be to institutions of community health, public health educators, the public and community at large and future patients seeking oral healthcare at public health
settings. The dissemination of the results of this study through publications and professional presentations will allow academic institutions and public health educators to evaluate public health settings procedures and criteria and possibility identify those criteria most likely to optimize oral healthcare services delivery.

6. **Risk-Benefit Ratio:** The potential benefits of this study outweigh the possible risks. No member of the research team will see data linked with an identifier during data collection. In addition, all subsequent treatment of the collected data will be in anonymous format. Furthermore, the research team will be obligated to maintain confidentiality of all data throughout the project.
CHAPTER IV
RESULTS AND ANALYSES

A retrospective longitudinal study was conducted to examine the system performance in delivering oral health services in a public health dental clinic based on the Conceptual Framework to Measure Performance of the Public Health System (PHS). Purposeful sample consists of five public health district dental clinics of Hampton Roads for the fiscal years, 2005-2010. For the purpose of this study the following five public health district dental clinics were chosen: Norfolk, Virginia Beach, Hampton, Peninsula, and Western Tidewater (Appendix E). Norfolk Public Health District operates two sites: Little Creek and Park Place. Virginia Beach Public Health District operates two sites: Birdneck and Pembroke. Western Tidewater Public Health District operates two sites: Isle of Wight and Southampton.

The system under investigation includes real structural capacities and personnel parameters such as number of dental chairs, radiographs units, dentists, dental assistants, and receptionists. The current dental team operating the dental clinics at the public health districts does not include a dental hygienist. Public health district dental clinic opens from 9 AM to 5 PM, 8 hours per day.

The data essential for this study were obtained from VDH and have been verified by the dental directors of the five health districts under investigation for the fiscal years, 2005, 2006, 2007, 2008, 2009, and 2010. These datasets were used to collect the parameters needed to build the simulation model necessary for this research.
By using these datasets, the researchers placed specific questions which would be used to measure the performance of oral healthcare services delivery at public health districts. These datasets contain the following performance metrics:

a. the average number of patients' visits per day at a public health district dental clinic.

b. the average number of diagnostic and preventive dental services delivered by the dentist or the dental hygienist per day at a public health district dental clinic.

c. the average number of corrective services provided by the dentist per day at a public health district dental clinic.

d. the average number of total dental services per day at a public health district dental clinic.

Paired t-test and confidence intervals were used to analyze the data to determine whether or not there is a statistically significant difference between scenario one with no dental hygienist and scenario two with adding a dental hygienist.

To confirm the results of the paired t-test analysis using SPSS, the repeated-measures analysis of variance (ANOVA) was used. Paired t-test and repeated-measures ANOVA should yield identical p values.

This fourth chapter of this dissertation presents the modeling and simulation analysis, Arena software and its two applications; Arena Input Analyzer and Arena Output Analyzer; Goodness-of-fit tests for distributions and number of replications estimation. The chapter concludes by describing Arena models with and without a dental hygienist, the statistical tests and the results of hypotheses testing.
Modeling and Simulation Analysis: Arena Input Analyzer and Arena Output Analyzer

Arena simulation software is a true Microsoft Windows operating system that is compatible with different Windows applications such as word processor, spreadsheet and computer-aided design (CAD) package (Kelton, Sadowski, & Swets, 2010). Arena's fundamental modeling building templates are modules and elements which have been built in SIMAN modeling language (Altiok & Melamed, 2007). By using these modules and element, different scenarios with the flow of transactions among multiple processes can be modeled and simulated.

Arena Input Analyzer and Output Analyzer are two additional tools associated with Arena software. Arena Input Analyzer is used to determine an appropriate statistical distribution for raw data such as interarrival rate, number of patients' visits rate, diagnosis, preventive and corrective services process time. The researcher can use these statistical distribution directly in Arena model (Altiok & Melamed, 2007). On the other hand, Arena Output Analyzer is used to analyze the results obtained from running Arena model. Output Analyzer provides different output analyses such as plots, correlograms, histograms, confidence intervals, and one-way analysis of variance (one-way ANOVA) (Takus & Profozich, 1997).

Goodness-of-fit Tests for Distributions

Arena Input Analyzer was used to determine the theoretical distributions that best fit sample data related to public health district dental clinics under investigation for a 6-
year period of time for all variables related to performance metrics (Excel spreadsheets from VDH) and all other relevant variables (Appendix F).

The theoretical distributions for the following parameters were determined:

1. average number of diagnosis and preventive services per recare visit,
2. average number of corrective services per return visit,
3. average number of other services per return visit,
4. interarrival rate (without dental hygienist),
5. interarrival rate (with dental hygienist),
6. check-in process time for first/recare visit,
7. check-in process time for return visit,
8. check-out process time for first/recare visit,
9. check-out process time for return visit,
10. dentist's treatment process time for first/recare visit,
11. dentist's treatment process time for return visit,
12. dental assistant's radiographs taking process time,
13. dental assistant's initial preventive services process time,
14. dental hygiene diagnosis and preventive services process time.

To determine the best theoretical distribution for a sample data, a statistical test was conducted. The null hypothesis states that the chosen distribution is a sufficiently good fit to the sample data. Whereas, the alternate hypothesis states that it is not (Altiok & Melamed, 2007). Theoretical distributions were used to fit the data under investigation. Arena Input Analyzer function (Fit All) was applied. This function fits all of the applicable distributions to the data by calculating the necessary statistics such as
1. Chi-Square test,

2. Komogorov-Smirnov (K-S) goodness-of-fit hypothesis test, and

3. square errors criteria.

All distributions are ordered according to the minimum square error values. Square error values is a measure of the quality of the distribution that best fit the data (Kelton, et al., 2010; Rossetti, 2010). In addition, Arena Input Analyzer reports the corresponding p-value which takes values between 0 and 1. The larger p-value means the better fits of the theoretical distribution to the data. The p-value is the largest value of the type-I error probability that allows the distribution to fit the data. For example, if the p-value is greater than 0.10, then we would not reject the null hypothesis of a good fit at level = 0.10. The p-value is the probability to determine the theoretical distribution that most likely and truly fit the real data we obtain.

**Number of Replications**

Since this model is considered as a terminating simulation model, estimating the number of replications is a critical parameter of the associated output analysis. This is the only method to determine the sample size of any given estimator (Altiok & Melamed, 2007). In order to compute the number of the replications, three parameters are needed: sample standard deviation, desired length of confidence interval, and the desired level of confidence. This is a repetitive and iterative process. The researchers used five preliminary sets of replications to compute the first estimate of the standard deviation for the results. Based on standard deviation of the preliminary set of replications, the
researchers estimated the number of replications necessary to conduct different statistical analyses related to the performance metrics of this research (Equation 1).

**Estimation of Sample Standard Deviation**

Five replications were run to estimate the standard deviation. The following equation was used to compute standard deviation.

\[ s^2 = \frac{\sum (x - \bar{x})^2}{N-1} \]  

(Equation 1)

where:

- \( s \) = standard deviation
- \( x \) = variable for which the sample variance is desired (i.e. average number of preventive/diagnosis services)
- \( \bar{x} \) = average value of the variable produced by the model runs (i.e. average number of preventive/diagnosis services)
- \( N \) = number of model runs

**Selection of Desired Confidence Level**

In this research 95% confidence level was used with a precision of ±5%.

**Selection of Desired Confidence Interval**

The confidence interval can be defined as a range of numbers within which a true mean value of the population may lie. Smaller confidence intervals require more replications of numbers to obtain the desired level of confidence.

**Computation of Minimum Replications**

The process of obtaining the exact number of replications of a model is iterative and repetitive. Determining the number of replications in advance is impossible. Therefore, researchers need to run the model for a few runs (5) to estimate the number of
replications required to compute valid statistical results (Altiok & Melamed, 2007; Dowling, Skabardonis, & Alexiadis, 2004).

The following equation was used to obtain the desired confidence interval to be able to determine the number of replications:

\[
CI_{1-\alpha\%} = 2 \times t_{\left(1-\frac{\alpha}{2}\right), N-1} \frac{s}{\sqrt{N}} \quad \text{(Equation 2)}
\]

where:

\(CI_{(1-\text{alpha})\%}\) = (1-alpha)\% confidence interval for the true mean, where alpha equals the probability of the true mean not lying within the confidence interval

\(t_{(1-\text{alpha}/2), N-1}\) = Student's t-statistic for the probability of a two-sided error summing to alpha with N-1 degrees of freedom, where N equals the number of replications

\(s\) = standard deviation of the model results

In order to obtain the first estimate of the standard deviation (SD), the researcher ran the model for five replications in order to determine the valid number of replications.

The confidence interval (CI) is = 95% with ± 5% precision

After running the Arena model five replications, the researcher found the following daily number of preventive/diagnosis services = (23.1, 21.8, 18.5, 22.7, 17.1)

By using Arena Output Analyzer, we found that the mean = 20.64 with SD = 2.65

By using the equation:

\[
CI_{1-\alpha\%} = 2 \times t_{\left(1-\frac{\alpha}{2}\right), N-1} \frac{s}{\sqrt{N}}
\]

CI = 95% (given)
From the student's t-table when d.f = 4 and P = 0.05 the t-value is 2.776

So,

95% = 2 * 2.776 * S / √N

90% = 2 * 2.776 * 2.65 / √N

We solve for N

√N = 14.71 / .95

√N = 15.48

Therefore, N = 239.6

We concluded that the number of replications should be 240 runs.
RESULTS

Site One: Norfolk Public Health District, Little Creek's Dental Clinic

The dental clinic at Norfolk public health district has one dentist, two dental assistants, no dental hygienist and no office manager. One of the two dental assistants works as a receptionist. Patients are mainly children (0-18). Patients arrive to the clinic based on their scheduled appointments. They check in and proceed to a single dentist queue for treatment. The patients wait in a single queue until it is their turn for treatment.

As reported in this study, more than 45% of the patients are male and less than 55% are female.

Based on their individual needs, patients were categorized into two treatment categories:

- Preventive treatment: diagnosis and preventive services. This category includes new and recare patients.
- Corrective treatment: all other services except diagnosis and preventive. This category includes returning patients who have not finished their dental care plan.

Approximately 58% of patients make first or recare visits that require diagnosis and preventive services. The remaining 42% of patients make a more complex treatment, corrective treatment. When patients complete service, they leave the dental clinic after checking out with the receptionist.

The dental clinic operates from 9:00 AM to 5:00 PM each day (8 hours a day), four days a week. At the beginning of the day, the dental clinic starts empty and idle. At 5:00 PM, the entrance is locked but patients already in the queue are treated before the dental clinic closes. The performance metrics of interest are: (1) average daily patients'
visits; (2) average daily diagnosis and preventive services; (3) average daily corrective services; and (4) average daily total services.

The authors developed an Arena simulation model to determine the desired performance measures and to compute the required statistical analyses based on the two scenarios studied in this research, without a dental hygienist and with a dental hygienist.

Research Questions and Hypotheses

Research Question Two

To what extent does employing a dental hygienist affect oral health services’ delivery at a public health district dental clinic? The following specific oral health services outcomes were investigated:

a. the average number of patient visits per day at a public health district dental clinic.

b. the average number of diagnostic and preventive dental services delivered by the dentist or the dental hygienist per day at a public health district dental clinic.

c. the average number of corrective services provided by the dentist per day at a public health district dental clinic.

d. the average number of total services provided by the dentist per day at a public health district dental clinic.

Hypothesis Two

The second hypothesis stated that employing a dental hygienist has no effect on oral health services’ delivery at a public health district dental clinic.
2.a. The second hypothesis (a) stated that the average number of patients' visits per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist. Paired t-test revealed that the mean number of patients' visits per day at a public health district dental clinic which employs a dental hygienist (M = 12.85, SD = 1.10) was significantly greater compared to a public health district dental clinic with no dental hygienist (M = 6.77, SD = .88), t (239) = 93.98, p < 0.05. The 95% confidence interval for the mean differences between the two paired variables was 5.95 to 6.21. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence. This means that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 5.95 and 6.21. To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values.

2. b. The second hypothesis (b) stated that the average number of diagnostic and preventive services delivered per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist. Paired t-test revealed that the mean number of diagnostic and preventive services per day at a public health district dental clinic which employs a dental hygienist (M = 36.11, SD = 9.11) was significantly greater compared to a public health district dental clinic with no
dental hygienist (M = 20.15, SD = 7.72), t (239) = 31.61, p < 0.05. The 95% confidence interval for the mean differences between the two paired variables was 14.97 to 16.96. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence. This means that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 14.97 and 16.96.

To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values.

2.c. The second hypothesis (c) stated that the corrective services provided by the dentist per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist.

Paired t-test revealed that the mean number of corrective services per day at a public health district dental clinic which employs a dental hygienist (M = 10.10, SD = 5.74) was significantly greater compared to a public health district dental clinic with no dental hygienist (M = 4.86, SD = 4.06), t (239) = 13.27, p < 0.05. The 95% confidence interval for the mean differences between the two paired variables was 4.46 to 6.02. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence. This means that we are 95% confident that the true difference in the number of patients' visits per day
between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 4.46 and 6.02. To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values.

2.d. The second hypothesis (d) stated that the average number of total dental services per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist. Paired t-test revealed that the mean number of total dental services per day at a public health district dental clinic which employs a dental hygienist (M = 48.72, SD = 8.57) was significantly greater compared to a public health district dental clinic with no dental hygienist (M = 26.36, SD = 7.35), t (239) = 37.04, p < 0.05. The 95% confidence interval for the mean differences between the two paired variables was 21.17 to 23.55. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence. This means that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 21.17 and 23.55. To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values. All statistics results and paired t-test hypotheses testing results related to Norfolk, Little Creek's public health district's dental clinic are summarized in the following tables.
Table 8: Paired t-test statistics results, Norfolk, Little Creek

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>N</th>
<th>Std. Dev.</th>
<th>Std. Err. Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients' visits: With RDH</td>
<td>12.85</td>
<td>240</td>
<td>1.11</td>
<td>.07</td>
</tr>
<tr>
<td>Number of patients' visits: No RDH</td>
<td>6.77</td>
<td>240</td>
<td>.88</td>
<td>.06</td>
</tr>
<tr>
<td>Diagnostic and preventive services: With RDH</td>
<td>36.11</td>
<td>240</td>
<td>9.11</td>
<td>.59</td>
</tr>
<tr>
<td>Diagnostic and preventive services: No RDH</td>
<td>20.15</td>
<td>240</td>
<td>7.72</td>
<td>.49</td>
</tr>
<tr>
<td>Corrective services: with RDH</td>
<td>10.10</td>
<td>240</td>
<td>5.74</td>
<td>.37</td>
</tr>
<tr>
<td>Corrective services: no RDH</td>
<td>4.86</td>
<td>240</td>
<td>4.06</td>
<td>.26</td>
</tr>
<tr>
<td>Total dental services: with RDH</td>
<td>48.72</td>
<td>240</td>
<td>8.57</td>
<td>.55</td>
</tr>
<tr>
<td>Total dental services: No RDH</td>
<td>26.36</td>
<td>240</td>
<td>7.35</td>
<td>.47</td>
</tr>
</tbody>
</table>

Table 9: Paired t-test hypothesis testing results, Norfolk, Little Creek

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean Diff</th>
<th>Std. Dev</th>
<th>Std. Err. mean</th>
<th>95% CI of the paired difference</th>
<th>t</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients' visits: paired</td>
<td>6.08</td>
<td>1.00</td>
<td>.06</td>
<td>5.96</td>
<td>6.21</td>
<td>93.98</td>
</tr>
<tr>
<td>Diagnostic/ preventive services: paired</td>
<td>15.97</td>
<td>7.83</td>
<td>.51</td>
<td>14.97</td>
<td>16.96</td>
<td>31.61</td>
</tr>
<tr>
<td>Corrective services: paired</td>
<td>5.24</td>
<td>6.12</td>
<td>.39</td>
<td>4.46</td>
<td>6.02</td>
<td>13.27</td>
</tr>
<tr>
<td>Total dental services: paired</td>
<td>22.36</td>
<td>9.36</td>
<td>.60</td>
<td>21.17</td>
<td>23.55</td>
<td>37.04</td>
</tr>
</tbody>
</table>
Site Two: Norfolk Public Health District, Park Place's Dental Clinic

The dental clinic at Norfolk Public Health District, Park Place has one dentist, two dental assistants, no dental hygienist and no office manager. One of the two dental assistants works as a receptionist. Patients are mainly children (0-18). Patients arrive to the clinic based on their scheduled appointments. They check in and proceed to a single dentist queue for treatment. The patients wait in a single queue until it is their turn for dental care treatment.

As reported in this study, more than 44% of the patients are male and less than 56% are female.

Based on their individual needs, patients were categorized into two treatment categories:

- Preventive treatment: diagnosis and preventive services. This category includes new and recare patients.
- Corrective treatment: all other services except diagnosis and preventive. This category includes returning patients who have not finished their treatment plan.

Approximately 53% of patients make a first or recare visit that require diagnosis and preventive services. The remaining 47% of patients make a more complex treatment, corrective treatment. When patients complete service, they leave the dental clinic after checking out with the receptionist.

The dental clinic operates from 9:00 AM to 5:00 PM each day (8 hours a day), one day a week. At the beginning of the day, the dental clinic starts empty and idle. At 5:00 PM, the entrance is locked but patients already in the queue are treated before the dental clinic closes. The performance metrics of interest are: (1) average daily patients'
visits; (2) average daily diagnosis and preventive services; (3) average daily corrective services; and (4) average daily total services.

The authors developed an Arena simulation model to determine the desired performance measures and to compute the required statistical analyses relevant to this research based on the two scenarios studied in this research, without a dental hygienist and with a dental hygienist.

Research Questions and Hypotheses

Research Question Two

To what extent does employing a dental hygienist affect oral health services' delivery at a public health district dental clinic? The following specific oral health services' outcomes will be investigated:

a. the average number of patient visits per day at a public health district dental clinic.

b. the average number of diagnostic and preventive dental services delivered by the dentist or the dental hygienist per day at a public health district dental clinic.

c. the average number of corrective services provided by the dentist per day at a public health district dental clinic.

d. the average number of total services provided by the dentist per day at a public health district dental clinic.

Hypothesis Two

The second hypothesis stated that employing a dental hygienist has no affect on oral health services' delivery at a public health district dental clinic.
2.a. The second hypothesis (a) stated that the average number of patients' visits per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist. Paired t-test revealed that the mean number of patients' visits per day at a public health district dental clinic which employs a dental hygienist (M = 10.9, SD = 1.5) was significantly greater compared to a public health district dental clinic with no dental hygienist (M = 5.88, SD = 1.08), \( t(239) = 50.57, p < 0.05 \). The 95% confidence interval for the mean differences between the two paired variables was 4.90 to 5.30. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence. This means that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 4.90 and 5.30.

To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values.

2. b. The second hypothesis (b) stated that the average number of diagnostic and preventive services delivered per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist.

Paired t-test revealed that the mean number of diagnostic and preventive services per day at a public health district dental clinic which employs a dental hygienist (M = 29.03, SD = 9.121) was significantly greater compared to a public health district dental clinic with
no dental hygienist $(M = 15.94, SD = 6.727)$, $t (239) = 20.90, p < 0.05$. The 95% confidence interval for the mean differences between the two paired variables was 11.854 to 14.321. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence.

This means that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 11.854 and 14.321.

To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values.

2.c. The second hypothesis (c) stated that the corrective services provided by the dentist per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist.

Paired t-test revealed that the mean number of corrective services per day at a public health district dental clinic which employs a dental hygienist $(M = 8.33, SD = 5.424)$ was significantly greater compared to a public health district dental clinic with no dental hygienist $(M = 3.76, SD = 2.819)$, $t (239) = 11.442, p < 0.05$. The 95% confidence interval for the mean differences between the two paired variables was 3.780 to 5.353. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence.
This means that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 3.780 and 5.353.

To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values.

2.d. The second hypothesis (d) stated that the average number of total dental services per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist. Paired t-test revealed that the mean number of total dental services per day at a public health district dental clinic which employs a dental hygienist (M = 39.64, SD = 9.430) was significantly greater compared to a public health district dental clinic with no dental hygienist (M = 20.79, SD = 6.255), t (239) = 28.614, p < 0.05. The 95% confidence interval for the mean differences between the two paired variables was 17.556 to 20.152. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence.

This means that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 17.556 and 20.152.

To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values. All statistics
results and paired t-test hypotheses testing results related to Norfolk, Park Place's public health district's dental clinic are summarized in the following tables.

### Table 10: Paired t-test statistics results, Norfolk, Park Place

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>N</th>
<th>Std. Dev.</th>
<th>Std. Err. Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients' visits: With RDH</td>
<td>10.98</td>
<td>240</td>
<td>1.503</td>
<td>.097</td>
</tr>
<tr>
<td>Number of patients' visits: No RDH</td>
<td>5.88</td>
<td>240</td>
<td>1.075</td>
<td>.069</td>
</tr>
<tr>
<td>Diagnostic / preventive services: With RDH</td>
<td>29.03</td>
<td>240</td>
<td>9.121</td>
<td>.589</td>
</tr>
<tr>
<td>Diagnostic and preventive services: No RDH</td>
<td>15.94</td>
<td>240</td>
<td>6.727</td>
<td>.434</td>
</tr>
<tr>
<td>Corrective services: with RDH</td>
<td>8.33</td>
<td>240</td>
<td>5.424</td>
<td>.350</td>
</tr>
<tr>
<td>Corrective services: no RDH</td>
<td>3.76</td>
<td>240</td>
<td>2.819</td>
<td>.182</td>
</tr>
<tr>
<td>Total dental services: with RDH</td>
<td>39.64</td>
<td>240</td>
<td>9.430</td>
<td>.60</td>
</tr>
<tr>
<td>Total dental services: No RDH</td>
<td>20.79</td>
<td>240</td>
<td>6.25</td>
<td>.40</td>
</tr>
</tbody>
</table>

### Table 11: Paired t-test hypothesis testing results, Norfolk, Park Place.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean Diff.</th>
<th>Std. Dev.</th>
<th>Std. Error mean</th>
<th>95 % CI of the paired difference</th>
<th>t</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients' visits: paired</td>
<td>5.10</td>
<td>1.56</td>
<td>.101</td>
<td>4.90 5.30</td>
<td>50.5</td>
<td>.000</td>
</tr>
<tr>
<td>Diagnostic/preventive services: paired</td>
<td>13.08</td>
<td>9.70</td>
<td>.62</td>
<td>11.85 14.32</td>
<td>20.9</td>
<td>.000</td>
</tr>
<tr>
<td>Corrective services: paired</td>
<td>4.56</td>
<td>6.18</td>
<td>.399</td>
<td>3.78 5.35</td>
<td>11.4</td>
<td>.000</td>
</tr>
<tr>
<td>Total dental services: paired</td>
<td>18.85</td>
<td>10.20</td>
<td>.659</td>
<td>17.55 20.15</td>
<td>28.6</td>
<td>.000</td>
</tr>
</tbody>
</table>
Site Three: Virginia Beach Public Health District, Pembroke Dental Clinic

The dental clinic at Virginia Beach Public Health District at Pembroke has one dentist, two dental assistants, one receptionist and no dental hygienist. Patients are mainly children (0-18). Patients arrive to the clinic based on their scheduled appointments. They check in and proceed to a single dentist queue for treatment. The patients wait in a single queue until it is their turn for treatment.

As reported in this study, approximately 50% of the patients are female. Based on their individual needs, patients were categorized into two treatment categories:

- Preventive treatment: diagnosis and preventive services. This category includes new and recare patients.
- Corrective treatment: all other services except diagnosis and preventive. This category includes returning patients who have not finished their treatment plan.

Approximately 40% of patients make a first or recare visit that require diagnosis and preventive services. The remaining 60% of patients make a more complex treatment, corrective treatment. When patients complete service, they leave the dental clinic after checking out with the receptionist.

The dental clinic operates from 8:30 AM to 4:30 PM each day (8 hours a day), five days a week. At the beginning of the day, the dental clinic starts empty and idle. At 4:30 PM, the entrance is locked but patients already in the queue are treated before the dental clinic closes. The performance metrics of interest are: (1) average daily patients' visits; (2) average daily diagnosis and preventive services; (3) average daily corrective services; and (4) average daily total services.
The author developed an Arena simulation model to determine the desired performance measures and to compute the required statistical analyses relevant to this research base on the two scenarios studied in this research, without a dental hygienist and with a dental hygienist.

**Research Questions and Hypotheses**

**Research Question Two**

To what extent does employing a dental hygienist affect oral health services' delivery at a public health district dental clinic? The following specific oral health services' outcomes will be investigated:

a. the average number of patient visits per day at a public health district dental clinic.

b. the average number of diagnostic and preventive dental services delivered by the dentist or the dental hygienist per day at a public health district dental clinic.

c. the average number of corrective services provided by the dentist per day at a public health district dental clinic.

d. the average number of total services provided by the dentist per day at a public health district dental clinic.

**Hypothesis Two**

The second hypothesis stated that employing a dental hygienist has no affect on oral health services' delivery at a public health district dental clinic.
2.a. The second hypothesis (a) stated that the average number of patients' visits per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist. Paired t-test revealed that the mean number of patients' visits per day at a public health district dental clinic which employs a dental hygienist (M = 14.68, SD = 1.06) was significantly greater compared to a public health district dental clinic with no dental hygienist (M = 7.70, SD = .73), t (239) = 102.94, p < 0.05. The 95% confidence interval for the mean differences between the two paired variables was 6.84 to 7.11. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence. This means that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 6.84 and 7.11. To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values.

2. b. The second hypothesis (b) stated that the average number of diagnostic and preventive services delivered per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist. Paired t-test revealed that the mean number of diagnostic and preventive services per day at a public health district dental clinic which employs a dental hygienist (M = 48.15, SD = 21.7697) was significantly greater compared to a public health district dental clinic
with no dental hygienist \((M = 25.61, SD = 16.25), t (239) = 15.59, p < 0.05\). The 95% confidence interval for the mean differences between the two paired variables was 19.69 to 25.38. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence. This means that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 19.69 and 25.

To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values.

**2.c.** The second hypothesis (c) stated that the corrective services provided by the dentist per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist.

Paired t-test revealed that the mean number of corrective services per day at a public health district dental clinic which employs a dental hygienist \((M = 6.225, SD = 2.42)\) was significantly greater compared to a public health district dental clinic with no dental hygienist \((M = 3.16, SD = 1.60), t (239) = 00.00, p < 0.05\). The 95% confidence interval for the mean differences between the two paired variables was 2.73 to 3.38. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence. This means that we are 95% confident that the true difference in the number of patients' visits per day
between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 2.73 and 3.38. To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values.

2.d. The second hypothesis (d) stated that the average number of total dental services per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist. Paired t-test revealed that the mean number of total dental services per day at a public health district dental clinic which employs a dental hygienist (M = 61.46, SD = 20.53) was significantly greater compared to a public health district dental clinic with no dental hygienist (M = 32.49, SD = 15.20), t (239) = 20.48, p < 0.05. The 95% confidence interval for the mean differences between the two paired variables was 26.18 to 31.75. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence. This means that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 26.18 and 31.75. To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values. All statistics results and paired t-test hypotheses testing results related to Virginia Beach, Pembroke's public health district's dental clinic are summarized in the following tables.
Table 12: Paired t-test statistics results, Virginia Beach, Pembroke

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>N</th>
<th>Std. Dev.</th>
<th>Std. Err. Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients' visits: With RDH</td>
<td>14.68</td>
<td>240</td>
<td>1.06</td>
<td>.06</td>
</tr>
<tr>
<td>Number of patients' visits: No RDH</td>
<td>7.70</td>
<td>240</td>
<td>.73</td>
<td>.04</td>
</tr>
<tr>
<td>Diagnostic/ preventive services: With RDH</td>
<td>48.15</td>
<td>240</td>
<td>21.76</td>
<td>1.40</td>
</tr>
<tr>
<td>Diagnostic and preventive services: No RDH</td>
<td>25.61</td>
<td>240</td>
<td>16.25</td>
<td>1.04</td>
</tr>
<tr>
<td>Corrective services: with RDH</td>
<td>6.22</td>
<td>240</td>
<td>2.42</td>
<td>.15</td>
</tr>
<tr>
<td>Corrective services: no RDH</td>
<td>3.16</td>
<td>240</td>
<td>1.60</td>
<td>.10</td>
</tr>
<tr>
<td>Total dental services: with RDH</td>
<td>61.46</td>
<td>240</td>
<td>20.53</td>
<td>1.32</td>
</tr>
<tr>
<td>Total dental services: No RDH</td>
<td>32.49</td>
<td>240</td>
<td>15.20</td>
<td>.98</td>
</tr>
</tbody>
</table>

Table 13: Paired t-test hypothesis testing results, Virginia Beach, Pembroke.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean Diff.</th>
<th>Std. Dev.</th>
<th>Std. Err. mean</th>
<th>95% CI of the paired difference</th>
<th>t</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients' visits: paired</td>
<td>6.98</td>
<td>1.05</td>
<td>.067</td>
<td>6.84, 7.11</td>
<td>102.9</td>
<td>.000</td>
</tr>
<tr>
<td>Diagnostic and preventive services: paired</td>
<td>22.54</td>
<td>22.39</td>
<td>1.44</td>
<td>19.69, 25.38</td>
<td>15.59</td>
<td>.000</td>
</tr>
<tr>
<td>Corrective services: paired</td>
<td>3.05</td>
<td>2.53</td>
<td>.16</td>
<td>2.73, 3.38</td>
<td>18.70</td>
<td>.000</td>
</tr>
<tr>
<td>Total dental services: paired</td>
<td>28.97</td>
<td>21.91</td>
<td>1.41</td>
<td>26.18, 31.75</td>
<td>20.48</td>
<td>.000</td>
</tr>
</tbody>
</table>
Site Four: Virginia Beach Public Health District, Birdneck's Dental Clinic

The dental clinic at Virginia Beach, Birdneck has one part-time dentist, no dental hygienist, no office manager, a temporary dental assistant plus one of the main clinic dental assistants who works as receptionist, handles administrative tasks and assists as needed. Birdneck site opens only on Mondays. Clinic does not operate if dentist is absent. Patients are mainly children (0-18). Patients arrive to the clinic based on their scheduled appointments. They check in and proceed to a single dentist queue for treatment. The patients wait in a single queue until it is their turn for treatment.

As reported in this study, more than 51% of the patients are male and less than 49% are female.

Based on their individual needs, patients were categorized into two treatment categories:

- Preventive treatment: diagnosis and preventive services. This category includes new and recare patients.
- Corrective treatment: all other services except diagnosis and preventive. This category includes returning patients who have not finished their treatment plan.

Approximately 47% of patients make a first or recare visit that require diagnosis and preventive services. The remaining 53% of patients make a more complex treatment, corrective treatment. When patients complete service, they leave the dental clinic after checking out with the receptionist.

The dental clinic operates from 9:00 AM to 5:00 PM each day (8 hours a day), one day a week (Monday). At the beginning of the day, the dental clinic starts empty and idle. At 5:00 PM, the entrance is locked but patients already in the queue are treated before the dental clinic closes. The performance metrics of interest are: (1) average daily
patients' visits; (2) average daily diagnosis and preventive services; (3) average daily corrective services; and (4) average daily total services.

The authors developed an Arena simulation model to determine the desired performance measures and to compute the required statistical analyses relevant to this research based on the two scenarios studied in this research, without a dental hygienist and with a dental hygienist.

Research Questions and Hypotheses

Research Question Two

To what extent does employing a dental hygienist affect oral health services' delivery at a public health district dental clinic? The following specific oral health services' outcomes will be investigated:

a. the average number of patient visits per day at a public health district dental clinic.

b. the average number of diagnostic and preventive dental services delivered by the dentist or the dental hygienist per day at a public health district dental clinic.

c. the average number of corrective services provided by the dentist per day at a public health district dental clinic.

d. the average number of total services provided by the dentist per day at a public health district dental clinic.

Hypothesis Two

The second hypothesis stated that employing a dental hygienist has no affect on oral health services' delivery at a public health district dental clinic.
2.a. The second hypothesis (a) stated that the average number of patients' visits per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist. Paired t-test revealed that the mean number of patients' visits per day at a public health district dental clinic which employs a dental hygienist (M = 13.25, SD = 2.24) was significantly greater compared to a public health district dental clinic with no dental hygienist (M = 7.05, SD = 1.54), t (239) = 54.67, p < 0.05. The 95% confidence interval for the mean differences between the two paired variables was 5.98 to 6.43. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence. This means that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 5.98 and 6.43.

To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values.

2. b. The second hypothesis (b) stated that the average number of diagnostic and preventive services delivered per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist. Paired t-test revealed that the mean number of diagnostic and preventive services per day at a public health district dental clinic which employs a dental hygienist (M = 33.27, SD = 12.10) was significantly greater compared to a public health district dental clinic with
no dental hygienist (M = 18.21, SD = 9.17), t (239) = 22.51, p < 0.05. The 95% confidence interval for the mean differences between the two paired variables was 13.74 to 16.38. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence.

This means that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 13.74 and 16.38.

To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values.

2.c. The second hypothesis (c) stated that the corrective services provided by the dentist per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist.

Paired t-test revealed that the mean number of corrective services per day at a public health district dental clinic which employs a dental hygienist (M = 10.90, SD = 4.66) was significantly greater compared to a public health district dental clinic with no dental hygienist (M = 5.76, SD = 3.72), t (239) = 15.03, p < 0.05. The 95% confidence interval for the mean differences between the two paired variables was 4.46 to 5.81. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence. This means
that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 4.46 and 5.81.

To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values.

**2.d.** The second hypothesis (d) stated that the average number of total dental services per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist. Paired t-test revealed that the mean number of total dental services per day at a public health district dental clinic which employs a dental hygienist (M = 49.01, SD = 11.57) was significantly greater compared to a public health district dental clinic with no dental hygienist (M = 26.45, SD = 9.41), t (239) = 31.32, p < 0.05. The 95% confidence interval for the mean differences between the two paired variables was 21.13 to 23.97. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence.

This means that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 21.13 and 23.97.

To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values. All statistics
results and paired t-test hypotheses testing results related to Virginia Beach, Birdneck's public health district's dental clinic are summarized in the following tables.

Table 14: Paired t-test statistics results, Virginia Beach, Birdneck

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>N</th>
<th>Std. Dev.</th>
<th>Std. Err. Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients' visits: With RDH</td>
<td>13.25</td>
<td>240</td>
<td>2.24</td>
<td>.14</td>
</tr>
<tr>
<td>Number of patients' visits: No RDH</td>
<td>7.05</td>
<td>240</td>
<td>1.54</td>
<td>.09</td>
</tr>
<tr>
<td>Diagnostic and preventive services: With RDH</td>
<td>33.27</td>
<td>240</td>
<td>12.10</td>
<td>.78</td>
</tr>
<tr>
<td>Diagnostic and preventive services: No RDH</td>
<td>18.21</td>
<td>240</td>
<td>9.17</td>
<td>.59</td>
</tr>
<tr>
<td>Corrective services: with RDH</td>
<td>10.90</td>
<td>240</td>
<td>4.66</td>
<td>.30</td>
</tr>
<tr>
<td>Corrective services: no RDH</td>
<td>5.76</td>
<td>240</td>
<td>3.72</td>
<td>.24</td>
</tr>
<tr>
<td>Total dental services: with RDH</td>
<td>49.01</td>
<td>240</td>
<td>11.57</td>
<td>.74</td>
</tr>
<tr>
<td>Total dental services: No RDH</td>
<td>26.45</td>
<td>240</td>
<td>9.41</td>
<td>.60</td>
</tr>
</tbody>
</table>

Table 15: Paired t-test hypothesis testing results, Virginia Beach, Birdneck.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean Diff.</th>
<th>Std. Dev.</th>
<th>Std. Err. mean</th>
<th>95 % CI of the paired difference</th>
<th>t</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients' visits: paired</td>
<td>6.20</td>
<td>1.75</td>
<td>.11</td>
<td>5.98 - 6.43</td>
<td>54.67</td>
<td>.000</td>
</tr>
<tr>
<td>Diagnostic and preventive services: paired</td>
<td>15.06</td>
<td>10.36</td>
<td>.6693</td>
<td>13.74 - 16.38</td>
<td>22.51</td>
<td>.000</td>
</tr>
<tr>
<td>Corrective services: paired</td>
<td>5.13</td>
<td>5.29</td>
<td>.34</td>
<td>4.46 - 5.81</td>
<td>15.03</td>
<td>.000</td>
</tr>
<tr>
<td>Total services: paired</td>
<td>22.5</td>
<td>11.15</td>
<td>.72</td>
<td>21.13 - 23.97</td>
<td>31.32</td>
<td>.000</td>
</tr>
</tbody>
</table>
Site Five: Hampton Public Health District Dental Clinic

The dental clinic at Hampton has one dentist, one dental assistant, no dental hygienist and no office manager. Patients are mainly children (0-18). Patients arrive to the clinic based on their scheduled appointments. They check in and proceed to a single dentist queue for treatment. The patients wait in a single queue until it is their turn for treatment. As reported in this study, more than 49% of the patients are male and less than 51% are female.

Based on their individual needs, patients were categorized into two treatment categories:

- Preventive treatment: diagnosis and preventive services. This category includes new and recare patients.
- Corrective treatment: all other services except diagnosis and preventive. This category includes returning patients who have not finished their treatment plan.

Approximately 80% of patients make a first or recare visit that require diagnosis and preventive services. The remaining 20% of patients make a more complex treatment, corrective treatment. When patients complete service, they leave the dental clinic after checking out with the receptionist.

The dental clinic operates from 9:00 AM to 5:00 PM each day (8 hours a day), five days a week. At the beginning of the day, the dental clinic starts empty and idle. At 5:00 PM, the entrance is locked but patients already in the queue are treated before the dental clinic closes. The performance metrics of interest are: (1) average daily patients' visits; (2) average daily diagnosis and preventive services; (3) average daily corrective services; and (4) average daily total services.
The author developed an Arena simulation model to determine the desired performance measures and to compute the required statistical analyses relevant to this research based on the two scenarios studied in this research, without a dental hygienist and with a dental hygienist.

**Research Questions and Hypotheses**

**Research Question Two**

To what extent does employing a dental hygienist affect oral health services' delivery at a public health district dental clinic? The following specific oral health services' outcomes will be investigated:

a. the average number of patient visits per day at a public health district dental clinic.

b. the average number of diagnostic and preventive dental services delivered by the dentist or the dental hygienist per day at a public health district dental clinic.

c. the average number of corrective services provided by the dentist per day at a public health district dental clinic.

d. the average number of total services provided by the dentist per day at a public health district dental clinic.

**Hypothesis Two**

The second hypothesis stated that employing a dental hygienist has no affect on oral health services' delivery at a public health district dental clinic.
2.a. The second hypothesis (a) stated that the average number of patients' visits per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist. Paired t-test revealed that the mean number of patients' visits per day at a public health district dental clinic which employs a dental hygienist (M = 10.042, SD = 1.88) was significantly greater compared to a public health district dental clinic with no dental hygienist (M = 7.317, SD = .9417), t (239) = 20.51, p < 0.05. The 95% confidence interval for the mean differences between the two paired variables was 2.46 to 2.98. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence. This means that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 2.46 and 2.98.

To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values.

2. b. The second hypothesis (b) stated that the average number of diagnostic and preventive services delivered per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist. Paired t-test revealed that the mean number of diagnostic and preventive services per day at a public health district dental clinic which employs a dental hygienist (M = 34.00, SD
was significantly greater compared to a public health district dental clinic with no dental hygienist (M = 31.94, SD = 7.98), t (239) = 3.08, p < 0.05. The 95% confidence interval for the mean differences between the two paired variables was .74 to 3.38. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence. This means that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 0.74 and 3.38.

To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values.

2.c. The second hypothesis (c) stated that the corrective services provided by the dentist per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist.

Paired t-test revealed that the mean number of corrective services per day at a public health district dental clinic which employs a dental hygienist (M = 3.37, SD = 3.45) was significantly greater compared to a public health district dental clinic with no dental hygienist (M = 1.63, SD = 2.23), t (239) = 00.00, p < 0.05. The 95% confidence interval for the mean differences between the two paired variables was 1.26 to 2.22. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence. This means
that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 1.26 and 2.22.

To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values.

2.d. The second hypothesis (d) stated that the average number of total dental services per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist. Paired t-test revealed that the mean number of total dental services per day at a public health district dental clinic which employs a dental hygienist (M = 39.35, SD = 8.31) was significantly greater compared to a public health district dental clinic with no dental hygienist (M = 34.64, SD = 7.77), t (239) = 6.63, p < 0.05. The 95% confidence interval for the mean differences between the two paired variables was 3.31 to 6.10. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence.

This means that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 3.31 and 6.10.

To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values. All statistics
results and paired t-test hypotheses testing results related to Hampton's public health district's dental clinic are summarized in the following tables.

Table 16: Paired t-test statistics results, Hampton.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>N</th>
<th>Std. Dev.</th>
<th>Std. Err. Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients' visits: With RDH</td>
<td>10.04</td>
<td>240</td>
<td>1.88</td>
<td>.12</td>
</tr>
<tr>
<td>Number of patients' visits: No RDH</td>
<td>7.31</td>
<td>240</td>
<td>.94</td>
<td>.06</td>
</tr>
<tr>
<td>Diagnostic and preventive services: With RDH</td>
<td>34.00</td>
<td>240</td>
<td>7.18</td>
<td>.46</td>
</tr>
<tr>
<td>Diagnostic and preventive services: No RDH</td>
<td>31.94</td>
<td>240</td>
<td>7.98</td>
<td>.51</td>
</tr>
<tr>
<td>Corrective services: with RDH</td>
<td>3.37</td>
<td>240</td>
<td>3.45</td>
<td>.22</td>
</tr>
<tr>
<td>Corrective services: no RDH</td>
<td>1.63</td>
<td>240</td>
<td>2.23</td>
<td>.14</td>
</tr>
<tr>
<td>Total dental services: with RDH</td>
<td>39.35</td>
<td>240</td>
<td>8.31</td>
<td>.53</td>
</tr>
<tr>
<td>Total dental services: No RDH</td>
<td>34.64</td>
<td>240</td>
<td>7.77</td>
<td>.50</td>
</tr>
</tbody>
</table>

Table 17: Paired t-test hypothesis testing results, Hampton.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean Diff.</th>
<th>Std. Dev.</th>
<th>Std. Err. mean</th>
<th>95 % CI of the paired difference</th>
<th>t</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients' visits: paired</td>
<td>2.72</td>
<td>2.05</td>
<td>.13</td>
<td>2.46</td>
<td>2.98</td>
<td>20.5</td>
</tr>
<tr>
<td>Diagnostic and preventive services: paired</td>
<td>2.06</td>
<td>10.37</td>
<td>.66</td>
<td>.74</td>
<td>3.38</td>
<td>3.0</td>
</tr>
<tr>
<td>Corrective services: paired</td>
<td>1.74</td>
<td>3.75</td>
<td>.24</td>
<td>1.26</td>
<td>2.22</td>
<td>7.2</td>
</tr>
<tr>
<td>Total services: paired</td>
<td>4.70</td>
<td>10.99</td>
<td>.70</td>
<td>3.31</td>
<td>6.10</td>
<td>6.6</td>
</tr>
</tbody>
</table>
Site Six: Peninsula Public Health District Dental Clinic

The dental clinic at Peninsula has two dentists, two dental assistants, no dental hygienist and one office manager. Patients are mainly children (0-18). Patients arrive to the clinic based on their scheduled appointments. They check in and proceed to a single dentist queue for treatment. The patients wait in a single queue until it is their turn for treatment. As reported in this study, more than 38% of the patients are male and less than 62% are female.

Based on their individual needs, patients were categorized into two treatment categories:

- Preventive treatment: diagnosis and preventive services. This category includes new and recare patients.

- Corrective treatment: all other services except diagnosis and preventive. This category includes returning patients who have not finished their treatment plan.

Approximately 77% of patients make a first or recare visit that require diagnosis and preventive services. The remaining 23% of patients make a more complex treatment, corrective treatment. When patients complete service, they leave the dental clinic after checking out with the receptionist.

The dental clinic operates from 9:00 AM to 5:00 PM each day (8 hours a day), five days a week. At the beginning of the day, the dental clinic starts empty and idle. At 5:00 PM, the entrance is locked but patients already in the queue are treated before the dental clinic closes. The performance metrics of interest are: (1) average daily patients' visits; (2) average daily diagnosis and preventive services; (3) average daily corrective services; and (4) average daily total services.
The author developed an Arena simulation model to determine the desired performance measures and to compute the required statistical analyses relevant to this research based on the two scenarios studied in this research, without a dental hygienist and with a dental hygienist.

**Research Questions and Hypotheses**

**Research Question Two**

To what extent does employing a dental hygienist affect oral health services’ delivery at a public health district dental clinic? The following specific oral health services’ outcomes will be investigated:

a. the average number of patient visits per day at a public health district dental clinic.

b. the average number of diagnostic and preventive dental services delivered by the dentist or the dental hygienist per day at a public health district dental clinic.

c. the average number of corrective services provided by the dentist per day at a public health district dental clinic.

d. the average number of total services provided by the dentist per day at a public health district dental clinic.

**Hypothesis Two**

The second hypothesis stated that employing a dental hygienist has no affect on oral health services’ delivery at a public health district dental clinic.
2. a. The second hypothesis (a) stated that the average number of patients' visits per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist. Paired t-test revealed that the mean number of patients' visits per day at a public health district dental clinic which employs a dental hygienist (M = 16.66, SD = 1.80) was significantly greater compared to a public health district dental clinic with no dental hygienist (M = 10.25, SD = 1.69), t (239) = 44.80, p < 0.05. The 95% confidence interval for the mean differences between the two paired variables was 6.12 to 6.68. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence. This means that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 6.12 and 6.68.

To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values.

2. b. The second hypothesis (b) stated that the average number of diagnostic and preventive services delivered per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist.

Paired t-test revealed that the mean number of diagnostic and preventive services per day at a public health district dental clinic which employs a dental hygienist (M = 37.27, SD
= 7.70) was significantly greater compared to a public health district dental clinic with no dental hygienist (M = 24.28, SD = 7.23), t (239) = 21.74, p < 0.05. The 95% confidence interval for the mean differences between the two paired variables was 11.81 to 14.17. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence. This means that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 11.81 and 14.17.

To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values.

2.c. The second hypothesis (c) stated that the corrective services provided by the dentist per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist.

Paired t-test revealed that the mean number of corrective services per day at a public health district dental clinic which employs a dental hygienist (M = 15.74, SD = 9.13) was significantly greater compared to a public health district dental clinic with no dental hygienist (M = 7.87, SD = 6.46), t (239) = 11.35, p < 0.05. The 95% confidence interval for the mean differences between the two paired variables was 6.50 to 9.23. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence. This means
that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 6.50 and 9.23. To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values.

2.d. The second hypothesis (d) stated that the average number of total dental services per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist. Paired t-test revealed that the mean number of total dental services per day at a public health district dental clinic which employs a dental hygienist (M = 151.67, SD = 64.50) was significantly greater compared to a public health district dental clinic with no dental hygienist (M = 79.85, SD = 42.66), t (239) = 15.98, p < 0.05. The 95% confidence interval for the mean differences between the two paired variables was 62.96 to 80.66. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence. This means that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 62.96 and 80.66. To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values. All statistics
results and paired t-test hypotheses testing results related to Peninsula's public health
district's dental clinic are summarized in the following tables.

Table 18: Paired t-test statistics results, Peninsula.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>N</th>
<th>Std. Dev</th>
<th>Std. Err. Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients' visits: With RDH</td>
<td>16.66</td>
<td>240</td>
<td>1.80</td>
<td>.11</td>
</tr>
<tr>
<td>Number of patients' visits: No RDH</td>
<td>10.25</td>
<td>240</td>
<td>1.69</td>
<td>.10</td>
</tr>
<tr>
<td>Diagnostic/ preventive services: With RDH</td>
<td>37.27</td>
<td>240</td>
<td>7.70</td>
<td>.49</td>
</tr>
<tr>
<td>Diagnostic and preventive services: No RDH</td>
<td>24.28</td>
<td>240</td>
<td>7.23</td>
<td>.46</td>
</tr>
<tr>
<td>Corrective services: with RDH</td>
<td>15.74</td>
<td>240</td>
<td>9.13</td>
<td>.58</td>
</tr>
<tr>
<td>Corrective services: no RDH</td>
<td>7.87</td>
<td>240</td>
<td>6.46</td>
<td>.41</td>
</tr>
<tr>
<td>Total dental services: with RDH</td>
<td>151.67</td>
<td>240</td>
<td>64.50</td>
<td>4.16</td>
</tr>
<tr>
<td>Total dental services: No RDH</td>
<td>79.85</td>
<td>240</td>
<td>42.66</td>
<td>2.75</td>
</tr>
</tbody>
</table>

Table 19: Paired t-test hypothesis testing results, Peninsula.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean Diff</th>
<th>Std. Dev</th>
<th>Std. Err. mean</th>
<th>95 % CI of the paired difference</th>
<th>t</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients' visits: paired</td>
<td>6.40</td>
<td>2.21</td>
<td>.142</td>
<td>6.12 to 6.68</td>
<td>44.80</td>
<td>.000</td>
</tr>
<tr>
<td>Diagnostic and preventive services: paired</td>
<td>12.99</td>
<td>9.25</td>
<td>.59</td>
<td>11.81 to 14.17</td>
<td>21.74</td>
<td>.000</td>
</tr>
<tr>
<td>Corrective services: paired</td>
<td>7.87</td>
<td>10.74</td>
<td>.69</td>
<td>6.50 to 9.23</td>
<td>11.35</td>
<td>.000</td>
</tr>
<tr>
<td>Total dental services: paired</td>
<td>71.81</td>
<td>69.61</td>
<td>4.49</td>
<td>62.96 to 80.66</td>
<td>15.98</td>
<td>.000</td>
</tr>
</tbody>
</table>
Site Seven: Western Tidewater Public Health District, Isle of Wight Dental Clinic

Western Tidewater Health District Dental Clinic has one dentist, no hygienist and one dental assistant. There are two part time secretaries who do the billing and eligibility. They work about twenty hours a week. The full time employees work forty hours per week. Patients are mainly children (0-18). Patients arrive to the clinic based on their scheduled appointments. They check in and proceed to a single dentist queue for treatment. The patients wait in a single queue until it is their turn for treatment.

As reported in this study, more than 41% of the patients are male and less than 59% are female.

Based on their individual needs, patients were categorized into two treatment categories:

- Preventive treatment: diagnosis and preventive services. This category includes new and recare patients.
- Corrective treatment: all other services except diagnosis and preventive. This category includes returning patients who have not finished their treatment plan.

Approximately 72% of patients make a first or recare visit that require diagnosis and preventive services. The remaining 28% of patients make a more complex treatment, corrective treatment. When patients complete service, they leave the dental clinic after checking out with the receptionist.

The dental clinic operates from 9:00 AM to 5:00 PM each day (8 hours a day), two days a week (Monday and Wednesday). At the beginning of the day, the dental clinic starts empty and idle. At 5:00 PM, the entrance is locked but patients already in the queue are treated before the dental clinic closes. The performance metrics of interest
are: (1) average daily patients' visits; (2) average daily diagnosis and preventive services; (3) average daily corrective services; and (4) average daily total services.

The author developed an Arena simulation model to determine the desired performance measures and to compute the required statistical analyses relevant to this research based on the two scenarios studied in this research, without a dental hygienist and with a dental hygienist.

**Research Questions and Hypotheses**

*Research Question Two*

To what extent does employing a dental hygienist affect oral health services' delivery at a public health district dental clinic? The following specific oral health services' outcomes will be investigated:

a. the average number of patient visits per day at a public health district dental clinic.

b. the average number of diagnostic and preventive dental services delivered by the dentist or the dental hygienist per day at a public health district dental clinic.

c. the average number of corrective services provided by the dentist per day at a public health district dental clinic.

d. the average number of total services provided by the dentist per day at a public health district dental clinic.
Hypothesis Two

The second hypothesis stated that employing a dental hygienist has no affect on oral health services’ delivery at a public health district dental clinic.

2.a. The second hypothesis (a) stated that the average number of patients' visits per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist. Paired t-test revealed that the mean number of patients' visits per day at a public health district dental clinic which employs a dental hygienist (M = 14.35, SD = 1.35) was significantly greater compared to a public health district dental clinic with no dental hygienist (M = 7.67, SD = 1.06), t (239) = 85.32, p < 0.05. The 95% confidence interval for the mean differences between the two paired variables was 6.52 to 6.83. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence. This means that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 6.52 and 6.83. To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values.

2. b. The second hypothesis (b) stated that the average number of diagnostic and preventive services delivered per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist.
Paired t-test revealed that the mean number of diagnostic and preventive services per day at a public health district dental clinic which employs a dental hygienist (M = 51.40, SD = 9.88) was significantly greater compared to a public health district dental clinic with no dental hygienist (M = 28.29, SD = 8.45), t (239) = 41.91, p < 0.05. The 95% confidence interval for the mean differences between the two paired variables was 22.02 to 24.19. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence. This means that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 22.02 and 24.19.

To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values.

2.c. The second hypothesis (c) stated that the corrective services provided by the dentist per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist.

Paired t-test revealed that the mean number of corrective services per day at a public health district dental clinic which employs a dental hygienist (M = 24.79, SD = 16.15) was significantly greater compared to a public health district dental clinic with no dental hygienist (M = 12.88, SD = 10.71), t (239) = 11.13, p < 0.05. The 95% confidence interval for the mean differences between the two paired variables was 9.80 to 14.01.
Since the confidence interval does not include zero, we can say that there is significant
difference between the means of the two populations at the 95% level of confidence.
This means that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 9.80 and 14.01.
To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values.

2.d. The second hypothesis (d) stated that the average number of total dental services per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist. Paired t-test revealed that the mean number of total dental services per day at a public health district dental clinic which employs a dental hygienist (M = 97.42, SD = 23.97) was significantly greater compared to a public health district dental clinic with no dental hygienist (M = 52.31, SD = 17.07), t (239) = 29.35, p < 0.05. The 95% confidence interval for the mean differences between the two paired variables was 42.08 to 48.14. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence. This means that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 42.08 and 48.14.
To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values. All statistics results and paired t-test hypotheses testing results related to Western Tidewater, Isle of Wight's public health district's dental clinic are summarized in the following tables.

Table 20: Paired t-test statistics results, Western Tidewater, Isle of Wight.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>N</th>
<th>Std. Dev.</th>
<th>Std. Err. Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients' visits: With RDH</td>
<td>14.35</td>
<td>240</td>
<td>1.35</td>
<td>.08</td>
</tr>
<tr>
<td>Number of patients' visits: No RDH</td>
<td>7.67</td>
<td>240</td>
<td>1.06</td>
<td>.06</td>
</tr>
<tr>
<td>Diagnostic/ preventive services: With RDH</td>
<td>51.40</td>
<td>240</td>
<td>9.88</td>
<td>.63</td>
</tr>
<tr>
<td>Diagnostic/ preventive services: No RDH</td>
<td>28.29</td>
<td>240</td>
<td>8.45</td>
<td>.54</td>
</tr>
<tr>
<td>Corrective services: with RDH</td>
<td>24.79</td>
<td>240</td>
<td>16.15</td>
<td>1.04</td>
</tr>
<tr>
<td>Corrective services: no RDH</td>
<td>12.88</td>
<td>240</td>
<td>10.71</td>
<td>.69</td>
</tr>
<tr>
<td>Total dental services: with RDH</td>
<td>97.42</td>
<td>240</td>
<td>23.97</td>
<td>1.54</td>
</tr>
<tr>
<td>Total dental services: No RDH</td>
<td>52.31</td>
<td>240</td>
<td>17.07</td>
<td>1.10</td>
</tr>
</tbody>
</table>

Table 21: Paired t-test hypothesis testing results, Western Tidewater, Isle of Wight.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean Diff.</th>
<th>Std. Dev.</th>
<th>Std. Err. mean</th>
<th>95 % CI of the paired difference</th>
<th>t</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients' visits: paired</td>
<td>6.68</td>
<td>1.21</td>
<td>.07</td>
<td>6.52</td>
<td>6.83</td>
<td>85.32</td>
</tr>
<tr>
<td>Diagnostic and preventive services: paired</td>
<td>23.1</td>
<td>8.54</td>
<td>.55</td>
<td>22.02</td>
<td>24.19</td>
<td>41.9</td>
</tr>
<tr>
<td>Corrective services: paired</td>
<td>11.9</td>
<td>16.57</td>
<td>1.07</td>
<td>9.80</td>
<td>14.01</td>
<td>11.13</td>
</tr>
<tr>
<td>Total dental services: paired</td>
<td>45.1</td>
<td>23.80</td>
<td>1.53</td>
<td>42.08</td>
<td>48.14</td>
<td>29.35</td>
</tr>
</tbody>
</table>
Site Eight: Western Tidewater Public Health District, Southampton Dental Clinic

The dental clinic at Western Tidewater, Southampton has one dentist, no hygienist and one dental assistant. There are two part time secretaries who do the billing and eligibility. They work about twenty hours a week. The full time employees work forty hours per week. Patients are mainly children (0-18). Patients arrive to the clinic based on their scheduled appointments. They check in and proceed to a single dentist queue for treatment. The patients wait in a single queue until it is their turn for treatment.

As reported in this study, more than 41% of the patients are male and less than 59% are female.

Based on their individual needs, patients were categorized into two treatment categories:

- Preventive treatment: diagnosis and preventive services. This category includes new and recare patients.

- Corrective treatment: all other services except diagnosis and preventive. This category includes returning patients who have not finished their treatment plan.

Approximately 74% of patients make a first or recare visit that require diagnosis and preventive services. The remaining 26% of patients make a more complex treatment, corrective treatment. When patients complete service, they leave the dental clinic after checking out with the receptionist.

The dental clinic operates from 9:00 AM to 5:00 PM each day (8 hours a day), two days a week (Tuesday and Thursday). At the beginning of the day, the dental clinic starts empty and idle. At 5:00 PM, the entrance is locked but patients already in the queue are treated before the dental clinic closes. The performance metrics of interest are:
(1) average daily patients' visits; (2) average daily diagnosis and preventive services; (3) average daily corrective services; and (4) average daily total services.

The authors developed an Arena simulation model to determine the desired performance measures and to compute the required statistical analyses relevant to this research based on the two scenarios studied in this research, without a dental hygienist and with a dental hygienist.

Research Questions and Hypotheses

Research Question Two

To what extent does employing a dental hygienist affect oral health services' delivery at a public health district dental clinic? The following specific oral health services’ outcomes will be investigated:

a. the average number of patient visits per day at a public health district dental clinic.

b. the average number of diagnostic and preventive dental services delivered by the dentist or the dental hygienist per day at a public health district dental clinic.

c. the average number of corrective services provided by the dentist per day at a public health district dental clinic.

d. the average number of total services provided by the dentist per day at a public health district dental clinic.
Hypothesis Two

The second hypothesis stated that employing a dental hygienist has no affect on oral health services' delivery at a public health district dental clinic.

2.a. The second hypothesis (a) stated that the average number of patients' visits per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist.

Paired t-test revealed that the mean number of patients' visits per day at a public health district dental clinic which employs a dental hygienist ($M = 15.02, SD = 2.03$) was significantly greater compared to a public health district dental clinic with no dental hygienist ($M = 9.23, SD = 1.55$), $t (239) = 36.39, p < 0.05$. The 95% confidence interval for the mean differences between the two paired variables was 5.47 to 6.10. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two populations at the 95% level of confidence. This means that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 5.47 and 6.10.

To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values.

2. b. The second hypothesis (b) stated that the average number of diagnostic and preventive services delivered per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist.
Paired t-test revealed that the mean number of diagnostic and preventive services per day at a public health district dental clinic which employs a dental hygienist ($M = 65.27, SD = 9.79$) was significantly greater compared to a public health district dental clinic with no dental hygienist ($M = 42.68, SD = 12.34$), $t(239) = 26.39, p < 0.05$. The 95% confidence interval for the mean differences between the two paired variables was 20.90 to 24.27. Since the confidence interval does not include zero, we can say that there is significant difference between the means of the two population at the 95% level of confidence. This means that we are 95% confident that the true difference in the number of patients' visits per day between a public health district dental clinic which employs a dental hygienist and a public health district dental clinic with no dental hygienist is between 20.90 and 24.27.

To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values.

2.c. The second hypothesis (c) stated that the corrective services provided by the dentist per day at a public health district dental clinic which employs a dental hygienist will increase significantly compared to a public health district dental clinic with no dental hygienist. Paired t-test revealed that the mean number of corrective services per day at a public health district dental clinic which employs a dental hygienist ($M = 19.44, SD = 10.50$) was significantly greater compared to a public health district dental clinic with no dental hygienist ($M = 10.18, SD = 6.72$), $t(239) = 13.35, p < 0.05$. The 95% confidence interval for the mean differences between the two paired variables was 7.89 to 10.62.
Since the confidence interval does not include zero, we can say that there is significant
difference between the means of the two populations at the 95% level of confidence.
This means that we are 95% confident that the true difference in the number of patients'
visits per day between a public health district dental clinic which employs a dental
hygienist and a public health district dental clinic with no dental hygienist is between
7.89 and 10.62.
To confirm the results, the repeated-measures ANOVA was conducted because paired t-
test and repeated-measures ANOVA should always yield identical p values.

2.d. The second hypothesis (d) stated that the average number of total dental services per
day at a public health district dental clinic which employs a dental hygienist will increase
significantly compared to a public health district dental clinic with no dental hygienist.
Paired t-test revealed that the mean number of total dental services per day at a public
health district dental clinic which employs a dental hygienist (M = 98.09, SD = 17.68)
was significantly greater compared to a public health district dental clinic with no dental
hygienist (M = 60.65, SD = 12.05), t (239) = 28.59, p < 0.05. The 95% confidence
interval for the mean differences between the two paired variables was 34.86 to 40.02.
Since the confidence interval does not include zero, we can say that there is significant
difference between the means of the two populations at the 95% level of confidence.
This means that we are 95% confident that the true difference in the number of patients'
visits per day between a public health district dental clinic which employs a dental
hygienist and a public health district dental clinic with no dental hygienist is between
34.86 and 40.02.
To confirm the results, the repeated-measures ANOVA was conducted because paired t-test and repeated-measures ANOVA should always yield identical p values. All statistics results and paired t-test hypotheses testing results related to Western Tidewater, Southampton's public health district's dental clinic are summarized in the following tables.

Table 22: Paired t-test statistics results, Western Tidewater, Southampton.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>N</th>
<th>Std. Dev.</th>
<th>Std. Err. Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients' visits: With RDH</td>
<td>15.02</td>
<td>240</td>
<td>2.03</td>
<td>.13</td>
</tr>
<tr>
<td>Number of patients' visits: No RDH</td>
<td>9.23</td>
<td>240</td>
<td>1.55</td>
<td>.10</td>
</tr>
<tr>
<td>Diagnostic/ preventive services: With RDH</td>
<td>65.27</td>
<td>240</td>
<td>9.79</td>
<td>.63</td>
</tr>
<tr>
<td>Diagnostic and preventive services: No RDH</td>
<td>42.68</td>
<td>240</td>
<td>12.34</td>
<td>.79</td>
</tr>
<tr>
<td>Corrective services: with RDH</td>
<td>19.44</td>
<td>240</td>
<td>10.50</td>
<td>.67</td>
</tr>
<tr>
<td>Corrective services: no RDH</td>
<td>10.18</td>
<td>240</td>
<td>6.72</td>
<td>.43</td>
</tr>
<tr>
<td>Total dental services: with RDH</td>
<td>98.09</td>
<td>240</td>
<td>17.68</td>
<td>1.14</td>
</tr>
<tr>
<td>Total dental services: No RDH</td>
<td>60.65</td>
<td>240</td>
<td>12.05</td>
<td>.77</td>
</tr>
</tbody>
</table>

Table 23: Paired t-test hypothesis testing results, Western Tidewater, Southampton.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean Diff.</th>
<th>Std. Dev.</th>
<th>Std. Err. mean</th>
<th>95% CI of the paired difference</th>
<th>t</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients' visits: paired</td>
<td>5.78</td>
<td>2.46</td>
<td>.15</td>
<td>5.47</td>
<td>6.10</td>
<td>36.3</td>
</tr>
<tr>
<td>Diagnostic and preventive services: paired</td>
<td>22.59</td>
<td>13.25</td>
<td>.85</td>
<td>20.90</td>
<td>24.27</td>
<td>26.3</td>
</tr>
<tr>
<td>Corrective services: paired</td>
<td>9.25</td>
<td>10.74</td>
<td>.69</td>
<td>7.89</td>
<td>10.62</td>
<td>13.3</td>
</tr>
<tr>
<td>Total dental services: paired</td>
<td>37.44</td>
<td>20.28</td>
<td>1.30</td>
<td>34.86</td>
<td>40.02</td>
<td>28.5</td>
</tr>
</tbody>
</table>
CHAPTER V

DISCUSSION AND CONCLUSIONS

The discussion in the next sections will be according to the following grouping of variables: Research Question One; Public Health System Performance Conceptual Framework (PHS), relationship between the PHS conceptual framework dimensions, essential services number 7, oral health care providers to patients ratio, Standards for Clinical Dental Hygiene Practice, collaborative practice in dentistry, Research Question Two; importance of using modeling and simulation in oral health services, the importance of adding a dental hygienist to a public health district dental clinic, limitations of the study, policy implications, future research and conclusions.

Discussion

The purpose of this study is to examine the system performance in delivering oral health services in a public health district based on the Conceptual Framework to Measure Performance of the Public Health System (PHS). The appropriate approach to study the impact of adding a dental hygienist to a public health district's dental clinic was by implementing modeling and simulation approach. By using modeling and simulation, a predictive model based on the conceptual framework dimensions, namely structural capacity, processes, and outcomes, was developed to predict the performance of a public health district in delivering oral health services. Purposeful sample consists of five public health district dental clinics of Hampton Roads for the fiscal years 2005-2010. For the purpose of this study, the following five public health district dental clinics were chosen: Norfolk, Virginia Beach, Hampton, Peninsula, and Western Tidewater (Appendix D).
This study uses 6-year longitudinal data obtained from the VDH for the five health districts under investigation to answer the research questions. The following specific research questions were answered for each of the five health districts:

1. To what extent do the public health system conceptual framework dimensions (mission, structural capacity, processes, and outcomes) explain the variance among the five health districts' performance in delivering oral health services over a six-year period?

2. To what extent does employing a dental hygienist affect oral health services delivery at a public health district dental clinic? The following specific oral health services' outcomes will be investigated:
   a. the average number of patient visits per day at a public health district dental clinic.
   b. the average number of diagnostic and preventive dental services delivered by the dentist or the dental hygienist per day at a public health district dental clinic.
   c. the average number of corrective services provided by the dentist per day at a public health district dental clinic.
   d. the average number of total services provided by the dentist per day at a public health district dental clinic.

The performance metrics in this study are the same as those VDH usually collects and analyzes. This would make the findings of this study more relevant, important and appropriate for the VDH.
The means of the performance metrics before and after adding a dental hygienist were different. In some sites, the increases were doubled. Whereas, in other sites the differences were relatively low (Appendix H). For instance, the increase in the number of diagnostic and preventive services at Hampton District's Dental Clinic was relatively low compared to other sites. One explanation of this is that the percentage of patients who are first or recare was 80%. This means that most patients seeking oral health services at Hampton District's Dental Clinic don't need corrective services. Therefore, the dentist spends most of his treatment time performing diagnostic and preventive services. Adding a dental hygienist has little impact on the number of diagnostic and preventive services. On the other hand, the number of corrective services have increased significantly compared to other oral health services. This means that the dentist has more time to perform more corrective services.

**Research Question One**

To what extent do the public health system conceptual framework dimensions: mission, structural capacity, processes, and outcomes explain the variance among the five health districts' performance in delivering oral health services over a six-year period?

**Public Health System Performance Conceptual Framework (PHS) Dimensions**

The conceptual framework used in this study was developed based on the work of Donabedian (1980) and Handler et al. (2001). This conceptual framework links the following dimensions together: mission, structural capacity, processes, and outcomes of the public health system. According to Donabedian's
framework, public health systems consist of three main dimensions: structure, process, and outcome. Originally, this framework was developed to study medical care delivery systems (Donabedian, 1980).

This model was used to measure public health system performance and the extent to which the organization achieves its mission. In the public health system, there should be an interaction and feedback loops between these components. This framework can be used at multiple levels to measure public health system performance. It can be applied at the national public health system, state public health system and local or community public health systems (Handler, et al., 2001) (Figure 17).

**Figure 17: Public Health System Performance Conceptual Framework.**

Note: adapted from Handler et al., 2001

The mission of the Division of Dental Health is to improve the oral health of all of Virginia's citizens (Virginia Department of Health). The structural capacities are the cumulative resources necessary to enable the public health services system to function properly to deliver oral health services such as information, organizational, physical,
human, and fiscal resources. Specifically, this study is focusing on human and physical resources.

The processes are the collective services (i.e. assessment, diagnosis, planning, implementing, evaluation, and documentation) that identify and address oral health problems for indigent preschool and school-aged children. These processes may include: oral examination and treatment plan, x-rays, medical and dental history, restorative dentistry, dental sealant, endodontic, space maintenance, scaling, prophylaxis and oral hygiene instructions and a topical fluoride therapy (Norfolk Department of Public Health).

The oral health service's outcomes include the performance metrics for delivering oral health care services at a public health district dental clinic. For the purpose of this study, these metrics include the average number of clinical hours worked per month of the dentist in delivering oral health care services (i.e. diagnosis, preventive, corrective) at a public health district dental clinic; the average number of patients' visits per day at a public health district dental clinic; the average number of diagnostic and preventive dental services delivered by the dentist or the dental hygienist each day at a public health district dental clinic and the average number of corrective services provided by the dentist each day at a public health district dental clinic.

Relationship Between the PHS Conceptual Framework Dimensions

The theoretical framework of in this study was used to drive research questions and hypotheses. In this study, structural capacities, processes, and outcomes dimensions were studied. These dimensions were based on the Framework to Measure Performance of the
Public Health System. Public health mission and purpose include the system philosophy, goals, and core functions. Structural capacity includes: information resources, organizational resources, physical resources, human resources, and fiscal resources (Handler, et al., 2001).

This study confirms the relationship between employing a dental hygienist (increasing the structural capacity) and the increased number in patients' visits, corrective, preventive, and total services (outcomes). This study seems to confirm the previous studies that showed that increasing structural capacities will in turn increase the health outcomes (Donabedian, 1980; Handler, et al., 2001; Mays, et al., 2009).

This study investigates the relationship between the three components of the theoretical framework; structure, process and outcome. The findings of this study support the relationship between these components. Public health improvement plans have spent great effort to measure the effects of improved structural capacities on the performance of public health processes and outcomes (Handler, et al., 2001).

Mays et al. (2009) stated that studying the dimensions of the public health systems such as structure, process, and outcome may prove the improvement of public health services. The researcher emphasized that continued research on public health delivery systems may address the need for evidence of the importance of improving and assuring the quality of investigation on public health delivery systems. They conducted a review study to examine published studies on topics related to public health systems between 1990 and 2007. They studied public health organization structure, staffing, and service delivering. They found that most public health systems are significantly different in their organizational structural capacities and personnel characteristics which have
impacted the effectiveness and efficiency of public health service’s delivery.

Specifically, they found that staffing is one of the most vital factors influencing service delivery and outcomes. In their study, they focused on organizational structural characteristics. Their findings indicated that there are huge gaps and uncertainties in the mechanisms through which public health systems deliver health services to the public. They recommended conducting further research to evaluate the rapid changes occurring in delivery system structure and staffing (Mays, et al., 2009).

In order to determine whether the public health system accomplishes its mission, it is necessary to measure each dimension of the system and its relationship with others. This study findings indicate that public health district's dental clinic should operate and interact to lead to desired outcomes. This result concur with Handler et al. (2001) who stated that feedback loops should exist between all different dimensions.

**Essential Public Health Service Number 7 in the Context of Oral Health Services**

The following essential public health service and its activities are described in the context of the role of oral health services (American Association for Community Dental Programs, 2006). This service may include the following activities:

1. Lead or join efforts to increase access to comprehensive culturally competent oral health care that includes health promotion, prevention, and treatment services.

2. Partner with the community to establish systems and programs to meet oral health treatment needs (e.g., for individuals with special health care needs, for families who are homeless).
3. Partner with the community to identify and establish systems and programs that include preventive services (e.g., school-based/linked dental sealant and fluoride programs, mouth guard programs, early-childhood-caries-prevention programs).

4. Link individuals to appropriate oral health services (e.g., using care coordination mechanisms, patient navigators).

**Oral Health Care Providers to Patients Ratio**

Chronic oral diseases such as dental caries and periodontal diseases become difficult to manage, treat and afford if not diagnosed and treated early. The consequences of untreated oral diseases can lead to pain, tooth loss and increased expenses (Centers for Disease Control and Prevention, 2007).

Virginia leads the nation in its provision of community-based healthcare centers that provide low cost services, with 53 free clinics operating a total of 67 sites and 73 community centers statewide (Virginia Interface Center for Public Policy, 2007). In addition, there are 35 public health districts in Virginia administered by VDH that provide oral health services to all Virginia residents (Virginia Department of Health).

According to Spielman (2005), the ratio of dentist to patients in the United States is 58 dentists per 100,000 patients. Rural areas have even less dentists per patients in terms of ratio. The Health Professional Shortage Area Act reported that there are more than 25 million Americans who live in rural area where access to oral health services is limited. Furthermore, more than 100 million Americans live in areas without access to fluoridated water (Spielman, Fulmer, Eisenberg, & Alfano, 2005).
Virginia ranks 11th nationally when total dentists are counted to be 4,395, compared to the US weighted average of 3,420 (Virginia Interface Center for Public Policy, 2007). Therefore, there is room for health services researchers to participate in improving Virginia's oral healthcare delivery system to be one of the most effective and efficient systems. According to the National Conference of State Legislatures (2008), serious disparities still exist in the delivery of oral health care across the country, especially for low-income populations.

The following table shows the change of percentage of the population of Hampton Roads (8.3%) compared to Virginia (14.4) and the United States population changes (13.2%) between years 1990 and 2000.

**Table 24: Hampton Roads Population.**

<table>
<thead>
<tr>
<th>Population</th>
<th>1990</th>
<th>2000</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hampton Roads</td>
<td>1,454,185</td>
<td>1,574,801</td>
<td>8.3%</td>
</tr>
<tr>
<td>Virginia Population</td>
<td>6,187,358</td>
<td>7,078,515</td>
<td>14.4%</td>
</tr>
<tr>
<td>US Population</td>
<td>248,709,873</td>
<td>281,421,906</td>
<td>13.2%</td>
</tr>
</tbody>
</table>

Note: Source: U.S. Census Bureau, 2010.

**Standards for Clinical Dental Hygiene Practice**

In 1985, ADHA developed the Standards for Clinical Dental Hygiene Practice to ensure the quality of provided care to the patients (Table 25). These standards of care are based on evidence-based practice. There are six components to the dental hygiene process of care: assessment, dental hygiene diagnosis, planning, implementation, evaluation, and documentation (Figure 18) (Darby & Walsh, 2010; Wilkins, 2009).
The Standards for Clinical Dental Hygiene Practice govern the relationship between the provider (dental hygiene clinician) and the patients. These standards should be applied also when a dental hygienist employed in other professionals roles such as educator, researcher, advocate, administrator and manager (Appendix G). In addition, these standards should be implemented to facilitate the collaborative practice among the dental team or other health professionals (American Dental Hygienists' Association, 2008).

Table 25: Standards for Clinical Dental Hygiene Practice.

<table>
<thead>
<tr>
<th>Standard</th>
<th>Procedures and Activities</th>
</tr>
</thead>
</table>
| **Standard 1: Assessment** | I. Patient History  
II. Perform a comprehensive clinical evaluation  
III. Risk Assessment |
| **Standard 2: Dental Hygiene Diagnosis** | I. Analyze and interpret all assessment data  
II. Determine patient needs that can be improved through the delivery of dental hygiene care.  
III. Incorporate the dental hygiene diagnosis into the overall dental treatment plan. |
| **Standard 3: Planning** | I. Identify, prioritize and sequence dental hygiene intervention  
II. Coordinate resources to facilitate comprehensive quality care  
III. Collaborate with the dentist and other dental care providers  
IV. Present and document dental hygiene care plan to patient.  
V. Explain treatment rationale, risks, benefits, anticipated outcomes, treatment alternatives and prognosis.  
VI. Obtain and document informed consent and/or informed refusal. |
| **Standard 4: Implementation** | I. Review and implement the dental hygiene care plan with the patient/caregiver.  
II. Modify the plan as necessary and obtain consent.  
III. Communicate with patient/caregiver appropriate for age, language, culture and learning style.  
IV. Confirm the plan for continuing care. |
| **Standard 5: Evaluation** | I. Use measurable assessment criteria to evaluate the outcomes of dental hygiene care  
II. Communicate to the patient, dentist and other health/dental care providers the outcomes of dental hygiene care.  
III. Collaborate to determine the need for additional diagnostics, |
Standard 6: Documentation

I. Documents all components of the dental hygiene process of care (assessment, dental hygiene diagnosis, planning, implementation, and evaluation).

II. Objectively records all information and interactions between the patient and the practice.

III. Records legible, concise and accurate information.

IV. Recognizes ethical and legal responsibilities of record keeping including guidelines outlined in state regulations.

V. Ensures compliance with the federal Health Information Portability and Accountability Act (HIPAA).

VI. Respects and protects the confidentiality of patient information.


Figure 18: The Six Components of the Dental Hygiene Process of Care.

Note. Adapted from Wilkins, 2005.
Collaborative Practice in Dentistry

There are many reasons behind developing and adopting collaborative practices in different medical and dental fields such as to increase access to health care, to improve productivity and efficiency, to reduce health care costs, to improve health care outcomes, and to improve patient satisfaction (Mertz, Dower, & Lindler, 2011).

According to ADHA's position paper "the collaborative relationship between dental hygienist and dentist professionals assures that the comprehensive treatment needs of the patient will be identified, addressed and evaluated" (American Dental Hygienists' Association, 2008).

The primary objective of collaborative practice in dentistry is to provide a comprehensive dental care treatment. Collaborative practices include "any ongoing systemic professional relationship between two or more health care providers, each having some degree of authority to independently provide health care services within his or her legal scope of practice" (Mertz, et al., 2011). ADHA has defined the relationship between the dental hygienist and the dentist "as a team members who work together, and both use critical thinking processes in order to deliver the most comprehensive, most effective and most individualized care addressing the specific needs of each patient" (American Dental Hygienists' Association, 2010).

This study's findings indicate that adding a dental hygienist to the existing oral health care providers at a public health district's dental clinic has significant increase in delivering oral health services at all eight public health districts' dental clinics as measured by the performance metrics the average number of patient visits per day at a public health district dental clinic, the average number of diagnostic and preventive
dental services delivered by the dentist or the dental hygienist per day at a public health district dental clinic, the average number of corrective services provided by the dentist per day at a public health district dental clinic and the average number of total services provided by the dentist per day at a public health district dental clinic. To confirm the result, 95% confidence interval, and repeated measures analysis of variance revealed also significant differences between the two scenarios under investigation (p <0.05). The findings of this study showed not only increased number of preventive services, as would be expected, but also increased number of corrective services.

The findings of the study indicate that a collaboration between dentists and dental hygienists is essential to deliver a comprehensive oral health care to underserved populations. This study focuses on the delivery of oral health in the clinical environment.

It is increasingly important for decision makers, community leaders and public oral health providers to have uninsured populations back into oral health care system.

The professional organizations such as American Dental Association (ADA) and American Dental Hygienists’ Association (ADHA) encourage oral health providers to reach out and to fund programs that targeted uninsured population (American Dental Association, 2009; American Dental Hygienist Association, n.d.).
Research Question Two

To what extent does employing a dental hygienist affect oral health services' delivery at a public health district dental clinic? The following specific oral health services' outcomes will be investigated:

a. the average number of patient visits per day at a public health district dental clinic.

b. the average number of diagnostic and preventive dental services delivered by the dentist or the dental hygienist per day at a public health district dental clinic.

c. the average number of corrective services provided by the dentist per day at a public health district dental clinic.

d. the average number of total services provided by the dentist per day at a public health district dental clinic.

There were four hypotheses at the 0.05 level of significance corresponding to the four performance metrics to test Research Question Two. The performance metrics under investigation were chosen based on their prevalence as traditionally collected data on VDH's monthly dental activity summary report; the evidence in the literature regarding their importance to administrators, academicians and institutions in measuring performance; the reported conflicting results of studies found in the literature; and the special interest of the faculty at this institution.

For the purpose of this study, corrective services include restorative, endodontic, periodontic, removable prosthodontic, fixed prosthodontic, oral surgery, and orthodontic services performed by a dentist. Preventive services include many procedures such as
oral examination and treatment plan, intra and extra-oral radiographs, medical and dental history, regular oral and dental checkup, prophylaxis, scaling, dental sealants, topical fluoride treatment, and oral hygiene instructions.

**Importance of Using Modeling and Simulation in Oral Health Services**

This study is the first to use M&S in dental hygiene to examine the system performance in delivering oral health services in a public health district's dental clinic. Many dental practice productions are complicated combinations of parameters such as information, organizational, physical, human and fiscal resources. Using simulation would be the reasonable approach when the system under investigation produces outcomes that are complicated, stochastic (i.e. involving probability), and dynamic. Non-linear production makes simulation models an appropriate methodology to study and improve the delivery of oral healthcare service outcomes in the public health districts. Using modeling and simulation is less expensive than conducting research with many different variables.

Based on the research questions and the hypotheses, the researchers developed two scenarios for each site. The first scenario was the current status of the personnel at a public health district dental clinic with no dental hygienist. The second scenario was by adding a new oral health care provider (a dental hygienist) to the model to determine the impact of this addition on the performance metrics. Four hypotheses were developed for each site. Paired t-test revealed that there is a statistically significant difference between scenario one (as is) and scenario two (adding a dental hygienist) at p-value less than 5%. This finding supports ElHaik and AlOmar who stated that using modeling and simulation
with a well-structured model provided reliable data, an accurate process outline, and
decreased the gap between modeling simulation and process application (ElHaik &
AlAomar, 2006).

By using Modeling and simulation, this research seeks to address issues that
affect the delivery of oral health care in the public health districts' dental clinics.
Modeling and simulation was used to explain and predict the performance of public
health services regarding delivering oral health services. The findings of this study
support the overall validity of this model when used to predict oral health services'
delivery. Of particular interest are that structural capacity, processes, and outcomes
variables were investigated in this study. By using a simulation model, the findings were
more accurate in explaining and predicting the performance of public health services in
delivering oral health services when modifying the number of resources.

Many healthcare providers are adapting new technologies to enhance their ability
to serve their clients with the best use of resources and time. Modeling and simulation
methodology has been used in different healthcare settings such as hospital management,
emergency departments, surgery rooms, pediatric clinics and public and private dental
practices. Modeling and simulation is an ideal approach when investigating different
systems with many options. Simulation requires minimal cost and personnel training and
limited risk to clients (Barnes, et al., 1997). Specifically, modeling and simulation has
been used to improve patient throughput in emergency departments (Kolker, 2008).

Modeling and simulation has been used in different educational institutions such
as medical schools, dental schools, nursing schools and applied health sciences schools.
Operations research principles such as queuing theory and process model simulation have been applied in the modeling and simulation field to study patient flow (Kolker, 2008).

Modeling and simulation is a new approach to be used in public oral health services settings. This study implemented modeling and simulation to develop a dental clinic layout using discrete event simulation software (Arena) to create two different scenarios based on different parameters such as average number of diagnosis and preventive services per recare visit, average number of corrective services per return visit, average number of other services per return visit, interarrival rate (without dental hygienist), interarrival rate (with dental hygienist), check-in process time for first/recare visit, check-in process time for return visit, check-out process time for first/recare visit, check-out process time for return visit, dentist's treatment process time for first/recare visit, dentist treatment process time for return visit, dental assistant radiographs taking process time, dental assistant initial preventive services process time, dental hygiene diagnosis and preventive services process time.

In this study, the system under investigation is a public health district dental clinic which consists of a dentist, a dental hygienist, a dental assistant, a receptionist, and patients. The system includes real structural capacities and personnel parameters such as number of dental chairs, radiographs units, dentists, dental assistants, and receptionists. The current dental team operating the dental clinics at the public health districts does not include a dental hygienist.

Arena software and its two associated applications (Arena Input Analyzer and Arena Output Analyzer) were used to model and simulate the public health district dental clinic and to create the required data to conduct the statistical tests.
After running the two Arena simulation models of the two scenarios, paired t-test revealed that there were statistically significant differences (p <0.05) between the two scenarios (with a dental hygienist and without a dental hygienist) in delivering oral health services at all public health districts' dental clinics as measured by the following performance metrics:

a. the average number of patient visits per day at a public health district dental clinic.

b. the average number of diagnostic and preventive dental services delivered by the dentist or the dental hygienist per day at a public health district dental clinic.

c. the average number of corrective services provided by the dentist per day at a public health district dental clinic.

d. the average number of total services provided by the dentist per day at a public health district dental clinic.

To confirm the result, 95% confidence interval, repeated measures analysis of variance revealed also significant differences between the two scenarios under investigation (p <0.05).

Modeling and simulation enabled the author to modify the changeable variables such as adding a new oral health provider (dental hygienists) without impacting the quality of care. In turn, by using modeling and simulation methodology public health districts dental clinics' directors will be able to serve their clients effectively and efficiently with the best use of physical and human resources, without compromising the quality of care.
The modeling simulation approach proved that the performance of public health district's dental clinic in delivering oral health services can be significantly increased when adding a new oral health provider (dental hygienist) to the existing personnel. Results of this study will contribute to the knowledge gap among oral health providers regarding the significance of modeling and simulation techniques in improving oral health care delivery.

**Importance of Performance Metrics**

Each site of the eight sites under investigation has one dentist except Peninsula Public Health District's dental clinic has two dentists. The proposed simulation model used in this site treated the dentists as a resource pool rather than two distinguishable resources. Pooling the resources and using one common queue approach has been used in different fields when using discrete event simulation methodology (Anderson, Sweeney, Williams, Camm, & Martin, 2010).

This study finding, that an increase in the performance metrics is statistically significant when using "pool resources" approach, supports Czech et al. (2007) who have pooled the resources and used one common queue and reported an increasing in the number of patients seen per day in a dental clinic (Czech, Witkowski, & Williams, 2007).

Adding a dental hygienist to this model has statistically significant increase in the number of patients' visits. Using number of patients' visits to measure the improvement in the performance concur with Arvy and Morin (1997) who used modeling and simulation to study the effect of modifying the number of resources on the number of patients seen at obstetrical and gynecological out-patient clinic (Arvy & Morin, 1997).
In this study, waiting time does not seem to be a significant variable to measure the performance of the public health districts' dental clinic since all patients visits are based on their appointment time.

Identifying number of patients' visits as a significant metric to measure the performance at a public health district's dental clinic may lend support to ElHaik (2006) recommendations to use patient throughputs to measure the performance whenever studying optimal staffing and facility productivity (ElHaik & AlAomar, 2006).

Simulation has been used to study staffing modification and clinical design in an out-patient diagnostic center (Wilt & Goddin, 1989) and in Hashimoto and Bell (1996) who has studied staffing and scheduling at an outpatient internal medicine clinic with multiple resources (Hashimoto & Bell, 1996). However, most researchers who have studied system staffing and modification have included the waiting time among their variables (Czech, et al., 2007).

In this study, the author modified the number of resources (adding a new oral health provider) to determine the impact of this modification on the performance metrics of the system (a dental clinic). Resources modifications have been used by many researchers to study the performance in different fields (Brenner et al., 2010; Merkle, 2002; van Oostrum et al., 2008). In this study, adding a new resource resulted in a significant difference between the existing scenario and proposed scenario as measured by a number of performance metrics. This finding is not surprising since previous research found modification of the resources typically drive the differences when comparing different scenarios. Merkle (2002) studied how modifying resources would improve the performance and the operational efficiency at Brooke Army Medical Center.
(BAMC). The researcher proposed different scenarios to determine the impact of resource modification on the patient visits, patient total time in clinic, and resource utilization (Merkle, 2002). As expected, the variables of average number of services (preventive, corrective, and total) consistently remained significant among all eight sites under investigation in both statistical tests, paired t-test and repeated-measures analysis of variance (ANOVA) with p value less than 5%.

It is difficult to compare the results of this study regarding the performance metrics with others because of the specific nature of this study. Even though the variables used in this study were chosen based on their prevalence as traditionally collected data on VDH's monthly dental activity summary report, but overall the findings of this study are consistent with previous results in different fields. Future research to evaluate public health district's dental clinic performance in delivering oral health care needs to consider not only the performance metrics used by VDH, but other metrics such as patient total time in clinic and resource utilization.

**Importance of Adding a Dental Hygienist to a Public Health District's Dental Clinic**

Most oral health experts agree that most oral diseases can be prevented and treated with low-cost procedures and less traumatic intervention if diagnosed and treated in their early stages (Gilbert, et al., 2002; Milgrom, et al., 1998). The consequences of untreated oral diseases can lead to pain, tooth loss and undefeatable expenses (Centers for Disease Control and Prevention, 2007). Preventive oral health services include many procedures such as regular oral and dental checkup, scaling and root debridement, applying dental sealants, fluoride therapy, and regular periodontal maintenance treatment.
Untreated oral diseases may impact an individual's self-esteem and total overall health. Advanced stages of oral infections have been indirectly linked with some diseases such as cardiovascular diseases, unfavorable pregnancy outcomes (low birth-weight, premature births) and diabetes (Genco, et al., 2002; Grossi & Genco, 1998; Kardeşler, et al., 2010; Soskolne & Klinger, 2001). Oral diseases such as dental caries and periodontal diseases are infectious diseases and become difficult to manage and treat when they advance to severe stages (Centers for Disease Control and Prevention, 2007).

More than 91% of adults (20 years or older) have experienced coronal caries. Approximately 23% of this population has untreated dental caries. More than 18% of the population has root caries. Furthermore, more than 90% of adults over 60 years have experienced dental caries. One forth of adults over the age of 60 have lost all of their teeth as a result of having tooth decay. Severe periodontal diseases affect 5 to 15% of adults in the United States (Centers for Disease Control and Prevention, 2007).

According to the U.S. Census Bureau report released in September 2010, the number of people who has no health insurance has increased from 46.3 million, 15.4% of the population, in 2008 to 50.7 million, 16.7% of the population, in 2010. In 2009, more than 10% of children (7.5 million) who are under 18 years old have no health insurance (US Census Bureau, 2010). Research reported that there are more than 45% of Americans (108 million) who have no dental insurance (National Health Interview Survey, 1995).

The ultimate goal of this study is to find out whether or not employing a dental hygienist by a public health district's dental clinic is effective in improving the delivery of oral health services and meet the oral health needs of the underserved and uninsured
populations in Hampton Roads, Virginia. There are fewer dentists graduating each year from dental schools while the population numbers are increasing and oral diseases such as dental caries and periodontal diseases are still prevalent (Bentley, 2007). The dental hygiene field is one of the top 10 fastest growing professions (Bond, 2004). As the dental hygiene profession enlists more and more graduates, the opportunity to expand the functions and responsibilities could mean an increase in the delivery of oral health care services to underserved populations (Bond, 2004). Employing a dental hygienist by a public health district's dental clinic would improve the delivery of oral health services to underserved population.

The American Dental Association emphasizes that everyone in the United States should have comprehensive oral healthcare since there is a strong relationship between oral health and general health. The ADA reports that the uninsured population is increasing which makes access to oral healthcare more critical to those who have no dental insurances (American Dental Association, 2009).

As the dental hygiene schools graduate more competent dental hygienists, this could mean an increase in the delivery of oral health care services. Dental hygiene advocates have demonstrated in the past that allowing a less restrictive supervision has not harmed or caused significant negative impacts on the communities who adopted these policies (Spielman, Fulmer, Eisenberg, & Alfano, 2005). General supervisions and local anesthesia are two of the most recent advancements in the scope of dental hygiene practice in Virginia.

In this study, the researchers used modeling and simulation approach to evaluate the effectiveness of employing a dental hygienist by a public health district's dental
M&S provides useful insight into the public health districts' dental clinics' performance. Adding a dental hygienist to the simulation model is to introduce a competent oral healthcare provider who can significantly contribute to the delivery of oral health services at a public health district's dental clinic.

The results of this study indicate that adding a new oral health provider (a dental hygienist) has a statistically significant impact in increasing oral health delivery at a public health district dental clinic (p <0.05). Specifically, adding a dental hygienist to the simulation model shows statistically significant increase in the following performance metrics:

1. the average number of patient visits per day at a public health district dental clinic.
2. the average number of diagnostic and preventive dental services delivered by the dentist or the dental hygienist per day at a public health district dental clinic.
3. the average number of corrective services provided by the dentist per day at a public health district dental clinic.
4. the average number of total services provided by the dentist per day at a public health district dental clinic.

In summary, one goal for any oral health intervention is to maximize the healthy life of each tooth. Many recent reports and studies support the implementation of preventive dental hygiene services. This will shift the focus from traditional restorative procedures to preventive procedures. In theory, preventive dental hygiene care can reduce costs for consequences treatment. There is an established evidence that preventive dental hygiene care can reduce the need for further restorative treatment (Matthew F. Savage, Lee,
Even though the efficacy of many preventive dental hygiene care is well established, public health district's dental clinics in Hampton Roads have no dental hygienists among their dental team.

**Limitations of the Study**

There is no perfect theoretical framework that fits all investigations. There are social, socioeconomic, demographic, and cultural differences that distinguish one population from another. This model might not be an appropriate for studying environmental and organizational factors that may have influences on how health services are delivered (Andersen, 1995).

Researchers strived to maintain high levels of validity and reliability; however, some limitations may occur. The following factors may affect the internal and external validity of this study's finding:

1. Using purposeful samples consisted of five public health district dental clinics of Hampton Roads which may limit the generalizability of the study's findings. Results obtained cannot be generalized to other public health districts' dental clinics in the United States.

2. The oral health providers and their patients' characteristics may change annually as population characteristics, environmental factors, and career opportunities fluctuate. Additional replication studies can explore the
degree to which the findings of this study can be generalized to different public health district's dental clinics.

3. The differences in the structural capacities (physical, organizational, informational, fiscal and human resources) across the eight public health district dental clinic sites over a 6-year period resulted in dissimilar data set. Dissimilar data sets are typical in longitudinal studies. The results of this research should be used cautiously.

4. There might be some challenges regarding the methods of investigating different oral health outcomes under real life conditions where there are many confounders and biases such as patient's age, patient's cooperation, and patient's compliance with oral health instructions.

5. This is a retrospective study to measure a quantitative relationship between dependent variables and independent variables; therefore, it will be difficult to control extraneous variables which might affect the oral health outcomes under investigation.

6. Using simulation model with multiple variables may limit the validity of the model. Modeling and simulation is to give insights not numbers.

Policy Implications

In 2000, the Surgeon General recognized that national oral health care needs more attention. According to this report, oral health care delivery was identified and recognized by different legislative parties such as lawmakers, some professional organizations, interested groups and public health departments as a big concern (Surgeon
General Report, 2000). Healthcare administrators are concentrating on identifying the areas where the healthcare delivery system needs the most appropriate approach to address the problem of delivering oral healthcare and to meet the need of uninsured individuals (Virginia Interface Center for Public Policy, 2007).

As the public, policymakers, and healthcare providers consider oral health to be less important than other health needs, barriers continue to exist. Oral diseases are still prevalent, and there are fewer dentists graduating from dental school to provide essential oral healthcare services compared to the increased number of population (Bentley, 2007). Oral health experts agree that most oral diseases can be prevented and treated with less traumatic intervention if diagnosed and treated in their early stages (Gilbert, et al., 2002; Milgrom, et al., 1998).

As long as public policymakers and medical providers less appreciate oral health services, barriers will continue to exist to prevent many patients from receiving essential oral health services. Additionally, there are many factors still limiting some patients from receiving essential oral healthcare such as transportation costs and accessibility, low dental insurance reimbursement to providers, lack of dental insurance, low socioeconomic status, and low level of education and knowledge about how oral health may affect whole body health (Manski & Magder, 1998).

The American Dental Association emphasizes that everyone in the United States should have comprehensive oral healthcare since there is a strong relationship between oral health and general health. The ADA reports that the uninsured population is increasing which makes access to oral healthcare more critical to those without dental insurance (American Dental Association, 2009). There are many factors that might
predict utilization of oral health services such as access to oral health care, levels of knowledge about oral health, ethnicity/race, age, and socioeconomic status (SES) (Alzahrani & Neff, 2010; Gilbert, et al., 2002; Manski & Magder, 1998). The results of this study will help not only to be used in predicting the impact of adding a dental hygienist, but also to identifying the impact of adding a different oral health care providers such as a dentist, a dental assistant and a secretary to the dental team at a public health district's dental clinic.

The simulation models will also be useful for measuring the performance of public health district's dental clinics in delivering oral health services with modifying certain variables. This study will not only assist public health district's dental clinic directors in understanding the performance of their clinics but also serve as a reference for the VDH whenever it conducts future research that investigates the influence of adding a new oral health provider to a public health district's dental clinic. The findings of this study have great implications when designing, evaluating, or implementing preventive oral health services. It is a great opportunity for health services researchers to participate in formulating, developing and delivering effective preventive oral health services targeting low SES, low education population, certain ethnicities, and uninsured populations.

Furthermore, this simulation model will serve as a good foundation for future when planning to employ dental hygienists. Public health districts' dental clinics, community leaders, and policy makers may benefit from these study findings in different ways such as increasing preventive oral health services such as screening programs, behavioral services such as nutritional counseling and community-based oral disease
preventive intervention such as oral health fairs, information centers and outreach interventions.

**Future Research**

Based on the results of this study, the following recommendations for future research are offered:

1. Replicate this study to determine the reliability and validity of applying findings at different public health districts.

2. Identify other variables that might predict the performance of a public health district's dental clinic in delivering oral health services.

In addition, the results of this study indicate that there are still some questions that need to be addressed and investigated. Future research should address the following unanswered questions:

1. What is the relationship between PHS conceptual framework dimensions at a large level?

2. Does public health district's dental clinic collaborate with the community to establish systems and programs to meet oral health treatment needs (e.g., for individuals with special health care needs, for homeless families)?

3. To what extent does public health district's dental clinics participate in leading or joining efforts to increase access to a comprehensive culturally competent oral health care that includes health promotion, prevention, and treatment services?

4. Does public health district's dental clinics partner with the community to identify and establish systems and programs that include preventive services (e.g., school-
based/linked dental sealant and fluoride programs, mouth guard programs, early-childhood-caries-prevention programs)?

Conclusions

The greatest potential benefit of this study will be to institutions of community oral health, public oral health educators, the public and community at large and future patients seeking oral healthcare at public health districts’ dental clinics. The dissemination of the results of this study through publications and professional presentations will allow academic institutions and public health educators to evaluate public health districts’ procedures and criteria and possibility identify those criteria most likely to optimize oral healthcare services’ delivery.

In conclusion, determining what influences the delivery of oral health services has been a persistent goal among many public health providers. For many years, studies have attempted to accurately identify the variables which influence the delivery of oral health services in public health settings. Numerous studies attempted to establish the best variables impacting the delivery of oral health services. The most prolific focused on structural capacities such as physical, human, information, organizational, and fiscal resources. In addition, some researchers have added other factors to the previous theoretical foundation such as macro context and mission of the organization. Research shows that the evaluation of public health performance in delivering oral health care services must be continued. This research’s findings indicate that studying the dimensions of the public health systems such as the structure, process, and outcome may prove that delivering oral health services to the public can be improved.
Considering the study findings and limitations, the following conclusions are made:

1. Results from this study add to the body of knowledge that attempts to identify the impact of adding a dental hygienist in delivering oral health services at a public health district's dental clinic.

2. The dissemination of the results of this study through publications and professional presentations may allow VDH, academic institutions and dental hygiene educators to consider employing dental hygienists at public health districts' dental clinics.

3. The VDH may have confidence in utilizing modeling and simulation whenever it plans to add a new oral health care provider to a dental clinic at a public health district.

4. Results indicate that the modeling and simulation is a reliable tool to determine the best performance metrics when evaluating the performance of a public health district's dental clinic in delivering oral health services.
REFERENCES


I am writing to request your approval for access to the oral health services data from the
dental public health database. I am working with Mohammad Alzahrani, a full time PhD
student enrolled in the Old Dominion University Health Services Research with a
concentration in oral health services.
Mr. Alzahrani is conducting research project to examine system performance in
delivering oral health services in a public health setting. He plans to develop a predictive
model that can examine using modeling and simulation to improve service delivery.
In order to build the most effective simulation model and conduct the research, we are
requesting permission for access oral health services data via the Public Health
Departments’ database. Mr. Alzahrani has met with Dr. Michelle Galloway who has
shared sample data for our examination that appears appropriate for the proposed
research study. Additionally, the study will be submitted for IRB approval for the
protection of human subjects through Old Dominion University. No personal information will be required for this study and we anticipate that the study will be deemed exempt. For the study purpose, Mr. Alzahrani also would like to acquired information regarding the mission statement, goals, personnel structure, and the outcomes for the dental public health services department. He would need to discuss this with you directly.

The result of this research study will be shared with you and our hope is that it will be useful for your future planning and development purposes. Thank you for your time, and will look forward to collaboration with you on this research endeavor.

Sincerely,

Deanne Shuman, BSDH, MS, PhD
Professor & Acting Chair
Old Dominion University
Health Sciences Building, Room 3104
Norfolk, VA 23529-0499
Office: 757-683-6953
APPENDIX B

DATA FROM DH1214, TO OBTAIN FROM VDH

In order to use the DH1214 data provided by the Virginia Department of Health (VDH) users must adhere to the following guidelines. Users shall

- use the data solely for statistical analysis and the reporting of aggregate information;
- will not use any identifying information beyond generic references to Virginia Department of Health data.
- refrain from distributing or selling the data to any other individual, institution, or organization without the written consent of the Virginia Department of Health.
- use only as described in the PhD project overview proposal of Mohammad Alzahrani

The accuracy of the users’ statistical analysis and the findings they report are not the responsibility of the Virginia Department of Health. The Virginia Department of Health shall not be held liable for improper or incorrect use of the data.

By signing this form, I hereby certify that I understand the preceding terms and provisions and accept responsibility for the use of the DH 1214 data provided to me.

If you are producing a report, please send a copy of all printed and published materials using Virginia Department of Health Division of Dental Health data to Dr. R. Lynn Browder

Mohammad Alzahrani MAlzahrani 7/19/2010

Printed Name Signature Date

Information

The Division of Dental Health dental activity reports (DH1214) reflect services provided and patient demographics. Reports are compiled annually by DDH from submissions by public health dentists in the Districts. No identifying patient information is included. This is strictly a statistical report. The candidate intends to use the data to develop a dental services modeling instrument as a doctoral project.

Our intent is to share the DH1214 District Annual reports, from FY 08, 09, 10 as needed without identifying locality information. We will attempt to provide supporting information to PhD candidate Mr. Alzahrani to help him understand our program.

Please mail or fax this form to:
Dr. R. Lynn Browder
Division of Dental Health, Virginia Department of Health
109 Governor Street, 9th Floor
Richmond, Virginia 23219
Phone: (804) 864.7776, (703) 792.6323, Fax: (804) 864.7783
Lynn.Browder@VDH.Virginia.gov
APPENDIX C

DATA REQUEST FORM DH 1214, TO OBTAIN DATA FROM VDH

Name: Mohammad Alzahrani

Organization: Old Dominion University

Address: ODU - School of Community & Environmental Health
        4608 Hampton Blvd., Room 3134

City: Norfolk
State: VA
Zip Code: 23508
Email: malza001@odu.edu
Telephone: (757) 217-7292
Fax: (757) 757-683-6333

If the intended use of the data is for research purposes, a submission to the VDH Internal Review Board may be necessary. If your institution has determined IRB approval is not required please attach documentation with this request.

Data requested (District & Years):
Virginia Beach, Norfolk, Chesapeake, Portsmouth, Hampton, Newport News and Suffolk.
2005-2010.

How will the data be used: This dataset will be used to collect the parameters needed to build the simulation model necessary for this research. By using this dataset, researcher placed specific questions which would be used to measure the performance of oral healthcare services delivery at public health settings based on the theoretical framework.

Date requested by: 07/19/2010

Please mail, fax or e-mail this form to:
Dr. R. Lynn Browder
Division of Dental Health
Virginia Department of Health
109 Governor Street, 9th Floor
Richmond, Virginia 23219
Phone: (804) 864.7776, (703) 792.6323, Fax: (804) 864.7783
Lynn.Browder@VDH.Virginia.gov
APPENDIX D

HEALTH DISTRICT'S CONTACT INFORMATION

Norfolk Health District, Dental Program

<table>
<thead>
<tr>
<th>Locality</th>
<th>Contact</th>
<th>Phone</th>
<th>District</th>
<th>Web site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norfolk City</td>
<td>Dr. Michelle Galloway</td>
<td>757-531-2133</td>
<td>Norfolk City Health District</td>
<td><a href="http://www.norfolk.gov/pub_health/">http://www.norfolk.gov/pub_health/</a></td>
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Virginia Beach Health District, Dental Program

<table>
<thead>
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<th>Web site</th>
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</thead>
<tbody>
<tr>
<td>Virginia Beach City</td>
<td>Dr. Martin Walton, III</td>
<td>757-518-2677</td>
<td>Virginia Beach Health District</td>
<td><a href="http://www.vdh.virginia.gov/lhd/vabeach/">http://www.vdh.virginia.gov/lhd/vabeach/</a></td>
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Peninsula Health District, Dental Program

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<th>Web site</th>
</tr>
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<tbody>
<tr>
<td>Peninsula</td>
<td>Dr. Folake Akinbi</td>
<td>757-594-7424</td>
<td>Peninsula Health District</td>
<td><a href="http://www.vdh.virginia.gov/LHD/peninsula/">http://www.vdh.virginia.gov/LHD/peninsula/</a></td>
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<tr>
<td></td>
<td>Dr. Arthur Diamond</td>
<td>757-594-7816</td>
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Western Tidewater Health District, Dental Program

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<th>Web site</th>
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<tr>
<td>Isle of Wight County and Southampton County</td>
<td>Dr. Elizabeth Bernhard</td>
<td>757-357-7156, 757-653-3040</td>
<td>Western Tidewater Health District</td>
<td><a href="http://www.vdh.virginia.gov/LHD/WestTide/">http://www.vdh.virginia.gov/LHD/WestTide/</a></td>
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Note. Source: Virginia Department of Health, available at:

http://www.vdh.state.va.us/
### APPENDIX E

**DATASETS BASED ON THE SITES AND PROVIDERS**

#### Fiscal Year 2005

<table>
<thead>
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<th>Districts</th>
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<tbody>
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<td>Zinas, Zinas, CONSOLIDATED</td>
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<td></td>
<td>ZINAS Birdneck, Pembroke</td>
<td>Abraham</td>
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<td>ABRAHAM VA BEACH</td>
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<td>Hampton</td>
<td>Hampton</td>
<td>Reaves</td>
</tr>
<tr>
<td>4.</td>
<td>Peninsula</td>
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<td>Sherman, Diamond Dickerson</td>
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<td>5.</td>
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<td>4.</td>
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</tr>
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<td></td>
<td></td>
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**Fiscal Year 2008**

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**Fiscal Year 2010**

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</tr>
<tr>
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<td>Hampton</td>
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<td>Newport News Newport News PENINSULA Akinbi Diamond CONSOLIDATED</td>
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<tr>
<td>5.</td>
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<td>Isle of Wight Southampton WESTERN TIDEWATER Bernhard Bernhard CONSOLIDATED</td>
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</table>
### APPENDIX F

**DISTRIBUTION SUMMARIES**

**NORFOLK PUBLIC HEALTH DISTRICT, LITTLE CREEK DENTAL CLINIC**

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameters</th>
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<th>Expression</th>
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<tbody>
<tr>
<td>1.</td>
<td>Diagnosis and preventive services per recare visit</td>
<td>Gamma</td>
<td>$1 + \text{GAMM}(0.627, 7.14)$</td>
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<tr>
<td>2.</td>
<td>Corrective services per return visit</td>
<td>Beta</td>
<td>$17 \times \text{BETA}(0.637, 4.55)$</td>
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<tr>
<td>3.</td>
<td>Other services per return visit</td>
<td>Exponential</td>
<td>$-0.001 + \text{EXPO}(0.48)$</td>
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<td>4.</td>
<td>Interarrival rate (No RDH)</td>
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<td>5.</td>
<td>Interarrival rate (With RDH)</td>
<td>Erlang</td>
<td>$11 + \text{ERLA}(2.7, 4)$</td>
</tr>
<tr>
<td>6.</td>
<td>Check-in process time for first/recare visit</td>
<td>Triangular</td>
<td>$\text{TRIA}(15, 25, 45)$</td>
</tr>
<tr>
<td>7.</td>
<td>Check-in process time for return visit</td>
<td>Triangular</td>
<td>$\text{TRIA}(3, 5, 8)$</td>
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<tr>
<td>8.</td>
<td>Check-out process time for first/recare visit</td>
<td>Triangular</td>
<td>$\text{TRIA}(5, 10, 15)$</td>
</tr>
<tr>
<td>9.</td>
<td>Check-out process time for return visit</td>
<td>Triangular</td>
<td>$\text{TRIA}(1, 2, 3)$</td>
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<tr>
<td>10.</td>
<td>Dentist's treatment process time for first/recare visit</td>
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<td>$\text{TRIA}(4, 5, 10)$</td>
</tr>
<tr>
<td>11.</td>
<td>Dentist's treatment process time for return visit</td>
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<td>$\text{TRIA}(25, 30, 45)$</td>
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<tr>
<td>12.</td>
<td>Dental assistant's taking radiographs process time</td>
<td>Triangular</td>
<td>$\text{TRIA}(3, 5, 10)$</td>
</tr>
<tr>
<td>13.</td>
<td>Dental assistant's initial preventive services process time</td>
<td>Triangular</td>
<td>$\text{TRIA}(10, 15, 20)$</td>
</tr>
<tr>
<td>14.</td>
<td>Dental hygiene diagnosis and preventive services process time</td>
<td>Triangular</td>
<td>$\text{TRIA}(15, 20, 30)$</td>
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### Distribution Summary

**Norfolk Public Health District Dental Clinic, Park Place Dental Clinic**

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<td>Triangular</td>
<td>TRIA(2, 4, 10)</td>
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<tr>
<td>2.</td>
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<td>Erlang</td>
<td>-0.001 + ERLA(0.899, 2)</td>
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<td>3.</td>
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<td>-0.001 + EXPO(0.365)</td>
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<td>NORM(64.8, 29.6)</td>
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<td>5.</td>
<td>Interarrival rate (With RDH)</td>
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<td>NORM(32.4, 14.8)</td>
</tr>
<tr>
<td>6.</td>
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<td>Triangular</td>
<td>TRIA(15, 25, 45)</td>
</tr>
<tr>
<td>7.</td>
<td>Check-in process time for return visit</td>
<td>Triangular</td>
<td>TRIA(3, 5, 8)</td>
</tr>
<tr>
<td>8.</td>
<td>Check-out process time for first/recare visit</td>
<td>Triangular</td>
<td>TRIA(5, 10, 15)</td>
</tr>
<tr>
<td>9.</td>
<td>Check-out process time for return visit</td>
<td>Triangular</td>
<td>TRIA(1, 2, 3)</td>
</tr>
<tr>
<td>10.</td>
<td>Dentist's treatment process time for first/recare visit</td>
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<td>TRIA(4, 5, 10)</td>
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<tr>
<td>11.</td>
<td>Dentist's treatment process time for return visit</td>
<td>Triangular</td>
<td>TRIA(25, 30, 45)</td>
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<tr>
<td>12.</td>
<td>Dental assistant's taking radiographs process time</td>
<td>Triangular</td>
<td>TRIA(3, 5, 10)</td>
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<tr>
<td>13.</td>
<td>Dental assistant's initial preventive services process time</td>
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<tr>
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<td>Dental hygiene diagnosis and preventive services process time</td>
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### Distribution Summary
**Virginia Beach Public Health District, Pembroke Dental Clinic**

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<tr>
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<td>$0.1 + \text{LOGN}(1.09, 0.549)$</td>
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<td>3.</td>
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<td>$\text{ERLA}(0.142, 5)$</td>
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<td>5.</td>
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<td>6.</td>
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<td>Triangular</td>
<td>$\text{TRIA}(15, 25, 45)$</td>
</tr>
<tr>
<td>7.</td>
<td>Check-in process time for return visit</td>
<td>Triangular</td>
<td>$\text{TRIA}(3, 5, 8)$</td>
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<tr>
<td>8.</td>
<td>Check-out process time for first/recare visit</td>
<td>Triangular</td>
<td>$\text{TRIA}(5, 10, 15)$</td>
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<td>9.</td>
<td>Check-out process time for return visit</td>
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<td>$\text{TRIA}(1, 2, 3)$</td>
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<tr>
<td>10.</td>
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<td>Triangular</td>
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<tr>
<td>11.</td>
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<td>Triangular</td>
<td>$\text{TRIA}(25, 30, 45)$</td>
</tr>
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<td>12.</td>
<td>Dental assistant's taking radiographs process time</td>
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<tr>
<td>13.</td>
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<td>Triangular</td>
<td>$\text{TRIA}(10, 15, 20)$</td>
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<td>14.</td>
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<td>$\text{TRIA}(15, 20, 30)$</td>
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<td>5.</td>
<td>Interarrival rate (With RDH)</td>
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<td>4 + ERLA(13.6, 2)</td>
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<td>TRIA(15, 25, 45)</td>
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<td>7.</td>
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<td>TRIA(3, 5, 8)</td>
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<td>TRIA(5, 10, 15)</td>
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<td>Dental assistant's taking radiographs process time</td>
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## Distribution Summary

### Hampton Public Health District, Dental Clinic

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<td>TRIA(5, 10, 15)</td>
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<tr>
<td>9.</td>
<td>Check-out process time for return visit</td>
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<td>TRIA(1, 2, 3)</td>
</tr>
<tr>
<td>10.</td>
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<td>TRIA(4, 5,10)</td>
</tr>
<tr>
<td>11.</td>
<td>Dentist's treatment process time for return visit</td>
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<td>TRIA(25, 30,45)</td>
</tr>
<tr>
<td>12.</td>
<td>Dental assistant's taking radiographs process time</td>
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<td>TRIA(3, 5,10)</td>
</tr>
<tr>
<td>13.</td>
<td>Dental assistant's initial preventive services process time</td>
<td>Triangular</td>
<td>TRIA(10, 15,20)</td>
</tr>
<tr>
<td>14.</td>
<td>Dental hygiene diagnosis and preventive services process time</td>
<td>Triangular</td>
<td>TRIA(15, 20,30)</td>
</tr>
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### Distribution Summary

**Peninsula Public Health District, Dental Clinic**

<table>
<thead>
<tr>
<th>No.</th>
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<th>Expression</th>
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<tbody>
<tr>
<td>1.</td>
<td>Diagnosis and preventive services per recare visit</td>
<td>Weibull</td>
<td>$1 + \text{WEIB}(2.74, 1.51)$</td>
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<tr>
<td>2.</td>
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<td>3.</td>
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<td>4.</td>
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<td>TRIA(5, 15.4, 97)</td>
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<tr>
<td>5.</td>
<td>Interarrival rate (With RDH)</td>
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<td>TRIA(2, 10.8, 49)</td>
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<tr>
<td>6.</td>
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<td>TRIA(15, 25, 45)</td>
</tr>
<tr>
<td>7.</td>
<td>Check-in process time for return visit</td>
<td>Triangular</td>
<td>TRIA(3, 5, 8)</td>
</tr>
<tr>
<td>8.</td>
<td>Check-out process time for first/recare visit</td>
<td>Triangular</td>
<td>TRIA(5, 10, 15)</td>
</tr>
<tr>
<td>9.</td>
<td>Check-out process time for return visit</td>
<td>Triangular</td>
<td>TRIA(1, 2, 3)</td>
</tr>
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<td>10.</td>
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<td>TRIA(4, 5,10)</td>
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<td>11.</td>
<td>Dentist's treatment process time for return visit</td>
<td>Triangular</td>
<td>TRIA(25, 30,45)</td>
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<tr>
<td>12.</td>
<td>Dental assistant's taking radiographs process time</td>
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<td>13.</td>
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<td>Triangular</td>
<td>TRIA(10, 15,20)</td>
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<td>14.</td>
<td>Dental hygiene diagnosis and preventive services process time</td>
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### Distribution Summary

**Western Tidewater Public Health District, Isle of Wight Dental Clinic**

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<td>1. Diagnosis and preventive services per recare visit</td>
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<td>2. Corrective services per return visit</td>
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<tr>
<td>3. Other services per return visit</td>
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<tr>
<td>4. Interarrival rate (No RDH)</td>
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<td>NORM(51.6, 17.8)</td>
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<td>5. Interarrival rate (With RDH)</td>
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<tr>
<td>6. Check-in process time for first/recare visit</td>
<td>Triangular</td>
<td>TRIA(15, 25, 45)</td>
</tr>
<tr>
<td>7. Check-in process time for return visit</td>
<td>Triangular</td>
<td>TRIA(3, 5, 8)</td>
</tr>
<tr>
<td>8. Check-out process time for first/recare visit</td>
<td>Triangular</td>
<td>TRIA(5, 10, 15)</td>
</tr>
<tr>
<td>9. Check-out process time for return visit</td>
<td>Triangular</td>
<td>TRIA(1, 2, 3)</td>
</tr>
<tr>
<td>10. Dentist's treatment process time for first/recare visit</td>
<td>Triangular</td>
<td>TRIA(4, 5, 10)</td>
</tr>
<tr>
<td>11. Dentist's treatment process time for return visit</td>
<td>Triangular</td>
<td>TRIA(25, 30, 45)</td>
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<tr>
<td>12. Dental assistant's taking radiographs time</td>
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<td>TRIA(3, 5, 10)</td>
</tr>
<tr>
<td>13. Dental assistant's initial preventive services process time</td>
<td>Triangular</td>
<td>TRIA(10, 15, 20)</td>
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<tr>
<td>14. Dental hygiene diagnosis and preventive services process time</td>
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# Distribution Summary

**Western Tidewater Public Health District, Southampton Dental Clinic**

<table>
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<td>2.</td>
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<td>5.</td>
<td>Interarrival rate (With RDH)</td>
<td>Gamma</td>
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<td>6.</td>
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<td>TRIA(15, 25, 45)</td>
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<tr>
<td>7.</td>
<td>Check-in process time for return visit</td>
<td>Triangular</td>
<td>TRIA(3, 5, 8)</td>
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<td>8.</td>
<td>Check-out process time for first/recare visit</td>
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<td>TRIA(10, 15, 20)</td>
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<tr>
<td>14.</td>
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<td>Triangular</td>
<td>TRIA(15, 20, 30)</td>
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APPENDIX G

PROFESSIONAL ROLES OF THE DENTAL HYGIENIST

Note: Adapted from Wilkins (2005)
APPENDIX H

PERFORMANCE METRICS COMPARISONS OF PUBLIC HEALTH DISTRICTS' DENTAL CLINICS

Number of patients' visits

![Graph showing number of patients' visits for different districts.]

Diagnostic and preventive services

![Graph showing diagnostic and preventive services for different districts.]

- As is
- Plus RDH
VITA

NAME: Mohammad J. Alzahrani

EDUCATION

<table>
<thead>
<tr>
<th>Year</th>
<th>Degree and Institution</th>
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</thead>
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<tr>
<td>1994</td>
<td>Bachelor of Science, Dental Technology, King Saud University, Riyadh, Kingdom of Saudi</td>
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<tr>
<td></td>
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<tr>
<td>2004, May</td>
<td>Bachelor of Science, Dental Hygiene, Old Dominion University, Norfolk, Virginia, United</td>
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<td></td>
<td>States of America</td>
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<tr>
<td>2005, May</td>
<td>Master of Science, Dental Hygiene, Old Dominion University, Norfolk, Virginia, United</td>
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<tr>
<td></td>
<td>States of America</td>
</tr>
<tr>
<td>2009</td>
<td>Certified in Modeling and Simulation in Health Sciences, Old Dominion University, Norfolk</td>
</tr>
<tr>
<td></td>
<td>Virginia, United States of America</td>
</tr>
<tr>
<td>2011, August</td>
<td>PhD in Health Services Research, Old Dominion University, Norfolk, Virginia, United</td>
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<td>States of America</td>
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ACTIVITIES AND HONORS

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<th>Activity</th>
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<tr>
<td>1994</td>
<td>Honor class, King Saud University, Riyadh, Saudi Arabia</td>
</tr>
<tr>
<td>2003, Fall</td>
<td>Dean’s list.</td>
</tr>
<tr>
<td>2004, Spring</td>
<td>Dean’s list.</td>
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<tr>
<td>2004</td>
<td>National Board Dental Hygiene Examination (NBDHE)</td>
</tr>
<tr>
<td>2005, May</td>
<td>Outstanding Teaching Assistant, Old Dominion University, School of Dental Hygiene, Norfolk, Virginia, USA</td>
</tr>
<tr>
<td>2009</td>
<td>Wall of Achievement for Saudi students in USA on Saudi Students Fair, Saudi Embassy, Washington DC, 2009</td>
</tr>
<tr>
<td>2010</td>
<td>Wall of Achievement for Saudi students in USA on Saudi Students Fair, Saudi Embassy, Washington DC, 2010</td>
</tr>
</tbody>
</table>

The word processor used in this dissertation is Microsoft® Office Word, 2007.