Summer 6-21-2014

Forensic DNA Analysis and the Human Element: A Team-Based Efficiency Model for the Biology Unit of the Contra Costa County Office of the Sheriff, Forensic Services Division

Debra McKillop

Forensic DNA Analysis and the Human Element: A Team-Based Efficiency Model for the Biology Unit of the Contra Costa County Office of the Sheriff, Forensic Services Division

Submitted by

Debra McKillop
Golden Gate University
San Francisco, California

EMPA 396
Graduate Research Project in Public Management

Faculty Advisors:
Dr. Mick McGee and
Dr. Jay Gonzalez

June 21, 2014

Table of Contents

Abstract

Forensic DNA analysis is a valuable tool for law enforcement and judicial communities because it offers the discriminating power to either convict, exonerate or eliminate individuals in criminal investigations. The growing demand for DNA analysis is creating significant DNA backlogs at crime laboratories across our county. Federal grants from the National Institute of Justice (NIJ) have assisted in developing and adopting methods to improve laboratory processes. These methods serve as models for forensic science laboratories in creating efficiency improvement strategies. This research study evaluated and implemented a team-based DNA analysis model based on grant funded research using a "lean laboratory" approach currently in operation at the Oakland Police Crime Laboratory. This study's findings will determine if a DNA lean laboratory team-based approach operates with greater efficiency than analysts working independently, thus producing greater throughput, faster turnaround time, reduced costs and improved morale. Since 1986, this forensic science practitioner has served in the capacity of criminalist, toxicologist, drug chemist, serologist, crime scene responder, and DNA analyst. While a Criminalistics Unit and DNA Unit Supervisor, she developed and instituted case management systems and established operational workflows. As the current Forensic Manager at the Contra Costa County Office of the Sheriff (CCCSO), Forensic Services Division, Criminalistics Section, she oversees the Biology Unit, which performs DNA analysis. Satisfying the demanding needs of the criminal justice community has been an on-going struggle facing the laboratory. New, novel and progressive approaches were evaluated and implemented for the purpose of this research study.

Introduction

Forensic DNA analysis has played a crucial role in the investigation and resolution of thousands of crimes since the late 1980s. Today most crime laboratories, whether they are government or private facilities, offer some degree of DNA analysis to their clients. DNA, or deoxyribonucleic acid, is found inside a central area of the human cell called the nucleus. DNA contains genetic information that is passed from parent to offspring during reproduction. Human DNA is unique, and with the exception of identical siblings, no two humans have ever been found to have the same DNA. The unique nature of DNA affords forensic scientists the ability to discriminate among individuals within a population. Therefore, a single individual can be identified when DNA from a crime scene matches DNA from a person. The term "DNA Match" has widely been used when associations such as these are generated. This type of comparison is the principle behind forensic DNA analysis.

Background and History

Violent crimes such as rape or murder often result in biological fluids either being exchanged between people or being left behind at the crime scene. Law enforcement agencies rely on crime scene investigators to document, collect and submit biological evidence to the crime laboratory with the expectation that Forensic DNA analysis may generate investigatory leads, (information that can greatly aid an investigation), if results are received in a timely manner. In addition, within the legal community DNA has the ability to convict those charged with a crime, and exonerate those falsely accused. Due to its investigatory potential, discriminatory nature, and overall increased awareness, the demand for DNA analysis has far exceeded the current capabilities of our nation's public crime laboratories. More evidence samples are collected at crime scenes, and these samples are becoming increasingly more complex to process and interpret. Therefore, the National Institute of Justice (NIJ) funded forensic research and development projects to identify ways to

increase the efficiency and capacity of DNA analysis. These projects explore the tools, technologies and novel ways of developing and adopting improved forensic laboratory processes (NIJ, 2012). The objective of the NIJ grant program entitled "Forensic DNA Unit Efficiency Improvement" was to "publish successful and carefully evaluated novel efficiency improvement methodologies. These are intended to serve as models to be considered by other forensic science laboratories." (NIJ, 2012). As a result of the NIJ grant program, many models were published and shared.

The Louisiana State Police Laboratory approached the task of efficiency improvement by utilizing a concept new to the field of Forensic Science. As a 2008 NIJ Forensic DNA Unit Efficiency Improvement Grant recipient, they employed the services of Sorensen Forensics and began implementing Lean Six Sigma tools. The intent of Lean Six Sigma is to streamline processes, reduce waste, and deliver quality products to customers in a timely manner. The goal of a Lean Six Sigma Laboratory is to improve quality while simultaneously reducing employee stress, use fewer resources, and reduce turnaround time. Basically, a Lean Six Sigma Laboratory focuses on delivering results in the most efficient way in terms of cost and timing. The Louisiana State Police successfully established a team-based operational model to address DNA forensic casework and increase efficiency. Among their many successes was that the DNA Unit was able to increase the number of samples processed each month by 280% during the NIJ Grant period (Richard, M., & Kupferschmid, T.D., 2011). In addition, the improvements to their DNA process has led to a 134% completion rate in the number of DNA cases completed in 2010 (Richard, M., & Kupferschmid, T.D., 2011). Using Lean Six Sigma tools made possible through an NIJ Grant, the South Carolina Law Enforcement Division (SLED) Forensic DNA laboratory was able to improve the turnaround time for the analysis of prioritized violent crime casework by 42% after the implementation of a new team-based case management process (Taylor, R. et al., 2009).

Building from the models developed by the Louisiana and South Carolina Crime laboratories, and using the application of Lean Six Sigma, the Oakland, California, Police Department Crime Laboratory developed their own highly productive team-based DNA analysis case management model. This model involves the formation of a "POD", which is simply three DNA analysts that work together in a team environment, supported by a DNA technician. The pod or team work together to complete 30 cases in a 5 week rotation period. Team members share case processing duties. This approach has resulted in a 48% increase in sample productivity and improved staff morale. In addition, case turnaround time and reagent costs have been greatly reduced according to DNA Unit Supervisor, Jennifer Mihalovich.

Traditionally, most laboratories follow a simple case assignment and processing model that focuses on the individual DNA analyst. Cases are submitted to the crime laboratory and are then assigned to each DNA analyst regardless of their personal backlog of incomplete work. If more cases are assigned than the analyst can complete, their personal backlog increases. Over time, these backlogs can reach high numbers. At the Oakland Police Department Crime Laboratory this practice has been replaced with a team-based model that has significantly improved overall case management efficiency. The DNA unit holds the unassigned cases in a queue and assigns them to the pods in a batch for analysis.

The Contra Costa County Office of the Sheriff (CCCSO), Biology Unit has been struggling to improve sample productivity, turnaround time, reagent costs, and morale. The DNA analysts follow an individual case management model and work their cases independent of their co-workers, although they do not carry a personal backlog since unassigned cases are held in a unit queue. The management of their time, use of equipment, analysis of samples, consumption of supplies and reagents are all performed at an individual level.

Purpose of Study

This research study explores a lean laboratory team-based approach to DNA analysis as defined by the Oakland Police Department Crime Laboratory, and examines whether or not this "POD" or lean laboratory team based model would have positive affects on sample productivity, turnaround time, reagent costs, and morale when implemented at the Contra Costa County Office of the Sheriff, Biology Unit. With the exception of a DNA technician who can be substituted by a DNA analyst, this team-based model can be easily implemented. Strategies to combat the current backlog and the anticipated increase of DNA analysis are challenges facing the Contra Costa County Office of the Sheriff, Biology Unit. The author has the administrative authority to create, implement and evaluate exploratory research models. The overall efficiency of this lean laboratory team-based DNA case management model has been directly researched in-house against four criteria: sample productivity, turnaround time, reagent costs and morale.

The Contra Costa County Office of the Sheriff, Biology Unit moved their operations to a new facility on December 24, 2012. Due to space restrictions, the old facility did not allow for a research project of this nature. In anticipation of establishing a Biology Unit efficiency improvement plan, careful consideration was given to the floor plan design and layout of the Biology Unit with respect to unit operations. In addition, the administrative aspects to sample management, such are worksheets, checklists, case notes and report formats were streamlined and modified to accommodate the lean laboratory team-based model. In order to collect sufficient data to evaluate the performance criteria, the lean laboratory team-based DNA case management system research study began in March 2013. Data collected over nine months was evaluated and compared to a previous nine-month case working period. The results of this research study were analyzed to determine if the team-based case management system demonstrates greater efficiency over the traditional individual assignment system. This data, in combination with the Oakland

Police Department Crime Laboratory "POD" Model and additional crime laboratory DNA efficiency studies will be used to find the best system of case management to maximize the overall efficiency and effectiveness of the Biology Unit.

Research Hypothesis and Variables

The hypothesis for the research proposes is that implementation of a lean laboratory team-based approach to DNA case management will produce an increase in sample productivity and moral while reducing turnaround time and reagent costs. The independent variable is the implementation of a lean laboratory, team-based processing model for DNA case management and the four dependent variables are sample productivity, turnaround time, reagent cost and moral.

In order to arrive at this hypothesis, the author reviewed technical and non-technical literature pertaining to laboratory efficiency improvement strategies, attended California Association of Crime Laboratory Directors conferences and training seminars, spoke with forensic practitioners and consulted industry leaders. The pros and cons of various strategies were investigated until the lean laboratory team-based model was selected for implantation and evaluation. This research further proposes that the Oakland Police Department Crime Laboratory lean laboratory team-based case management system, when implemented at the Contra Costa County Office of the Sheriff, Forensic Services Division, Biology Unit, will demonstrate greater efficiency over the traditional individual assignment system.

According to Bozeman, a policy philosophy is a set of values about the most desirable means of achieving purpose. "The policy philosophy of rationalism is rooted in a faith in man's reason and the assumption that problems of governance are amenable to reasonable solution through scientific analysis, logic, and systematic inquiry. The prototypical rationalist administrator is the management scientist" (Bozeman, 1979, p62). The idea that there is a best way to proceed, and that it is found through reason, and is scientifically grounded, also defines rationalism. The lean

laboratory team based DNA efficiency model has evolved from scientific experimentation, evaluation, modification and peer review, all of which are processes that inspire confidence among stakeholders. The goal was to define a system that maximizes outputs and minimizes costs, and ultimately provide the framework to develop a positive overall outcome. This model is measurable on a quantifiable basis, so the results generated can be evaluated, allowing for scientific assessment. The overwhelming consensus from the published data suggests implementation of an efficiency model will produce maximum social gain at minimum expense, another dimension of Rationalism.

According to Brewer (1983), the more powerful the source of the policy the more likely it will be effectively implemented. The lean laboratory team based DNA efficiency model was initiated by upper management in an effort to improve productivity. Considerable research was done to investigate available models, theories and practices in an effort to select the best approach that meets the operational needs of the Contra Costa County Office of the Sheriff, Forensic Services Division, Biology Unit. The Oakland Police Department Crime laboratory team-based "Pod" case management system was selected as the best model.

Research Question and Sub-questions

This research effort explores the question of whether or not a lean laboratory team-based DNA analysis approach will improve efficiency over the traditional individual assignment system against four measurable criteria: sample productivity, turnaround time, reagent costs and morale. To do so, the research focused on seeking answers to the following questions:

1. How will sample productivity be measured and what percent improvement will be considered significant?
2. How will turnaround time be defined and measured and what percent improvement will be considered significant?

3. How will reagents costs be measured and what percent improvement will be considered significant?
4. Can job satisfaction/moral be measured comprehensively through individual assessment via survey/ key informant interviews and what constitutes significant enhancement?
5. Will modifications/deviations to the selected team-based model have an impact on overall outcome?

A majority of the research methodologies within this study consist of primary data. This data was gathered in the form of key informant interviews, anonymous survey, and statistics derived directly from the research study via database query. The interviews and survey were designed to evaluate job satisfaction as it relates to team moral. Team moral can be defined as the enthusiasm and persistence with which a member of a team engages in the prescribed activities of that group (Verwijs, 2012). In a cohesive team with high moral, people are generally happy, proud, exhibit less stress, and willing to go the extra mile. Laboratory database queries pull primary data and generate statistics associated with the productivity and turnaround time for the Biology Unit staff within the specific periods of time. Reagent cost will be isolated to the standardized quantification kit (Human Duo Kit) purchased from Life technologies. Review of purchasing documents, run logs, and sample sheets provided statistics on the number of batched casework performed during the study periods evaluated and compared.

Additional research methodologies include a literature search which primarily focused on governmental documents, forensic journals, research studies and articles authored by forensic practitioners and research organizations. This secondary research served as the basis to evaluate efficiency models and previous research conducted in the area of process improvement.

Review of Literature

The search of literature related to the establishment of a lean laboratory team-based approach to case management within the forensic discipline of DNA analysis resulted in a multitude of relevant research materials. Selected reference materials focus on the contributing factors for and the current state of our nation's DNA evidence backlog, which establishes the reasons why innovative and efficient DNA processing models are being so diligently evaluated and explored. Backlog reduction strategies include staffing, equipment, automation, robotics, new technologies, outsourcing casework, and various efficiency improvement models.

Despite NIJ grant funding efforts to support government crime laboratories, the backlog of unexamined evidence continues to grow. According to Mark Grant, a senior program manager with the Office of Investigative and Forensic Sciences at the National Institute of Justice and author of, *Making Sense of the DNA Backlogs, 2010-Myths vs. Reality*, "crime laboratories are processing more cases than even before, but their expanded capacity has not been able to meet the increase demand" (Nelson, 2011, p. iii). Backlog can be defined many ways, but the NIJ considers a case backlogged if the evidence remains untested 30 days after submission to the laboratory. NIJ funding for backlog reduction programs provided $394,872,665.00 to crime laboratories between 2004 and 2010 (Nelson, 2012, p. 6). The author states that one reason for our nation's DNA evidence backlog is that now, more than ever, there is increased awareness and knowledge of the potential for DNA evidence to solve crimes. Therefore, more evidence is collected at crime scenes and submitted to crime laboratories for DNA analysis (Nelson, 2011).

Dean Gialamas, the Director of the Los Angeles County Crime Laboratory, was interviewed at the 2010 NIJ Conference in Arlington, Virginia, and stated that "Backlog also tells you nothing about efficiency…We need to be focusing on true performance; that would be inputs, outputs, what we can achieve based on what comes in" (National Institute of Justice, 2012, June 14-16).

Timothy Kupferschmid, of Sorensen Forensics, a private forensic laboratory specializing in Lean Six Sigma methodologies, stated in the article, *Shovel Away Your DNA Backlog with Lean Six Sigma Tools*, "The Laboratory Lean Six Sigma Practices improvement model shows real gains in production and efficiencies, without terminating or hiring staff and without adding any new diagnostic equipment" (Kupferschmid, 2011, p. 1).

In contrast with this view point, the 2012 Federal Bureau of Investigation Crime Laboratory Audit Report states that the addition of personnel played a role along with the application of efficiency improvements to reduce the Nuclear DNA case backlog (U.S. Department of Justice, 2012). In a 2012 NIJ supported grant project technical report focusing on a DNA efficiency improvement model at the Denver Police Department Crime laboratory, it was determined that staffing was a key factor in reducing the backlog and turnaround time. Their laboratory model proved that "trained personnel were the primary limiting resource for DNA Unit efficiency" (Horvat, 2012, p. 70). Equipment and instrumentation were not limiting factors in increasing capacity or reducing the backlog or turnaround time.

However, several articles indicate the opposite position and clearly state that instrumentation including automation and robotics offer significant contributions to enhanced capacity, backlog reduction and reduced turnaround time. The San Diego Police Department Crime Laboratory developed a procedure for DNA extraction using the BioRobit EZ1, a simple automated instrument. When employed appropriately and in conjunction with organic extraction, sample processing times will be reduced without sacrificing casework quality. In addition, use of the BioRobot EZ1 drastically reduced the potential for human error. The timesaving high quality DNA extraction method helped meet the rising demand for crime laboratory services while reducing analyst time and the sample backlog (Montpetit, 2005, p. 8). Automation, use of robotics and a capillary electrophoresis instrument streamlined workflow and allowed staff to focus on data

analysis and less on administrative paperwork. These changes improved sample productivity, turnaround time, sample handling and data management at the Austrian Ministry of the Interior DNA Intelligence Database Laboratory (Steinlechner, 2001). It became evident that the proper use of automation and robotics clearly benefit DNA laboratory operational efficiency.

An insightful discussion on automation was reflected in the article titled, Dealing with Increasing casework Demands of DNA Analysis, by Varlaro and Duceman (2002) where the goal of automation was not just productivity, but "an attendant increase in data reproducibility and reliability" with the expected outcomes to "include decreased throughput times, enhanced process quality, improved reproducibility and superior data traceability". According to Duceman, another benefit of automation is freeing up highly skilled DNA analysts from preforming tedious and repetitive tasks, and allowing more time to be dedicated to evidence evaluation, stain identification, data interpretation and preparation for courtroom testimony. Repetitive stress disorders is a major medical concern for DNA staff within the CCCSO, Biology Unit due to the repetitive nature of tasks, therefore robotic equipment has been acquired and equipment validation is underway. Duceman further states that multiple strategies should be explored to combat modern day DNA laboratory challenges, a philosophy shared by this author and reflected in this research study. According to Duceman, these strategies include increasing staffing levels, introduction of batching processes, and embracing a new generation of faster DNA technologies.

New technologies are being developed today that will allow for Rapid DNA, a term used to describe an instrument that can generate a DNA result within a few hours at a police station without the need for a DNA analyst or crime laboratory. In the future, Rapid DNA can generate cost effective investigative leads for law enforcement officers, provide identification during the booking process and promote intelligence-led policing in spite of reduced budgets (Blackledge, 2012).

If budgets are not a concern, outsourcing may serve as a viable tool for efficiency improvement. According to Crouse (2012), the Palm Beach County Sheriff's Office Forensic Biology Unit in partnership with Bode Technology Group began to outsource property crimes in an effort to generate DNA results that may serve as timely investigative leads, as well as being entered and searched in a DNA database of offenders and evidence samples. Outsourcing serves as another tool to streamline the DNA analysis process and allow for consistent and faster turnaround times, while relieving staff of administrative burdens, providing the citizens with a more timely investigation of property crimes, and ultimately solving crimes and reducing recidivism (Crouse, 2012). Realistically, outsourcing can be an expensive endeavor, and laboratories continue to strive for inexpensive methods of increasing casework demands for DNA analysis.

One low cost method was described in the literature as "Managed Forensics", a multi-faceted strategy to address the growing amount of casework submitted to crime laboratories (Varlaro, 2002, p. 3-6). The Boston Police Crime Laboratory developed this strategy to combat their backlog, which requires cooperation and understanding from the crime laboratory director to the DNA analysts and includes the investigators prosecutors and defense attorneys. The success of this method calls for traditional individual case working models to be streamlined, and staff trained to operate in a more efficient manner. Focus is then centered on identifying the most probative evidence through a collaborative discussion between the investigators, crime laboratory staff, and the prosecutors assigned to the case. These discussions whether conducted in person or through the phone foster education, training and convey the best practices and uses of DNA technology. This forensic team approach in which the DNA analyst provides scientific consultation helps to ensure that DNA analysis performed on the most probative evidence will provide scientifically meaningful information to the case. This process reduces the overall number of samples processed

per case which is critical claims Varlaro for managing casework in a timely and efficient manner. Varlaro further indicates that the past practice of performing DNA analysis on a majority of case evidence just to avoid a courtroom explanation for why testing was not performed must come to an end. These same messages have been conveyed to prosecutors and law enforcement officers in Contra Costa County, but without a formal process, which is this author's 2014 project for future exploration, has not gained a solid foothold. "Managed Forensics" and "developing key relationships between investigators, the crime lab, and prosecutors is just as important as developing new technology" (Varlaro, 2002, p. 4).

Perhaps the most pertinent researched literature was generated from grantee reports as a result of the National Institute of Justice, Forensic DNA Efficiency Improvement Grant Program that provided 15 grants totaling 6.3 million dollars to government crime laboratories between 2008 and 2010 (Awards related to: Laboratory efficiency. (n.d.)). Four grant recipients reported on the efficiency improvement programs instituted at their crime laboratories that focused on the use of team-based models to address a management or organizational need. In addition to a team-based approach to improve efficiency, the National Institute of Justice, National Institute of Health, and private business models support the use of Lean and Six Sigma. These two process improvement methodology used to systematically analyze and improve process flow and efficiency have gained a great deal of notoriety due to their successful application within the field of forensic DNA analysis.

Lean is a management approach that reduces wasteful activities and improves work flow to efficiently produce a product or service. A Lean assessment involves the use of "value stream mapping" or "process mapping" where flowcharts, diagrams and handwritten materials help visualize a particular analytical process. "The main goal of value stream mapping is to document all value and non-value added information and actions to eliminate wasteful steps within a given

process" (French, 2006, p. 1). The information gained from such scrutiny helps forensic laboratories derive solutions to maximize efficiency (U.S. Dept. of Justice, 2008).

Six Sigma is a management approach that seeks to maximize profits by making a process more uniform and precise through the application of scientific principles to reduce variation and promote optimization (Maleyeff, 2007, p.9). According to Schweikhart (p. 3), combinations of Lean and Six Sigma have been developed that are process-centered and data-driven, and proponents of a combined approach believe that organizations will benefit from adopting this methodology. This blend of process improvement methodologies is commonly referred to as Lean Six Sigma (LSS) or "lean laboratory", which focuses on "customer satisfaction, a culture of continuous improvement, the search for a root cause, and comprehensive employee involvement" (Maleyeff, 2007, p. 8).

In our current economic times, where state and city budgets are being cut, yet demand for forensic services increases, crime laboratories are being forced to do more with less. Reduction of staff through layoffs, hiring freezes, and retirement incentives have further limited staffing resources. Yet, there an increasing demand to work better, faster and be more cost effective. Finding a low cost, no cost solution to these increasing demands upon our workforce would be beneficial to crime laboratory operations. According to Kupferschmid, in a crime laboratory setting "Lean Six Sigma tools, applied in a programmatic way, can yield remarkable results that are both cost-effective and morale-building" (Kupferschmid, 2011, p. 2).

The National Institute of Health (NIH) shares the same belief, and has established a "Roadmap for Medical Research" focused on obtaining maximum value from biomedical research investments using lean and six sigma tools to improve the timeliness and efficiency (Schweikhart, 2009, p. 2). The goal is to embrace strategies for process improvement through a set of coordinated principles and practices that promote greater efficiency and effectiveness, with fewer wasteful practices or errors. The IBM Center for The Business of Government published a report

titled, *Improving Service Delivery in Government with Lean Six Sigma* that highlights the need to translate Lean Six Sigma methods from applications in manufacturing to the service-oriented environment of the public sector (Maleyeff, 2007, p. 4).

In a 2008 NIJ Report titled, *Increasing Efficiency in Crime Laboratories*, the use of Lean Six Sigma tools, such as process mapping, has helped "managers review their laboratory systems and processes and determine how best to allocate staff and resources. The techniques are often used to redesign and streamline laboratory procedures and plan for new technologies" (U.S. Dept. of Justice, 2008, p. 2). According to French, in the article titled, *Using Process Mapping to Improve Efficiency in a Forensic Laboratory,* "This improvement process, which begins as an organizational and communication tool, can eventually become a discipline, a culture and a way of thinking in your laboratory" (French, 2006, p. 1). There are additional benefits of process mapping seen at a personnel level. Process mapping involves every person in a unit, thereby creating a sense of ownership. Allowing bench-level staff to steer the direction of the unit creates excitement, builds morale and a positive work environment. This philosophy is shared by Kupferschmid, as he states, "increased accountability of each team member has increased morale" (Kupferschmid, 2011, p. 3).

According to Verwijs "morale can be defined as the enthusiasm and persistence with which a member of a team engages in the prescribed activities of that group (Verwijs, 2012). Research performed by Verwijs, indicates that measuring morale can be difficult especially if questions focus on elements of happiness, which is much more subjective in scope than morale. Verwijs and colleagues established a set of questions that reliably measure team moral in a valid, scientifically and statically sound manner which were slightly modified for his assessment of teams interacting in a software development interactive framework environment. Verwijs designed eight questions, to be rated on a 1 to 7 scale, that are specific at measuring intangible concepts. Team morale is the

average of the individual averages. These measurements can be useful when assessing a team's well-being, and were used as described within this research study. Management certainly benefits from the use of lean laboratory approaches and being in touch with your staff and the morale of your team is important and powerful information when assessing the human element, the people that make your organization shine.

Lean six sigma tools have many applications, and on a larger scale can be applied in a comprehensive manner to evaluate crime laboratory processes, and to generate organizational and management models. These models not only apply to the originating laboratory, but also serve as a model to be shared and duplicated (Kupferschmid, 2011). This theme was also seen in the NIJ Forensic DNA Efficiency Improvement Grant objectives, which states:

> "NIJ's objective is to publish successful and carefully evaluated novel efficiency improvement methodologies. These are intended to serve as models to be considered by other forensic science laboratories…Under this program, NIJ funded novel and innovative ways to improve the efficiency and capacity of public forensic DNA laboratories by developing and adopting an improved laboratory process" (NIJ, 2012, October 10, p. 1).

Careful evaluation of published NIJ Forensic DNA Unit Efficiency Improvement grant reports resulted in the identification of four efficiency models related to DNA analysis. Non-NIJ funded DNA efficiency models were also identified.

The Orange County Crime Laboratory adopted a team based approach for property crime DNA analysis. Three teams were created each consisting four members, supported by part-time staff and a technician. These teams worked together within a five day rotational block to complete tasks. The teams work schedules were staggered to facilitate a continual flow of analysis activities. In addition, teams met weekly to communicate and triage cases. This process fostered a cooperative effort that ensured cases were screened and prioritized prior to DNA analysis.

Implementation of this process resulted in a reduction in turnaround time from 125 days to 114 days for property crimes, and from 89 days to 62 days for violent crimes. On the down side was the realization that increased throughput resulted in additional need for court testimony, which disrupted the strict weekly schedule. This report indicated that further study needed to be conducted to evaluate how to modify the strict five day rotational time frame in light of increased court obligations. The requirement of Melendez-Diaz testimony from all analysts participating in the high volume team analysis also created more court testimony requests. Melendez-Diaz refers to a Massachusetts court decision that states that any laboratory support personnel that contributed to the outcome of a case report may be subject to provide court testimony in regards to their contribution to the case. Generally, it still remains that the author of the case report is the individual that provides court testimony. The impact of this decision has not been significantly evaluated or studied to offer a clear conclusion as to any impact it may have team-based work flow operations (Thompson, E., Hong, M., Hill, C., & Scoville, S., 2012).

The Los Angeles Police Department Crime Laboratory also developed a team based approach allowing DNA analysts to process their cases together and to batch like cases together, in an effort to eliminate duplication of work. This new concept resulted in an improvement to productivity, and the number of samples per analyst per month increased by 82% (Anderson, V. J., & Thompson, J., 2011).

The Louisiana State Police Crime laboratory grant objectives were to provide LSS tools and operational structure to increase efficiency in forensic DNA casework and to maintain that efficiency. One of the operations developed was to create three person teams of DNA analysts supported by technicians to work with a five-day processing timeframe. Employees were more accountable for the process and took greater ownership in resolving issues, creating an

improvement to morale. Productivity increased by 280% by the end of the grant period, turnaround time was reduced from 129 days to 59 days (Richard& Kupferschmid, 2011).

The South Carolina Law Enforcement Division (SLED) Forensic DNA Laboratory employed Lean Six Sigma tools including process mapping to overhaul their case management system. The goal was to improve the turnaround time for analysis of prioritized violent crime casework. The average turnaround time was reduced from 83 to 35 days, and sample productivity has increased by 30% (Taylor, R. *et al*., 2009).

Another reference associated with efficiency improvement using LSS tools and a team based model was discovered in a master's thesis titled, *Lean DNA extraction for polymerase chain reaction improvement: a risk analysis based evaluation with lean six sigma solutions.* This study focuses on the application of LSS tools to the clinical molecular laboratory setting. Elimination of waste, increased productivity and decreased turnaround time were evaluated with positive outcomes. Cost factor could not be evaluated due to lack of information. One study limitation was the lack of team work and team brainstorming that may have caused some bias, further supporting that a team-based effort contributes to better process improvement outcomes (Jarrar, 2012).

Perhaps the best source of information on team-based models and improved DNA processing efficiency came from attending a presentation titled "POD Talk – DNA Casework Efficiency Through PODS" on November 6, 2012 at the California Association of Crime Laboratory Directors Fall Meeting in San Jose, California. The presentation was given by Jennifer Mihalovich, DNA Unit Supervisor at the Oakland Police Department Crime Laboratory. Further contact with Mrs. Mihalovih was conducted on December 4, 2012 and December 9, 2012 in the form of telephone interviews. The author was provided a copy of the PowerPoint presentation and POD schedule for Fall/Winter, 2012. Since these materials are not published, they are not reflected in the list of references. During these interactions it became evident that an evaluation of

a lean laboratory team-based approach to DNA case management and sample processing would be ideal for a research study. In an effort to best devise and select an efficiency improvement model for this research study, both LSS and team-based applications were evaluated and incorporated into this project. In summary, there is a wealth of research materials that evaluate and explore different efficiency improvement models and the application of LSS tools to enhance the development of these models. This research study addresses the use of LLS tools and improvement strategies in the form of a team-based model to determine the impact on sample productivity, turnaround time, reagent costs, and morale.

Research Methods

Overview

Initial research methodology focused on the review of published governmental documents consisting of NIJ funded forensic research and development projects designed to explore tools, technologies, and novel ways of increasing the efficiency and capacity of DNA analysis. These reports featured methodologies intended to serve as models for forensic science laboratories. This literature review expanded to include additional efficiency improvement strategies applicable to DNA analysis and case management. These strategies focus on no-cost applications of the human element, and include the incorporation of lean six sigma tools, batching of casework, technician support and a team-based approach to DNA analysis. Based on information generated from the literature review, and an interview with DNA Unit Supervisor, Jennifer Mihalovich, of the Oakland Police Department Crime Laboratory regarding their DNA team-based "POD" system, a comprehensive research study was designed to evaluate a lean laboratory team-based approach to DNA sample processing and case management within the CCCSO Biology Unit.

The backbone of the Oakland Police Department Crime Laboratory "Pod" system is the three member DNA analyst team. Teams work together over an 18 week period which consists of three-

five week blocks plus three additional weeks. At the end of the 18 week cycle, the pod teams are recombined. Every five weeks, each team receives 30 cases ranging in case type from robbery to sexual assault to homicide. The cases are divided among the team, with each DNA analyst assigned to specific case taking responsibility for the work performed by all members of the team. The evidence is screened for biological material, and if identified, a portion is sampled for DNA analysis. The screening, sampling, extraction and data interpretation phases are performed by the assigned DNA analyst; however, the sample handling activities are conducted by a technician. In the CCCSO Biology Unit a DNA analyst will act as the technician. The technician does not conduct interpretation or draw any conclusions about the work performed, they merely set up and run the instruments and provide data to the assigned DNA analysts. The assigned DNA analyst evaluates the data, directs work and writes the report. The technical and administrative review of the work product and final report is conducted in a symbiotic manner by the team members.

The individual sample processing activities performed within each POD are scheduled over the five week period to ensure keeping with the timeline. For example, week one tasks focus on screening, week two may incorporate additional screening and extraction, week three focuses on quantitation, amplification and data analysis, week four continues data analysis and consultation, and week five is dedicated to report writing and review. PODs operate on a staggered schedule, such that when Pod #1 is beginning week three activities, Pod #2 is beginning week one tasks. This ensures a continual flow of activities, reduced bottlenecks and allows for urgent cases to be integrated into the system, since one POD will be conducting the initial screening phase during any part of the week.

The Oakland Police Department DNA Unit has nine analysts, which evenly form three pod teams of three, supported by one technician with one supervisor. The CCCSO Biology Unit only has the capacity to form two PODS of three, supported by one DNA analyst working in a

technician role, with one supervisor. The total number of analysts may be lower, but the model and system processes remain the same.

Research Problem

Forensic DNA analysis plays a significant role in both the law enforcement and criminal justice communities because of its ability to discriminate among individuals based on their genetic profile. Convictions, exonerations and eliminations of those suspected of crimes can all be attributed to the powerful illumination potential of DNA analysis. Such knowledge and insight are beneficial to the distribution of justice. Requests for DNA analysis continue to grow, as does the complexity of the evidence samples leading to increased processing times and expanding backlogs. To meet these challenges, the forensic community must take a fresh look at traditional practices. Finding new and innovative ways to use limited resources in the most efficient and cost effective manner is paramount. One model that has received significant notoriety is based on a lean laboratory team-based approach to DNA case management.

Controlling for Internal and External Validity

External validity focuses on to what degree one can apply an established model to another group under the same or slightly different conditions. This research will evaluate the external validity associated with this model and determine if the results generate the same success seen at the Oakland Police Department Crime Laboratory.

Several factors were taken into account to ensure the research will also be internally valid, and that a high level of confidence will be associated with the outcomes. First, although the CCCSO Forensic Services Division moved to a new facility the same DNA instruments and equipment were utilized during this research study that were in use during the two preceding years. The same technical protocols previously utilized were also employed during the study. These factors remained in effect during the study period to ensure continuity with unit practices and support

internal validity. However, between the two study periods, the unit supervisor and technical leader using Lean and Six Sigma approaches evaluated and streamlined work flow elements, documentation, and administrative activities associated with DNA case management.

Research Hypothesis

The hypothesis for this research study is that the implementation of a lean laboratory evaluated team-based approach to DNA case management will produce an increase in sample productivity and moral while reducing turnaround time and reagent costs. This hypothesis guided the research study by devising a way to collect and evaluate the outputs of an individual verses team-based DNA case management process operating within a lean laboratory modified environment. Attention was given to defining each measurable criterion, creating a method to accurately collect data, followed by devising ways of scientifically assessing and determining if the value is considered significant for each element evaluated.

Variables and Operational Definitions

The independent variable is the implementation of a lean laboratory team-based approach to DNA case management, and the dependent variables are sample productivity, turnaround time, reagent costs and morale. The independent variable should be the only factor to affect change on the dependent variables, which were explored through the collection of primary and secondary data. Significance was be established by inter comparing the outputs of the POD model, and similar efficiency improvement models to predict realistic outcomes.

Dependent Variable #1: Sample Productivity

(Significance based on a 20% increase in sample productivity)

For the purposes of this study, "sample productivity" is defined as the number of samples processed per DNA analyst per month. "Processed" refers to those DNA samples that the analyst actually takes ownership of through case assignment, with the results appearing in an

administratively reviewed report. The number of samples processed for each case request assigned will be entered by the assigned analyst into JusticeTrax, a Laboratory Information Management System (LIMS) designed for electronic tracking case information. Once data is entered into JusticeTrax, it can be queried via a reporting functions built into the software. Another form of productivity is "case productivity" which is defined as the number of cases or requests completed in a selected time period. Since the number of samples per case varies significantly, it is difficult to correlate analyst productivity solely on cases completed.

Dependent Variable #2: Analyst Casework Turnaround Time

(Significance based on a 20% decrease in analyst casework turnaround time)

For the purposes of this study, "analyst casework turnaround time" will be defined as the number of days between analyst assignment and completion of a case. The date that a specific case request is assigned to a DNA analyst will be entered into the "date assigned" data field by the Biology Unit supervisor. This information will allow for the calculation of the number of days from analyst assignment to case completion. "Completion" is recognized when the administrative review of the case request has been approved, which is the final requirement prior to releasing the report to the client agency. Another form of turnaround time is the overall laboratory processing time or "laboratory casework turnaround time" which is defined as the number of days from submission of a case request to the laboratory and administrative review. This value may be larger than the analyst's turnaround time, since many case requests submitted to the laboratory are held in the Biology Unit queue awaiting assignment. Justicetrax has the ability to generate statistical reports from the data and information captured electronically during case processing steps from the initial entry date to the completion or administrative review date.

Dependent Variable #3: Reagent Cost (Human Duo Kit)

(Significance based on a 10% reagent cost reduction)

For the purposes of this study, the "reagent cost" will be isolated to the standardized quantification kit (Human Duo Kit) purchased from Life Technologies. The cost of Human Duo Kits was determined by reviewing the purchasing documents for Life Technologies. A "quantifiler run" is a test performed to determine the quantity of DNA in test samples using the Human Duo Kit. Changes to kit usage as a result from employing a team-based approach and batching strategy verses an independent analyst testing model will be defined as "reagent cost reduction" and based on the cost per case per run.

Dependent Variable #4: Individual and Team Morale

(Significance based on a self-perceived increase in individual and team morale)

The evaluation of morale was determined by a combination of in-person intensive interviews and an 8 question anonymous survey. For the purpose of this study, the Biology Unit staff will be considered key informants. Primary data will be gathered through key informant interviews of all seven Biology Unit staff members that participated in the study using 7 standardized questions. The interviews will focus on morale, but will also obtain feedback on teamwork, confidence and job satisfaction.

Research Design

The study participants included all members of the Biology Unit: seven DNA analysts, one DNA Analyst/Technical Leader and the unit supervisor. The study duration consisted of two nine month periods covering both pre-implementation and post implementation timeframes. The pre-implementation period ranges from November 1, 2011 to July 31, 2012. The post-implementation period ranges from June 1, 2013 to February 28, 2014.

The focus of this research study was to evaluate the hypothesis by using a variety of data collection tools to determine the value associated with each dependent variable when comparing the two nine month study periods. The design incorporated both qualitative and quantitative

elements in a mixed method case study approach to data collection in order to gain information and statistical data to evaluate against the hypothesis. Research methodology consisted of both primary and secondary data.

Data Collection Plan Overview

Primary data in the form of laboratory database statistics was obtained by reports generated through the use of JusticeTrax, a Laboratory Information Management System (LIMS) or software program used for tracking a wide variety of case information and chain of custody. Quantitative data for DNA sample productivity and analyst turnaround time were obtained from reports designed specifically to query data from information that staff are required to input into the LIMS system. The effectiveness of the team-based system verses the independent analyst system will be measured by examining the percent difference in analyst turnaround time between study periods, as well as, sample productivity and case productivity.

Additional quantitative data to assess reagent cost was isolated to the Human Duo Kit, a standardized commercial kit purchased from Life Technologies, and used to calculate the amount of DNA in an evidence sample. Each kit costs $1,600.00 and contains enough reagents to test 400 samples given the volumes used per standard laboratory protocol. In addition, these quantifiler kits have specific lot numbers which can be associated with the actual samples processed during any specified time period. Data was obtained by reviewing run logs, and sample sheets for each quantifiler run performed over a three year period, including the two study periods. A “quantifiler run” is a test performed to determine the quantity of DNA in test samples. Each run requires 22 standard or control samples to help evaluate the results, leaving space for up to74 case samples per run. Changes to kit usage as a result of employing a team-based approach and batching strategy verses an independent analyst testing model will be defined as “reagent cost reduction” and based

on the cost per case per run. Statistical data will be represented by percent, percent change or numerical value.

Qualitative data in the form of key informant semi-structured interviews and anonymous survey were used to assess both individual and team morale resulting from operating in the team-based study period. Face-to-face interviews were conducted with seven staff members of the CCCSO Biology Unit between April 2, 2014 and April 4, 2014. Prior to the interview, each DNA analyst reviewed an overview document detailing the purpose of the interview, as well as the actual questions. (See attachment A). All seven analysts agreed to participate in the interview process, which lasted approximately 15 to 25 minutes. In order to avoid bias and interpretation error, all interviews were recorded and sent to a certified court reporter to be transcribed. Each key informant was asked the same 7 questions covering topics relating to soliciting of opinions/ideas, fair distribution/batching, confidence, accountability, team member support, flexibility/time management and teamwork satisfaction. The interviews attempted to assess a self-perceived increase in morale associated with teamwork and job satisfaction while working in a team-based system compared to working independently.

Primary data associated with morale was also gathered using an on-line survey with 8 questions created using Fluidsurvey.com. The survey was disturbed through a link via email and also contained an overview document regarding its purpose. All surveys were taken after completing the key informant interviews. The surveys allowed the seven DNA analysts an anonymous way to submit their response to questions covering topics related to enthusiasm, meaning/purpose, pride, challenge, energy, security/capability, setbacks and stamina. The survey attempted to assess individual and team morale resulting from working in a team-based system compared to working independently. All surveys were received between April 3, 2014 and April 10, 2014. In order to avoid measurement bias, a 1-7 rating scale was used to capture survey

responses. Overall, both individual and team morale was assessed using a Likert scale rating system and key informant interview responses.

Research Limitations

This study is heavily dependent on a single resource, the human element, Biology Unit staff consisting of 7 DNA analysts, a technical leader/analyst and supervisor. If issues come up that impact the ability for staff to perform their job, or if there is a need for staff to be redirected due to a significant public safety concern, then modifications would need to be made to this team-based efficiency model. Some issues are short term and can be easily accommodated, like court, crime scene processing, holidays and vacations. However, this author experienced a rather large hurdle to jump when 5 of the 7 female staff became pregnant during the study period. Due to the hazardous nature of chemical reagents, pregnant women are unable to fulfill all their job assignments and are place on modified duty. This situation impacts the work flow, especially when multiple staff are in the same situation. In addition, maternity leave further complicates staffing levels. During 2013 and 2014, the crime laboratory welcomed five babies into our Biology Unit family. The impact of these staffing shortages required a modification to the structure of the team-based model, allowing staff to interact within one larger team instead of two smaller teams. This modification gave staff more flexibility to interact, and overcome exposure restrictions while still implementing this team-based research study.

Results and Findings

The methodology for this research project began with a review of relevant literature and research along with conversations with forensic practitioners, attendance at educational conferences and seminars. From this secondary data, DNA processing strategies were identified which developed into the establishment of a DNA case management efficiency improvement model tailored after successful programs across the nation. Using both quantitative and qualitative measurements to evaluate the significance and impact of this applied model, this chapter will describe the results obtained from primary data including statistical and financial reports, key informant interviews, and a survey conducted to address the research hypothesis and underlying questions.

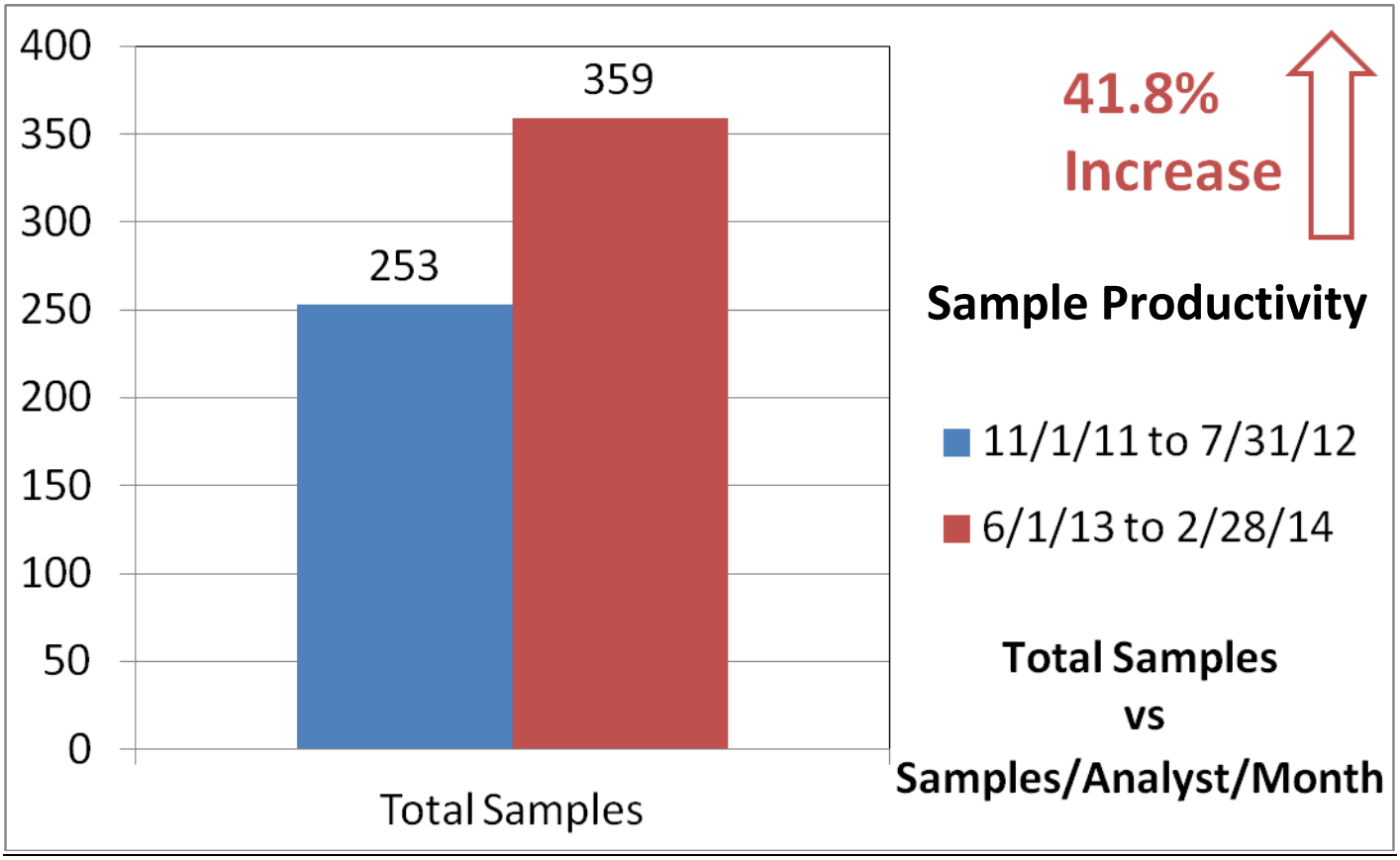
DNA Case Management Efficiency Improvement Model - Primary Data Results

Dependent Variable #1: Sample Productivity (Significance based on a 20% increase)

JusticeTrax, the CCCSO Laboratory Information Management System (LIMS) was used to generate reports that reflect DNA sample productivity for the two study periods. The original plan was to report this data as the number of samples processed per analyst per month, however, due to staffing restrictions and limitations resulting from the medical condition of multiple staff members, a more accurate description and reflection of this data is overall sample productivity. The number of samples processed for each case request was entered by the assigned analyst into JusticeTrax as originally intended; however, the DNA analysts worked together as a single team to overcome staffing challenges, therefore, the results are reflected as a group accomplishment.

The total number of samples completed during the 2012-2013 study period, displayed in blue, indicates that 253 samples were completed when analysts worked in a more independent system. The team-based system, displayed in red, produced 359 total samples in a similar nine month

period. This data indicates that 106 additional samples were processed to completion during the 2013-2014 study period.

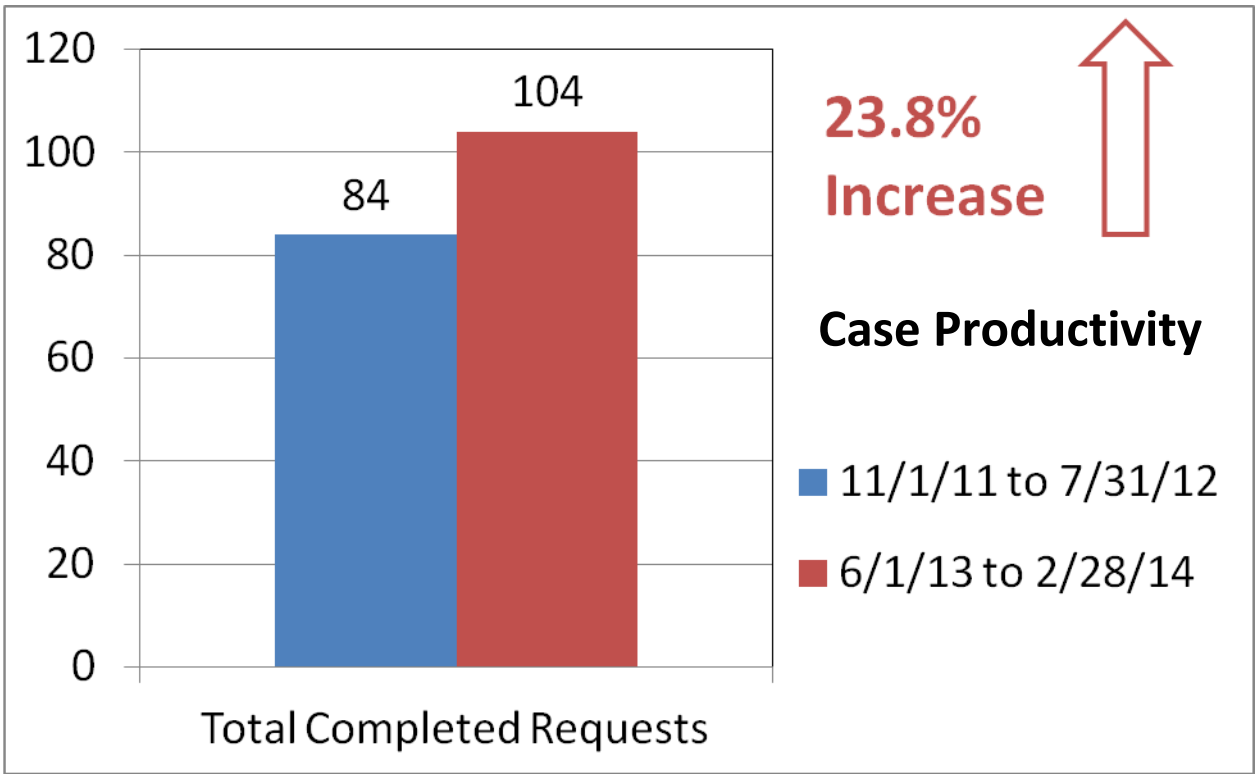


The effectiveness of the team-based system verses the independent analyst system is represented by a 41.8% increase in sample productivity, as depicted in the bar graph. This accomplishment far exceeds the 20% increase estimated to represent operational significance.

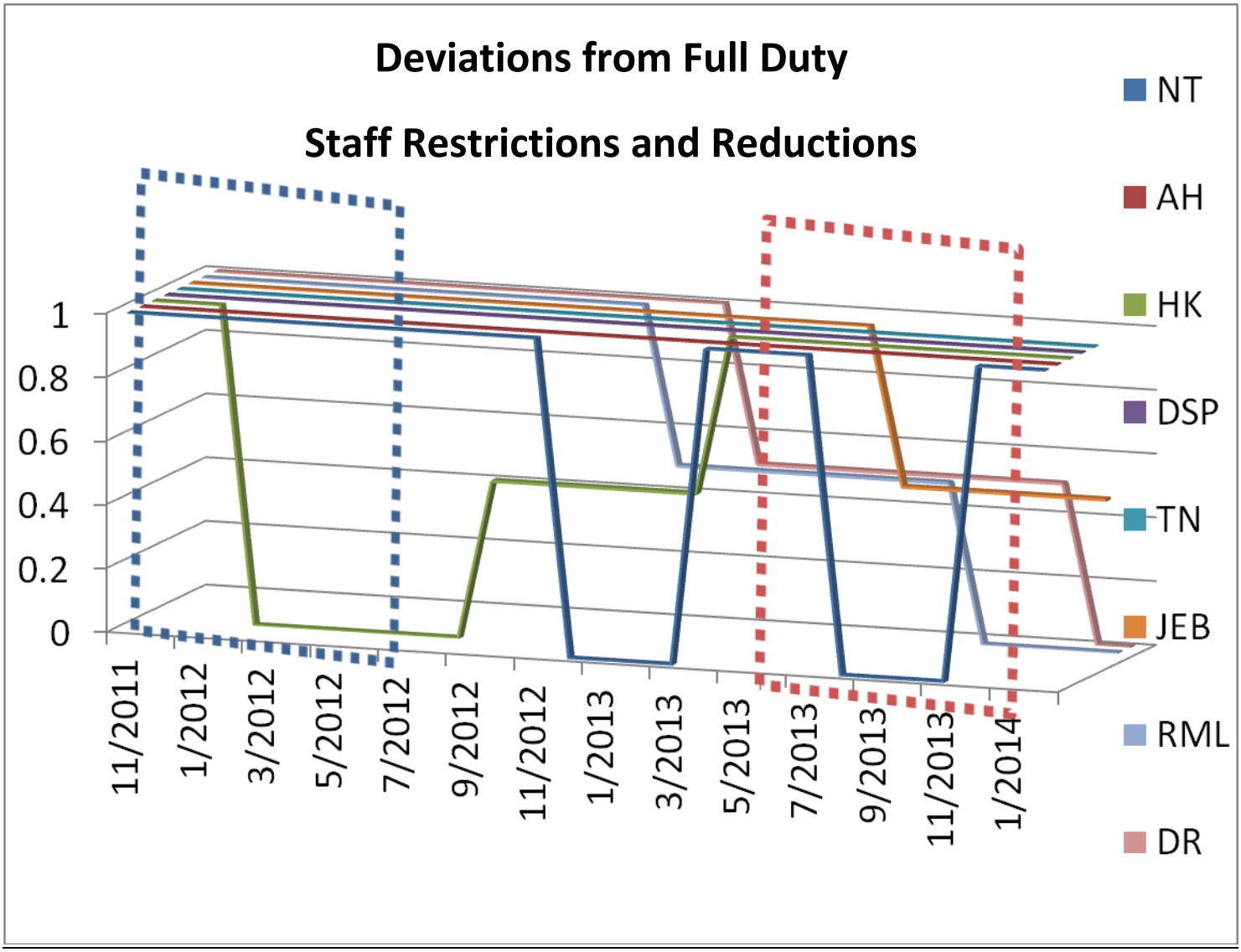
Another measure of efficiency is case productivity, however, the number of samples per case varies significantly, and it may be difficult to correlate analyst productivity solely on cases completed. Therefore, this statistic should be carefully evaluated and used within proper context to supplement existing data.

The total number of cases completed during the 2012-2013 study period, displayed in blue, indicates that 84 cases were completed when analysts worked in a more independent system. The

team-based system, displayed in red, produced 104 total cases in a similar nine month period. This data indicates that 20 additional cases were processed to completion during the 2013-2014 study period. The effectiveness of the team-based system verses the independent analyst system is represented by a 23.8% increase in case productivity, as depicted in the bar graph.



An interesting fact worth mentioning is that the significant increase in productivity celebrated by the laboratory was produced with limited staffing, since four DNA analysts were pregnant and on restricted duty during the study period. Two of these four DNA analysts reached full term, delivered healthy babies, and were on maternity leave during the 2013-2014 study period. Despite these shortfalls, the Biology Unit was able to generate more casework in nine months than ever before. The blue and red dashed boxes indicate the two study periods, and the solid lines represent deviations from full duty over time. DNA analysts are differentiated by initials and color. The dips within dashed boxes indicate staffing shortfalls within the two study periods.



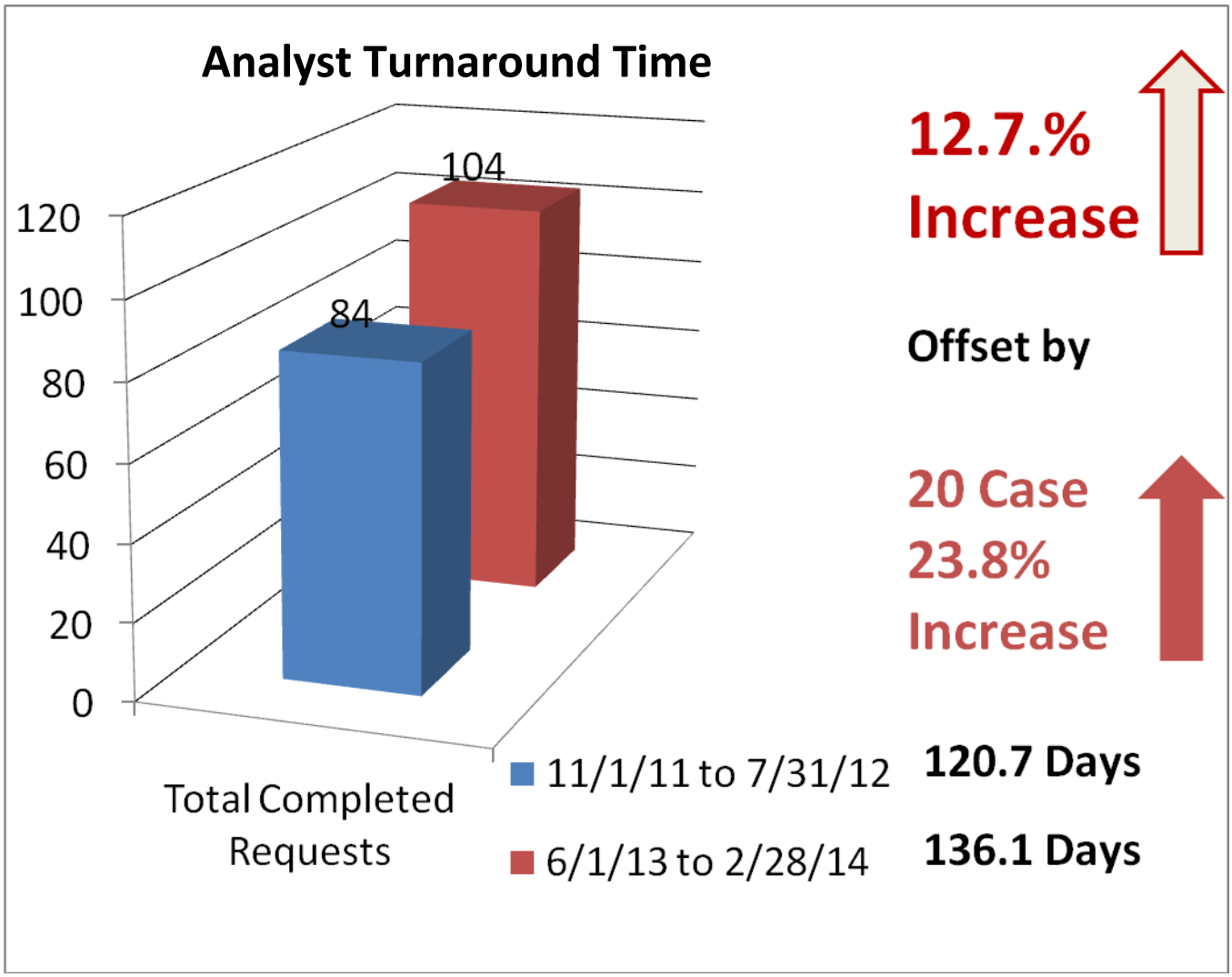
Dependent Variable #2: Analyst Casework Turnaround Time

(Significance based on a 20% decrease)

JusticeTrax, the CCCSO Laboratory Information Management System (LIMS) was used to generate reports that reflect both the analyst and laboratory casework turnaround time for the two study periods. These reports reflect the number of days from assignment to completion of an entire case along with the total number of cases completed. The focus was on analyst turnaround time, since this is a direct result and true reflection of the case processing activities of the DNA

analysts relative to their efficiency improvement strategies. The number of cases processed per analyst was tracked by JusticeTrax, and the average turnaround time was generated via LIMS.

During the 2012-2013 study period, displayed in blue, the average analyst turnaround time was 120.7 days compared to136.1 days during the 2013-2014 study period reflected in red. There was an unexpected increase in the analyst turnaround time of 15.4 calendar days. Initially, this value was concerning since assessing the significance of this dependent variable was based on a projected 20% decrease. After thoroughly evaluating the collaborative and interactive nature of multiple factors, including the 12.7% difference in analyst turnaround time between study periods, as well as the 41.8% increase in sample productivity and 23.8% increase in case productivity, it was determined that the drastic increase in case productivity (20 cases) generated some unrealized challenges. The more samples that are processed the more likely to encounter problematic samples or samples that require greater time to interpret, generate results and ultimately reflect those results in a report which is required to successfully pass the peer review system. These problematic outliers skew the statistics and contribute to increased turnaround times. The turnaround time increase of two weeks is certainly offset by the fact that overall productivity rose by 41.8% and 20 additional cases were completed with the introduction of a team-based model.

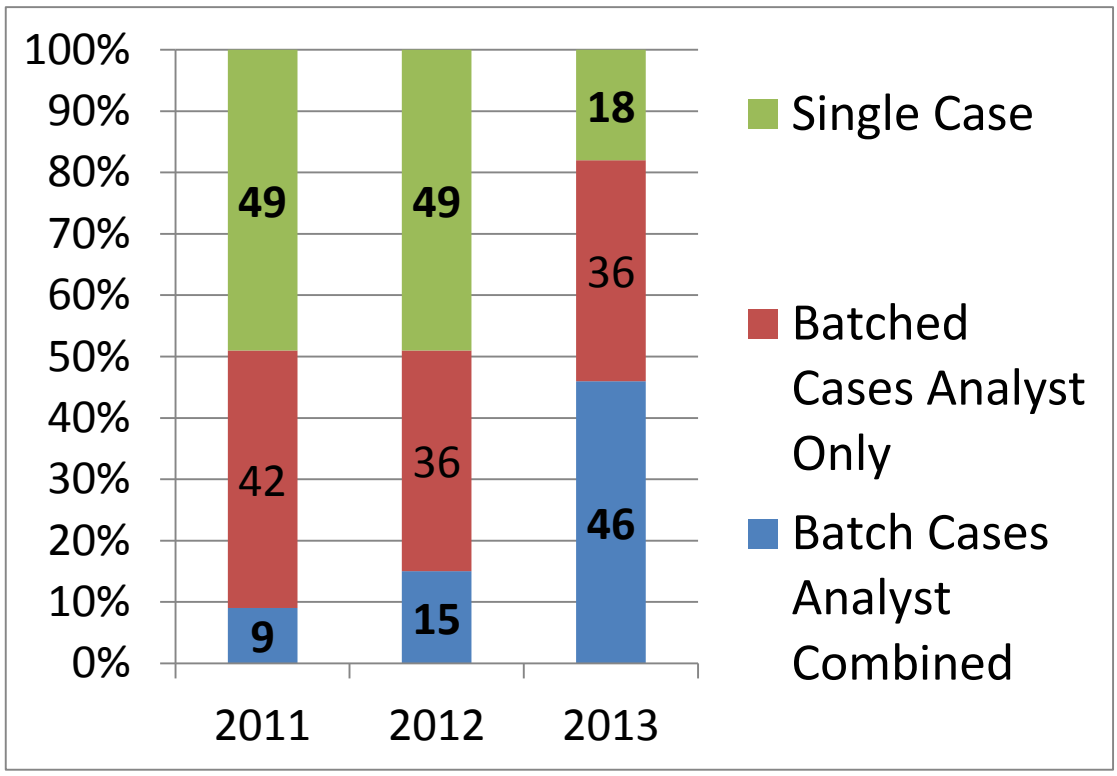


Dependent Variable #3: Reagent Cost (Human Duo Kit)

(Significance based on a 10% cost reduction)

In order to determine the reagent cost reduction associated with the Human Duo Kit, a comprehensive review and evaluation was performed of all quantifier run data over a three year period (2011, 2012 and 2013). The purpose of this labor intensive process was twofold. The first step was to separate the quantifiler runs associated with casework from those associated with quality assurance and validation efforts which are essential to support laboratory operations. The second step was to take those quantifiler runs truly associated with casework and divide them into the three categories of: batched runs analyst only, batched runs analyst combined, and single case

runs. These categories then enable changes, such as batching strategies, to be easily observed, numerically defined, and visually represented over the timeframe investigated, as depicted in the graph below.

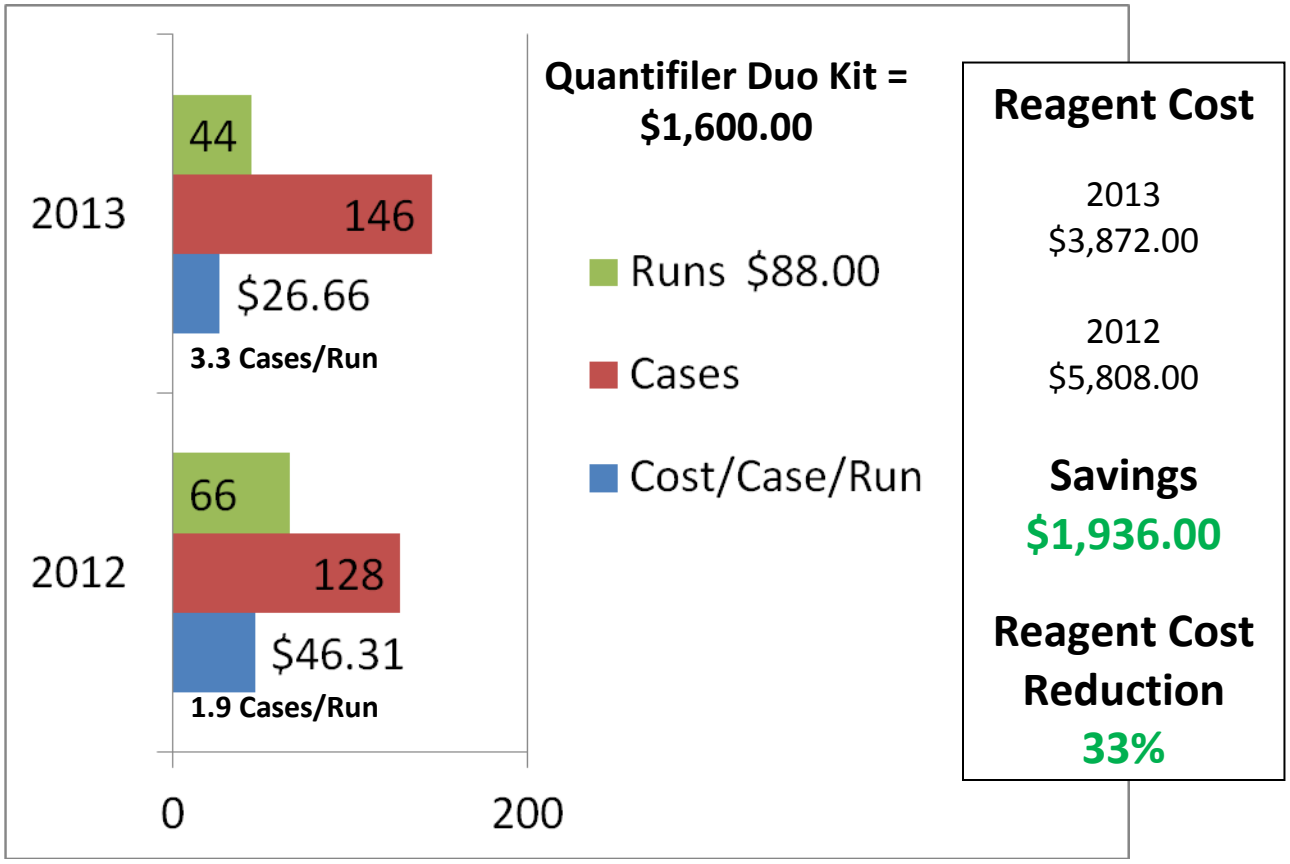


The results of this data mining were quite interesting, and showed a consistency in the distribution of quantifiler run data in both 2011 and 2012. However, with the deliberate introduction of a team-based batching strategy, the distribution of quantifiler runs drastically changed in 2013. Batched cases analyst only dropped from 42% in 2011 to 36% in 2012 and 2013. Batched cases analyst combined increased from 9% in 2011 to 15% in 2012 and then to 46% in 2013. Overall batched cases analyst combined increased by 31%, meaning DNA analysts were more often combining cases among each other to maximize efficiency. Single case runs dropped from 49% in 2011 and 2012 to 18% in 2013. Overall single case runs were reduced by 31%, meaning DNA analysts were less often operating the quantifiler instrument to test only one

case at a time. This is comparable to running a household dishwasher for one spoon. It is advantages to fill the dishwasher and run a full load, since the same amount of soap, spot remover and energy are required regardless the content of the dishwasher. In a laboratory setting, one can think of the dishwasher as the quantifiler instrument, and the soap and spot remover as the reagents contained in the Human Duo Kit.

For the purposes of this study, changes to Human Duo Kit usage as a result of employing a team-based approach and batching strategy verses an independent analyst testing model have been defined as "reagent cost reduction" which is based on the cost per case per run. In order to calculate this cost, the 2012 and 2013 casework quantifiler run data was compared. The 2011 data was not compared in this fashion due to the strong similarity with the 2012 data. DNA analysts clearly embraced the batching strategy, and had the ability to maximize efficiency when operating the quantifiler instrument by batching cases from multiple analysts or their own. Each quantifiler run requires a specific number of control samples and quality control measures that translates to a basic operational cost of $88.00 per run of Human Duo Kit reagents.

In 2012 there were 66 casework quantifiler runs performed which contained a total of 128 cases, which can be represented as 1.9 cases per run. The cost per case per run was determined to be $46.31. In 2013 there were only 44 casework quantifiler runs performed which contained a total of 146 cases, which can be represented as 3.3 cases per run. The cost per case per run was determined to be $26.66. Just as in the dishwasher analogy, it is clear from this quantifiler run data that the operational cost of the instrument remains the same relative to the control and quality control samples, but when casework samples are maximized, the cost per case is reduced. The savings in reagent costs by increasing combined analyst batching and reducing single case runs translates to $1,936.00 in savings over a single year; therefore, the reagent cost reduction was 33%, which exceeds the 10% increase estimated to represent operational significance.



Dependent Variable #4: Individual and Team Morale

(Significance based on a self-perceived increase in individual and team morale)

This section presents an analysis of the key informant interviews and survey conducted to evaluate dependent variable #4, Individual and Team Morale. This topic is divided into two sections; the first section describes the results and findings obtained from key informant interviews. The second section is dedicated to the results and findings from the anonymous survey. Both parts address the research hypothesis relative to morale. Finally, a summary of significant findings associated with both research tools will be explored. All seven of the Biology Unit DNA analysts were participants using both research methods.

Prior to conducting the key informant interviews, a printed version of the seven interview questions were provided to each of the seven participants along with a research study overview, and attached as Appendix A. Each of the seven semi-structured key informant interviews was conducted in person. Permission was obtained from each participant to have the interview digitally recorded. This methodology allowed the researcher to focus more on understanding the responses, and maintaining engagement in the conversation without struggling to manually take notes to record answers. Supplemental questions, if needed, were used to clarify responses, develop a greater understanding of perspective and narrow the scope of the response to the topic at issue. The recordings were subsequently transcribed and provided to the participants. The participants understood that the recorded interview would be summarized collectively and anonymously reflected in the study. To protect confidentiality, transcriptions of the key informant interviews are not attached to this study.

Key Informant Interview Results

The compilation of results for each interview question is examined individually for an in-depth analysis.

Question #1 - **Do you feel that sufficient effort was made by your supervisor to get your opinions and ideas related to adopting a team-based sample batching practice?**

Each of seven participants indicted that the concept and discussion around batching was introduced during Biology Unit staff meetings. This information was confirmed by a review of meeting minutes and the batching overview report provided to this researcher by the unit supervisor. The concept of batching was first conveyed to staff on March 6, 2013. Each of the participants further indicated that it was their understanding that incorporating sample batching was more a management directive than a voluntary practice. Several staff stated that there was some hesitance moving away from an individual to a team-based sample processing model.

However, during the introduction of batching, staff indicated there was brainstorming, suggestions were solicited, feedback was generated, and changes were made to create a flexible sample batching system. Staff worked together as a team to modify the initial process, and according to one staff "it definitely was a work in progress, and I think now we're all on the same page of how the batching system is working for team-based batching".

Question #2 - **Do you feel that the work assignments associated with the batching of samples were distributed fairly?**

All seven of the participants gave a positive response when addressing a fair distribution of work assignments relative to batching; however, six analysts indicated that some staff were more proactive or made a greater effort. According to one analyst, "most people are good about sharing the responsibility" and "some people are more proactive". However, "sometimes there are people who wait" and therefore don't do as much batching as others. One analyst described this as "skirting off" responsibilities, but also stated that "for the most part it's a good system, no system in 100%, it's close to fair". A monthly rotation was suggested to ensure equal distribution of batching steps, however, it was stated that "most people are good about sharing the responsibility". Two analysts also indicated that at one time early on there was some confusion about sample processing expectations, and if someone performed the initial batching steps they were expected to do all future steps. Division of DNA processing duties relative to batching was clarified by the supervisor, and was reported to be "working smoothly now". However, one analyst believes this mindset still exists for one staff member.

Another analyst stated that the DNA staff used an informal process to insure the DNA sample runs are full and "we've been really fair, I think, about splitting the tasks". Four analysts indicated that the group worked as a team and communicated via email or by just talking to each other. This process was described by one analyst as developing more transparency, leading to greater

confidence in their skills, opening the door to more conversation, allowing for more growth and exchange of information, knowledge and development of a collective consciousness.

Question #3 - **How confident are you with the work produced by your team members?**

Five of the seven participants expressed a higher level of confidence than the other two. The participants that expressed higher confidence stated that all analyst were "very good here" and that they have never had an issue with the work performed, however, mistakes happen and can happen to anyone. One analyst stated "I'm confident in whoever set up my samples; I don't worry about the final outcome". Although this attitude was fairly uniform, there were two analysts that expressed some reservations. One indicated that even though they had experienced "no significant problems" and no cases were compromised, they still had "some doubts regarding all skill levels and attitude". If there were any reservations, one analyst stated that they would just volunteer to perform that case work task, relieving a newer analyst of big batch burdens.

Question #4 - **Do you feel your team members are held accountable for the decisions they make?**

There was a unanimous response to the question of accountability by team members. All participants responded positively, and some gave examples attributing communication, planning ahead, and trust as factors demonstrating accountability. Planning up front between analysts was routine, and "rarely does it not happen on time" stated one analyst. Another analyst felt that "accountability has not been a problem" and that the group was "effective at communication". In contrast, an analyst stated that better communication would benefit the group to clarify responsibilities with certain staff members", however, this opinion was not reflective of the group, and was only voiced by one person.

Six analysts also gave examples of extenuating circumstances, such as court, crime scenes, and rush cases that caused deviations to the pre-agreed time frames for analysis, however, these

occurrences were not regarded as a lack of accountability, but rather due to unforeseen circumstances. According to one analyst, "if a delay occurs, another staff fills in and continues the process". "Your samples continue to move forward. Data is ready for review, it saves a lot of time, otherwise, samples sit for another week or so" claimed one analyst in support of team member accountability.

Question #5- **Do you feel supported by your team members?**

There was a unanimous response to the question of feeling supported by team members. All participants responded positively, and gave examples of how support was demonstrated. One example included a time when without asking, another analyst processed their samples when they were pulled away for court. Another example was that staff offer their support by asking "do you need help?" and "is there something I could do to help expedite the next process?" In addition, tasks such as cleaning the capillary electrophoresis instrument, turning on the computer and importing the sample sheet were other examples given of how team members supported each other. One analyst stated that "nobody wants anyone to fall behind" and another stated "I never felt left behind, you know, neglected or anything like that".

Question #6 - **In what ways, if any, has adopting this team-based sample processing model allowed you greater flexibility in managing your time during sample processing?**

Responses to this question were split, three analysts indicated that the team-based sample processing model gave them more flexible in managing their time, and two did not feel there was a significant impact, but there were no adverse effects. On occasion, but not often, one analyst felt stressed when working rush cases through the system, because they were waiting for other analysts, and it would have been easier to process them individually. In contrast, another analyst indicated that batching was more efficient, and allows for more flexibility in organizing their process. They further stated "I feel like I have more flexibility with how much time I devote to

each case in the sampling process". In support of a team-based approach, another analyst stated that by "piggy backing off each other, instead of waiting…you can actually do a lot more at the same time."

According to another analyst, the team-based model allows for "your samples to move forward" when you are facing court, crime scenes or training, and "it allows analysts to perform on a dual function level". This analyst further stated that "it helped in the efficiency of the time that I'm using" and "allows you to meet obligations without making mistakes trying to cram too many things into the same time frame." In addition, "an analyst that can think ahead can really use the team approach to benefit them". The analyst also believed that this model "builds in mini deadlines", helpful in organizing time, and by using this model, "allows us to raise the bar", contributes to effective case review, sharing of experiences, open communication and building a stronger base. Another analyst indicated that there are pros and cons associated with a team-based sample processing model. On one hand, sample set up takes a long time and a full plate takes longer for the instrument to process. However, "when I'm not setting up anything, I have a lot more time to do whatever I want. We alternate duties so it comes out even".

One analyst felt it was a little less flexible, but stated "I like that the batching…everything gets done more quickly, and you get answers more quickly". This analyst further stated that you don't want to slow down your team, but you also don't want to be stuck waiting for other people to catch up. According to this analyst, bottlenecks occurred at the extraction step and staff work schedules also played a part in limiting flexibility. Another opinion was that "depending on the complexity of your case, you may not be ready to batch with the group…if you miss the run; you're on your own". This opinion was clearly in the minority, since others expressed that new batches are always forming, and only on the rare occasion when you have to expedite your case may you encounter the need to independently process your samples.

Question #7- **Overall, how satisfied are you with the teamwork within the Biology/DNA Unit?**

There was a unanimous response from all seven participants in regard to teamwork within the Biology Unit. All participants responded positively, and provided examples of how embracing a team-based sample processing model has improved their working relationship, efficiency, and overall cohesiveness as a group. These examples, as well as staff opinions, are highlighted in the following passages.

One analyst indicated that "I think we're doing great on the teamwork, especially with this batching. We're all very good with communicating with each other, telling each other, you know, where we're at, where we're going to be, where we plan to be. In each step everybody's very good about helping each other out." This analyst further stated that when an unexpected issue arises, they are more likely to share this with the group and alert others to look for it in their samples. Everyone is made aware up front and information is shared, as opposed to being left in the dark to fix a problem on your own. An example of this improved communication occurred when a dye blob falling into an allele bin was identified in one case. This information was then shared with all five staff in the batch. The dye blob issue was then resolved quickly and efficiently instead of everyone struggling to work it out independently. This information was reflected in all the cases, so when technically reviewed all reviewers were aware of this unique feature.

Another analyst shared that "I'm pretty happy…I feel like we all can trust each other…as a biology group as a whole, I think we work really well with each other." Having a new facility improved the Biology Unit layout, and this was mentioned as well, "… now we're all in the same room and same area. Everyone has been very cohesive." However, it was noted that some staff are "inclined to gravitate towards some (rather) than others".

A third analyst stated "I'm very satisfied. I think a lot of us are there to…as a team we work really well together. I'm definitely satisfied with how we work together." In addition to these comments the topic of turnaround time was mentioned. "I think batching-wise we're doing a great job…but we still have lots of issues when it comes to the report and the review". The concern is with the bottleneck at technical review, since the reports "get stuck there a lot longer, so it has the perception that you took longer, when in reality you took a shorter period of time."

A fourth analyst shared "…overall I'm pretty satisfied" and "…we all are pretty much open with each other. But having to talk more about our casework and how to share duties, we definitely have more communication". They also expressed some reservations "…in the beginning, it was a sketchy idea, and we were like, what? But now that we've gone through it and we've worked out our differences, I think it's really helped, and I know that a lot of labs are starting or they actually do the batching already." They went further to state that "so I feel it's normal for people to batch, and what we were doing was kind of nice….it really does push the casework through." According to the analyst, it seemed like "wow, we're ordering (reagents) again. Again? Like we just ordered some."

This analyst shared helpful comments related to observations made and workflow design, such as "I did notice with batching there's more traffic in the extraction room. So, for example, we needed a set of pipettes just to have in the middle of the room so that we can do our dilutions." This was followed up with "Also, I noticed there's traffic for the robots." This is an instrument used for DNA extraction, which relates to the previous comment shared in the interview regarding a potential bottleneck, "I noticed people do get annoyed having to wait for people to get through their extractions so that we can eventually fill up a plate." However, it was mentioned that these types of issues are discussed during unit meetings, and ideas are shared "like how we can make the process smoother."

A fifth analyst was passionate about the teamwork and the camaraderie shared among the group, "I like it. I mean, it works. It saves a lot of money and resources….with our close-knit group it works." According to this analyst, with other laboratories and a different spectrum of people, when something goes wrong, "there goes the unity and there goes the harmony". However, with the Biology Unit "being a close-knit group where we can call each other out and then just laugh it off" prevents grudges from developing. This analyst boasts about our system and indicted that "I tell people of our system and they're envious." In addition, this analyst stated that "everyone's accountable…whereas we're really good at investigating where the error happened and then fixing it."

A sixth analyst indicated that in regard to teamwork, "for the most part, I think we're doing really well…If you ever need help, like if you ask, some people will help you." However, they did indicate that there are other issues to address that would benefit the Biology Unit as well, but they are outside of this project.

The seventh analyst was fairly reflective, and stated "…in the beginning everybody including myself had reservations…change is hard…even if it's change you want to embrace." This analyst further indicated "…I found it uncomfortable to handoff my samples, but in short time found that to be very advantages." A comment was made regarding the new building layout, and improved communication, since staff were not housed in two separate rooms as in the previous laboratory space, "…it's helped…with communication between team members, not separated in two rooms and only talk to those proximal to you." This analyst believes that, "we're (biology staff) functioning more as a unit instead of two separate segments of a unit…overall I think that I see greater harmony between analysts and better practices as far as just keeping yourself organized."

To address the overall question of teamwork, this analyst stated, "…I would say overall for myself I'm happy with the teamwork method that we're doing." Although this analyst

expressed that the current team-based model is different than that originally presented, the seven Biology Unit staff took the example and "as a group we modified that to work or us…but it seems to be efficient for us (Biology Unit staff)." This analyst further elaborated that, "I think it's managed to create a bridge between people's comfort level and efficiency, so we were able to be more efficient but without totally giving up your comfort level, and in that same time I think it builds, it's been building stronger relationships between staff."

Summary of Key Informant Interviews - Significant Findings

The key informant interviews were used to assess both individual and team morale resulting from operating in a team-based DNA processing model conducting batched casework compared to working cases independently. An abundance of feedback was obtained on communication, teamwork, confidence, accountability, support and job satisfaction, all of which contribute to developing healthy morale. These themes, supported by normal work day examples, continually surfaced throughout the interviews.

Interview Topics:

Opinions/Ideas Solicited

Fair Distribution/Batching

Confidence in Work Product

Accountability

Team Member Support

Flexibility/Time Management

Teamwork Satisfaction

One significant finding was that both individual and team morale were positively impacted by the enhanced communication created by the project's formation and application. Each of the seven analysts indicated that it was their understanding that incorporating DNA sample batching was a management directive, and there was hesitance moving away from the comfort of individual case work processing to a team-based sample processing model. It was made clear during the interviews that the original proposed model was too structured for the

number of staff able to participate, due to staff restrictions and limitations. The fact that staff were freely allowed to work together as a team to modify the process generated a tremendous amount of buy-in and investment in the modified DNA sample processing and batching model. Staff reportedly brainstormed, solicited suggestions, experimented and continued to modify the process until a more flexible model was created. Using open communication and working together as a team supported by their supervisor, the staff developed a strong sense of ownership and unity around the modified process. Effective verbal and electronic communication continued throughout the study period.

Additional findings included a strong sense of accountability within the team, which was attributed to improved communication, cooperative planning, and trust factors. Relinquishing control of DNA samples to another analyst and trusting their ability to perform a proper analysis is paramount in a batching environment. Although there was hesitance in the beginning, over time this reservation diminished and the benefits of a forward sample flow were recognized among the team. Overall, analysts expressed a high level of confidence in their fellow team members. Slight reservations were noted, indicating there is room to grow, however with continued successes these concerns may diminish over time. Analysts expressed an overwhelming feeling of support and greater harmony within the group, and repeatedly provided examples of the actions that seeded these feelings and group attributes. The unanimous response to the satisfaction of the teamwork within the Biology Unit was significant when assessing morale. Examples of the improved working relationships and cohesiveness, together with the realization of greater efficiency recognized by the group, were repeated throughout the interviews. Participating in the team-based modified DNA sample processing model resulted in an improved level of communication, teamwork, confidence, and accountability, all of which culminated to raise job satisfaction and

overall morale, ultimately affecting both the individual and team dynamics within this research study.

Key Informant Surveys

Prior to their participation in the anonymous survey, each key informant was provided a research study overview and a link to the survey via email, which is attached as Appendix B. The anonymous survey was created and accessed by all seven participants through Fluidsurvey.com. A screen shot of the survey, as seen on the website is attached as Appendix C. A 100% return rate was obtained within 7 days of distribution. The eight survey questions are listed below, and the compilation of results for each survey question is examined individually for an in-depth analysis.

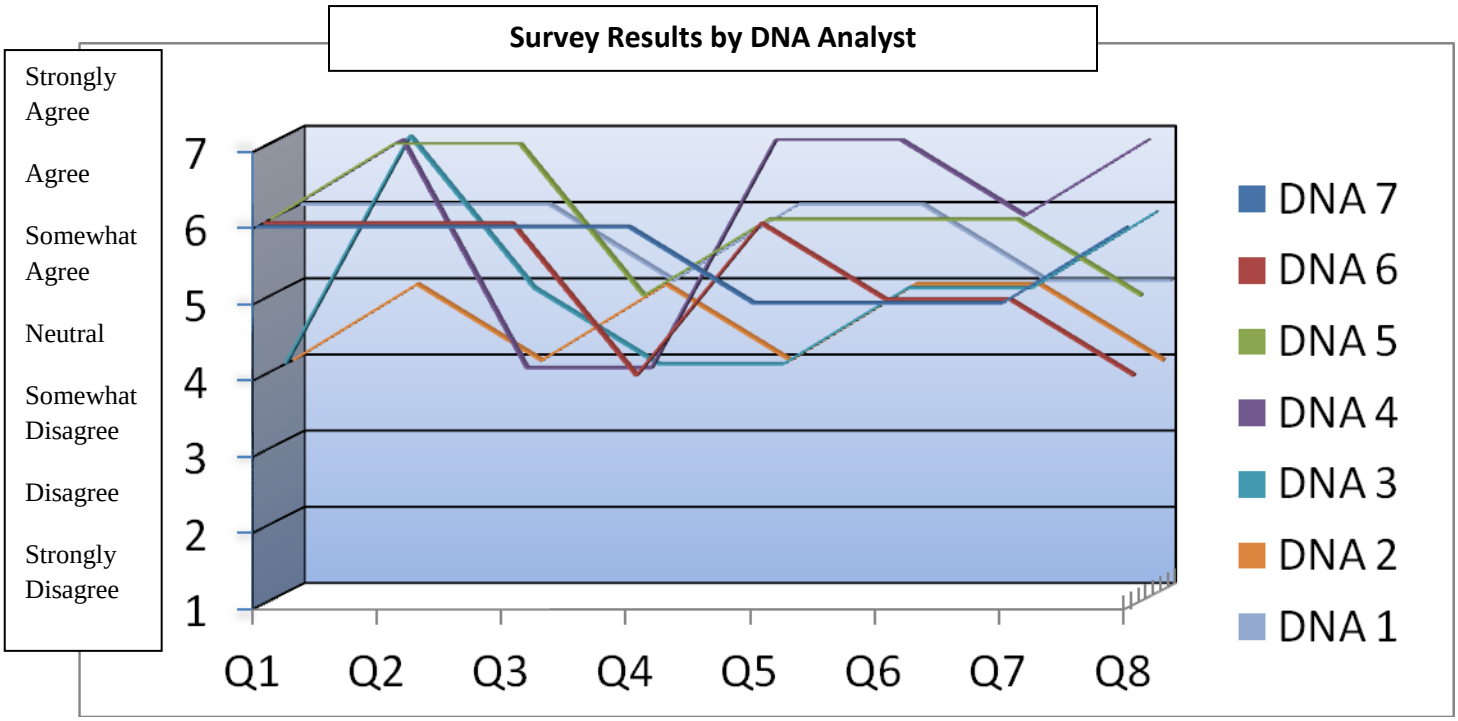
1. I am enthusiastic about the work that I do for my team
2. I find the work that I do for my team has meaning and purpose
3. I am proud of the work that I do for my team
4. To me, the work that I do for my team is challenging
5. In my team, I feel energized
6. In my team, I feel secure and capable
7. In my team, I quickly recover from setbacks
8. In my team, I can maintain stamina

The table below displays the anonymous survey results from each respondent associated with each question.

Overview of Survey Question Topics and Responses								
Question	1	2	3	4	5	6	7	8
Respondent	Q1 Enthusiasm	Q2 Meaning	Q3 Pride	Q4 Challenge	Q5 Energy	Q6 Security	Q7 Setbacks	Q8 Stamina
7	Agree	Agree	Agree	Agree	Somewhat Agree	Somewhat Agree	Somewhat Agree	Agree
6	Agree	Agree	Agree	Neutral	Agree	Somewhat Agree	Somewhat Agree	Neutral
5	Agree	Strongly Agree	Strongly Agree	Somewhat Agree	Agree	Agree	Agree	Neutral
4	Agree	Strongly Agree	Neutral	Neutral	Strongly Agree	Strongly Agree	Agree	Strongly Agree
3	Neutral	Strongly Agree	Somewhat Agree	Neutral	Neutral	Somewhat Agree	Somewhat Agree	Agree
2	Neutral	Somewhat Agree	Neutral	Somewhat Agree	Neutral	Somewhat Agree	Somewhat Agree	Neutral
1	Agree	Agree	Agree	Somewhat Agree	Agree	Agree	Somewhat Agree	Somewhat Agree

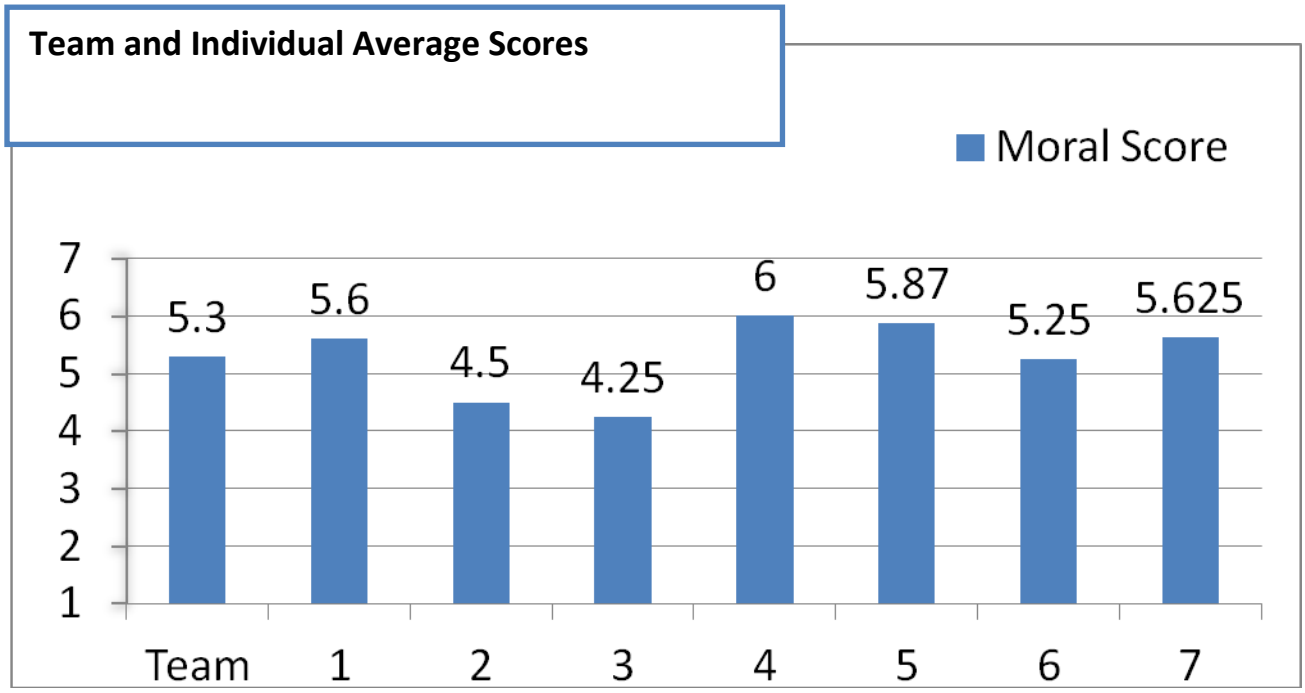
The rating of strongly disagree, disagree and somewhat disagree were never selected as a result. Strongly agree was selected three times in regard to question #2 indicating respondents found meaning and purpose in the work they perform for their team. Three additional respondents selected agree and one selected somewhat agree, making question #2 the highest rated question. In contrast, question #4 generated the lowest overall response, meaning the work performed is not regarded as highly challenging. Setting up and running equipment can become very routine, and most analysts agree that the more challenging work occurs at the interpretation stage of DNA analysis. The remaining six topics were relatively similar in their scores meaning they are

somewhat balanced across the group. The line chart below displays the anonymous survey results from each respondent associated with each question, which further visualizes the response variations among the Biology Unit staff. Questions #3 and #8, which deal with pride and stamina, respectively, appear to have the most varied responses among analysts, meaning these viewpoints are inconsistent among the group, or this question was not fully understood. Questions #1 and #7, which deal with enthusiasm and recovery from setbacks, respectively, appear to have the most uniform responses among the analysts, meaning these viewpoints are the most consistent among the group.



The survey questions adapted from research performed by Verwijis were used to reliably measure individual and team morale. Team morale is the average of the individual averages based on a seven point Likert scale (Verwijs, 2002). Individual raw scores based on the responses from all eight questions can range from a maximum value of 56 to a minimum value of zero. The

individual average can range from seven to zero. The team morale raw score can range from 392 to zero, with the average of individual averages ranging from seven to zero.



The highest individual morale score was 6 and the lowest was 4.25. Five of the seven analysts have scores above 5.25 and two scores were only slightly above the neutral range of 4.0. These variances indicate staff's self-perception of morale.

Question Topics:
Enthusiasm
Meaning/Purpose
Pride
Challenge
Energy
Security/Capability
Setbacks
Stamina

Summary of Key Informant Survey - Significant Findings

One notable finding was that no respondents entered a result below neutral using a seven point Likert rating scale. All respondents indicated either a neutral or positive response to morale related questions. The highest rated question focused on the meaning and purpose of the work performed. The most uniform responses were associated with enthusiasm for the work performed for the team and feeling that within their team they quickly recover from setbacks.

The lowest two individual morale scores were 4.25 and 4.5. These values are only slightly above neutral and indicated that attention be given to these analysts. Team members with low morale usually are unhappy in the team and don't enjoy working with them, they easily give up when faced with difficult situations, only do their part and nothing more, stick to a strict work schedule, do not feel a sense of pride in their work and withdraw from team activities. Although, these traits did not come out in the interviews, there was some concern regarding full acceptance of all team members.

Redundant sample processing that is amenable to robotics can become very boring and cause repetitive stress disorders; therefore, it was not surprising to find low scores associated with these batching practices. These activities are not particularly challenging, and this fact was reflected in the survey with lower responses. Steps are in place to combat this issue and eliminate redundant activities.

The overall team morale rating of 5.3 is significant when evaluating a team's well-being. Teams with high morale usually are willing to help each other out, are proud of the work they do, tend to go that extra mile, will persist in the face of technical problems or high work-pressure, are generally happy in their team, and enjoy working (Verwijs, 2002). Clearly there is some room to improve, but such a high value indicates a healthy team made up of dedicated individuals that are willing to communicate openly, and put in the time and energy needed to create a work environment that offers support, encouragement, security, and a sense of pride. The overall team results indicate an above average level of morale, and combined with the information generated from the key informant interviews, enhanced communication, improved confidence, support and greater harmony are attributed with embracing a team-based DNA processing model and batching of casework among analysts.

Conclusions, Recommendations and Areas of Further Study

Conclusions

The purpose and design of the this research study was to challenge the hypothesis that implementation of a lean laboratory evaluated team-based approach to DNA case management would produce an increase in sample productivity and moral while reducing turnaround time and reagent costs. Each dependent variable evaluated met or exceeded a level of expectation considered to be significant with the exception of analyst casework turnaround time, which had a higher degree of complexity than originally anticipated due to bottlenecks, staff restrictions, limitations and reductions during the study period. During the introduction of batching, staff worked together as a team, made changes, modified and created a more flexible sample batching system, however these modification did not seems to impact outcome.

Sample productivity exceeded expectations with a 41.8% increase using the team-based system; 106 additional samples were processed during this 9 month study period compared to a comparable 9 month period when analysts worked independently. Despite workforce reductions, this accomplishment far exceeded the 20% increase estimated to represent operational significance. As a secondary benefit, this increase in sample production generated a 23.8% increase in DNA cases completed which translates to the completion of 20 additional cases, bringing the total cases completed to 104.

Although benefits were gained in overall sample productivity, it was the analyst casework turnaround time that experienced an unexpected increase of 12.7%, the equivalent of 15.4 calendar days. This increase was attributed to four factors, sample complexity or problematic samples, interpretation complexity, technical and administrative review bottlenecks, and staff reductions. With a greater number of samples being process through the system, it is more likely to encounter one or more of the factors that negatively impact turnaround time; however, these factors were not

originally anticipated. Case completion requires a comprehensive technical and administrative review of all DNA samples, and with greater case volume, reductions in staffing levels and increased sample complexity, turnaround times were adversely influenced. It can be argued that the turnaround time increase of two weeks is certainly offset by the fact that overall productivity rose by 41.8% and 20 additional cases were completed with the introduction of a team-based model.

The impact of sample batching on reagent costs associated with the use of the Human Duo Kit for DNA quantification far exceeded the 10% increase estimated to represent operational significance. Due to the team-based batching strategy developed and modified by the DNA analysts through a collaborative effort, batched case runs were increased by 31% in 2013. The change in reagent cost resulting from this improved batching environment is defined as "reagent cost reduction", which in 2013 was calculated to be 33%, equivalent to $1,936.00 in savings.

As demonstrated by the interview and survey results, the participants developed a strong sense of ownership and unity when working together to modify the proposed DNA sample processing and batching model. The team credited effective communication as a significant factor in developing greater harmony within the group. Improved communication opened the door to cooperative planning, trust, confidence and accountability. There was a unanimous response with respect to teamwork and job satisfaction, which ultimately relates to morale. The team and individual morale scores generated from the survey clearly demonstrate a high level of both individual and team morale. With individual scores ranging from 6.0 to 4.25 out of a possible 7.0, and a team score of 5.3, morale values reached well above a neutral attitude.

This hypothesis guided research study provided a tentative explanation of proposed outcomes. However, by defining each measurable criterion, creating a method to accurately collect data, and devising ways of scientifically access and determine if the values are considered significant, it was

determined that the data supported the hypothesis. The one exception was related to the analyst casework turnaround time, but this was attributed to a drastic increase in case productivity, review bottlenecks, along with staffing reductions and limitations.

It is noteworthy to indicate that the improvements gleaned from this lean laboratory evaluated team-based approach to DNA case management were generated using a single resource, the human element. These dedicated men and women come to work every day with one goal, to produce the highest quality work product possible, in the most efficient way, using the tools and resources available to them. It is evident from this research study that their goals are being met, and this theme is echoed in the words of one analyst during a key informant interview. "I think it's managed to create a bridge between people's comfort level and efficiency, so we were able to be more efficient but without totally giving up your comfort level, and in that same time I think it builds, it's been building stronger relationships between staff."

Recommendations

Recommendation 1 - Bottlenecks: It is recommended that bottlenecks created by the team-based model be addresses and rectified. When more staff members are at the same step in the DNA process, there is greater competition for equipment or resources, which causes bottlenecks. Through supervisory oversight, and key informant interviews, bottlenecks were identified at three areas: the extraction station waiting for an instrument, during dilution set-up, and throughout the technical and administrative case review process.

Extraction Station Bottleneck: In March of 2014, the Biology Unit of the Contra Costa County Office of the Sheriff, Forensic Services Division acquired, through the use of federal grant funds, two Qiagen EZ1 Advanced XL automated extraction robots. In April 2014, Qiagen representatives performed an on-site instrument set-up and staff training. The Biology Unit Supervisor, DNA Technical Leader and Forensic Manager are responsible for the oversight of

instrument performance verifications, policy and procedures updates, and ensuring staff are adequately trained prior to authorizing the instruments for casework. This process is expected to be completed by August 1, 2014. This purchase brings the fleet of extraction robots to four. These new instruments allow for the automated processing of 14 samples per instrument run, and with two in operation a total of 28 samples can be processed in about 20 minutes. The addition of the two extraction robots more than doubles the capacity of the laboratory's extraction capabilities.

Dilution Set-up Bottleneck: This bottleneck was identified as a shortage of pipettes available for DNA sample dilutions. Pipettes are hand-held instruments that accurately transfer small amounts of liquid and are used routinely in DNA sample preparations. Pipettes are fairly inexpensive and easy to purchase, so this problem can be quickly remedied. On July 1, 2014, the beginning of the new fiscal year, the Biology Unit of the Contra Costa County Office of the Sheriff, Forensic Services Division will be able to purchase four pipettes in order to create additional sample dilution stations. These new dilution set-up stations will enhance the capacity of DNA sample processing.

Case Review Bottleneck: The increased abundance of casework needing review, the reduction or limitation of staff capable of reviewing casework, and the redundancy of the entire review process have contributed to this bottleneck. In 2013, the unit supervisor attempted to address the case review bottleneck by establishing monthly unit-wide case review sessions. During these sessions staff are brought together to discuss cases, the elements of the technical and administrative review are performed, and corrections are made immediately. It is advantages to have all Biology Unit staff present during these review sessions to expedite the review of cases. However, throughout 2013-2014 staff maternity leave time posed serious challenges to this model. In May 2014, the DNA Technical Leader who conducts a majority of the case review returned to the laboratory, and this presence is expected to have a significant impact on the case review turn around. It is

expected that by August 2014, all Biology Unit staff will have returned to laboratory duty, so review sessions should have all staff in attendance. It is further expected that with all staff present the productivity of these sessions will improve to meet unit demands. Overall analyst turnaround time will continue to be monitored for trends related to staffing, case abundance and complexity. These review sessions also serve as a learning tool where information is shared and exchanged, creating a collective consciousness among analysts, and eliminating redundancy.

During an interview, one analyst indicated that when unexpected issues arise within batched cases, it is more likely to be shared with the group so that others are alerted. The issue would then be reflected in all the batched cases, so when technically reviewed, all the reviewers were aware of this unique feature. The issue can then be resolved quickly and efficiently instead of everyone struggling to work it out independently, which takes much more time to resolve.

Recommendation 2 – Formalized Process: It is recommended to continue building and improving the team-based DNA processing model, to explore team dynamics, and make modifications as needed to improve work flow. A significant benefit of batching is that it keeps DNA samples moving through the DNA process, even when an analyst was summonsed to court, called to a crime scene, or works an alternate shift. A concern was that as the number of fully active unrestricted biology staff increase, the informal system of communication may become less effective. The Biology Unit is expected to be fully staffed by August 2014, and by the Fall, two additional DNA analysts (grant funded "forensic analysts-projects" positions) are expected to join the unit.

Beginning August 2014, the Biology Unit of the Contra Costa County Office of the Sheriff, Forensic Services Division will open the dialog to establish a more structured approach to the team-based DNA processing model. During interviews, several key informants indicated interest in establishing a more formal DNA processing model, where perhaps a monthly rotation of duties

would be established. However, taking on a more structured approach together with an increase in personnel will require greater supervisory oversight.

The supervisor along with the unit staff will be evaluating areas for improvement, including team and operational structure, rotation of duties, equipment set-up, communication pathways, report writing consistency and preparing for the incorporation of grant funded DNA analysts into the team-based DNA processing g model. These discussions may include designating staff to a specific team, and defining individual roles within teams. Roles include running DNA equipment, such as quantification, amplification and detection instrumentation. Strategies for enhanced communication and template report formats will be explored. Improvements to the existing model will ensure greater unit harmony, communication and that a more equitable distribution of batching responsibilities is shared among the Biology Unit staff.

Recommendation 3 – Lean Laboratory Consultant: It is recommended that the Biology Unit of the Contra Costa County Office of the Sheriff, Forensic Services Division employ the services of a professional "lean laboratory" consulting company, such as Bode LeanLab or Sorenson Forensics, to evaluate their overall DNA processing model. "Lean Laboratory" is a blending of both Lean and Six Sigma that is process-centered and data-driven, and proponents of a combined approach believe that organizations will benefit from adopting this methodology. Applied in a programmatic way, a lean laboratory approach can yield remarkable results that are both cost-effective and morale-building" (Kupferschmid, 2011, p. 2).

By October 2014, the Biology Unit will contract with a lean laboratory consulting firm and schedule an on-site visit. This researcher has successfully secured federal grant funds to cover the cost of the consulting fees. The services provided will help establish new team awareness, identify areas of redundancy and waste, and ultimately build upon and enhance the current DNA sample processing system. The goal is to embrace strategies for DNA process improvement through a set

of coordinated principles and practices that promote greater efficiency and effectiveness, with fewer wasteful practices or errors.

Areas of Further Study

This research project focused on the human element, and the ability to effectively use staff to achieve performance goals, be cost effective, all while improving morale among the team. Areas of further study involve the use of support staff, higher capacity equipment, and automation to support, supplement and enhance the existing process that has been established during this current research project.

Research has demonstrated that implementation of a technician supported, team-based, DNA sample processing model has been very successful. Overall productivity has been greatly improved, as demonstrated by the Oakland Police Department Crime Laboratory "Pod" model. Through the efforts of this researcher, the CCCSO Crime Laboratory was awarded a DNA Backlog Reduction Grant to hire two technicians to assist with sample productivity and batch processing in order to improve overall productivity. The addition of the two technicians and the impact of their contribution would be an excellent area of further study and assessment.

Integration of additional robotics and automated equipment within the Biology Unit would be another way to improve productivity and introduce capacity enhancement. Again, through the efforts of this researcher, the CCCSO Crime Laboratory has recently acquired through a federal DNA Backlog Reduction Grant, two extraction robots that increase the sample processing capabilities by over 50%. The impact of this new equipment in the sample processing system would be another area of further study.

Acknowledgment

This researcher would like to acknowledge all the members of the Biology Unit Team that invested their time and emotional energy to this research project. Only through the dedication and commitment of these outstanding staff was this research study able to explore the complex dynamics associated with teamwork, efficiency, effectiveness, expense and above all morale.

A special thank you goes to John Murdock for his continued support, guidance, and words of encouragement that inspires me to continue moving forward. Thank you to my family for having patience with me for taking on yet another challenge which decreases our time together. Thanks for supporting me and allowing me to reach out beyond my dreams.

The Team

Front Row (left to right): Eric Collins (Firearms Examiner), Kim Willey (Biology/DNA Unit Supervisor), Catherine Currier (Firearms Examiner), Dawn Romano (Biology Unit Technical Leader), Rosary Marcelo-Li (Biology Unit, DNA Analyst).

Back Row (left to right): Da-Shing Peng (Biology Unit, DNA Analyst), Angela Hiteshew (Biology Unit, DNA Analyst), Tony Nguyen (Biology Unit, DNA Analyst), Johanna Estrada-Ballardo (Biology Unit, DNA Analyst), Cindy Hull (Latent Print Unit Supervisor), Kathryn Novaes (Fingerprint Examiner) and Donnie Finley (Firearms Examiner).

Not present are Nichole Tuscher and Helen Kim (Biology Unit, DNA Analysts).

References

Anderson, V. J., & Thompson, J. (2011). *Decreasing the number of contract laboratory cases awaiting data review while improving DNA analysis efficiency.* (Document No. 236693). Retrieved from: https://www.ncjrs.gov/pdffiles1/nij/grants/236693.pdf

Awards related to: Laboratory efficiency. (n.d.). NIJ.gov. Retrieved from http://www.nij.gov/funding/awards/Pages/awards-list.aspx?tags=Laboratory%20Efficiency

Blackledge, J. W., Swiger, R. R., and Muldoon, D. F. (2012). Rapid DNA. *FBI National Academy Associate*, 14(3), 14-17.

Bozeman, B. (1979) *Public Management and Policy Analysis*. New York, New York: St. Martin's Press, NY, Chapter 3.

Brewer, G. (1983) *The Foundations of Policy Analysis*. Chicago: Dorsey Press.

Crouse, C., Sikorsky, J., Jeanguenat, A., Vreeland, T., and Looper, A. (2012, December). Evaluating the effectiveness of DNA analysis on property crime and identifying a new model for outsourcing. *Forensic Magazine*, Retrieved from http://www.forensicmag.com/articles/2012/12/evaluating-effectiveness-dna-analysis-property-crimes-and-identifying-new-model-outsourcing

French, J., (2006). Using process mapping to improve efficiency in a forensic laboratory. *Profiles in DNA* 9(2), 14–16. Retrieved from http://www.promega.com/~/media/files/resources/profiles%20in%20dna/902/using%20process%20mapping%20to%20improve%20efficiency%20in%20a%20forensic%20laboratory.pdf?la=en

Gerston, Larry N. (2010) *Public Policy Making, Process and Principles*. Armonk, New York: M.E, Sharpe.

Horvat, L., Berdine, S., & LaBerge, G. (2012). *Denver DNA efficiency improvement project, final technical report.* (Document No. 240638). Retrieved from: https://www.ncjrs.gov/pdffiles1/nij/grants/240638.pdf

Jarrar, H. M. (2012). *Lean DNA extraction for polymerase chain reaction improvement: a risk analysis based evaluation with lean six sigma solutions.* (M.S.Q.A., California State University, Dominguez Hills). Retrieved from *ProQuest Dissertations and Theses*. (1027223185).

Kingdon, J. W. (2011) *Agendas, Alternatives, and Public Policies*. Boston, MA: Longman.

Kupferschmid, T.D., Richard, M., Barnum, L., Becnel, A., et al. (2011). Shovel away your DNA backlog with lean six sigma tools. *Promega Corporation Web site.* Retrieved from: http://www.promega.com/resources/articles/profiles-in-dna/2011/shovel-away-your-dna-backlog-with-lean-six-sigma-tools/ Updated 2011. Accessed December 09, 2012.

Maleyeff, J. (2007). *Improving service and delivery in government with lean six sigma*. IBM Center for The Business of Government. Retrieved from http://www.doh.wa.gov/Portals/1/Documents/1000/PMC-ImproveServiceDeliveryLeanSixSigmaReport.pdf

Montpetit, S. A., Fitch, I. T., and O'Donnell, P. T. (2005). A simple automated instrument for DNA extraction in forensic casework. *Journal of Forensic Science*, 50(3), 555-563. doi: 10.1520/JFS2004181

National Institute of Justice. (Producer). (2010, June 14-16). The false metric of the DNA backlog. Retrieved from http://nij.ncjrs.gov/multimedia/video-nijconf2010-gialamas.htm

National Institute of Justice. (2012, October 10). Forensic DNA Unit Efficiency Improvement. Retrieved from http://www.nij.gov/topics/forensics/laboperations/capacity/efficiency/funding-program.htm

Nelson, M. (2011). *Making sense of DNA backlogs, 2010 - myth vs. reality*. Retrieved from https://www.ncjrs.gov/pdffiles1/nij/232197.pdf

Richard, M., & Kupferschmid, T.D., M.B.A., M.F.S. (2011). *Louisiana state police crime laboratory: increasing efficiency of forensic DNA casework using lean six sigma tools.* (Document No. 235190). Retrieved from https://www.ncjrs.gov/pdffiles1/nij/grants/235190.pdf

Rossi, P. H. (2004) *Evaluation A Systematic Approach*. Thousand Oaks, CA: SAGE

Sabatier, P. (1996) *The Conditions of Effective Implementation*. In Stillman, R. *Public Administration Concepts and Cases*. (pp. 382-391) Boston, MA: Houghton Mifflin Company.

Schweikhart, S. A., and Dembe, A. E. (2009). The applicability of lean and six sigma techniques to clinical and translational research, *Journal of Investigative Medicine*, 57(7), 748-755. doi: 10.231/JIM.0b013e3181b91b3a. Retrieved from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2835466/

Steinlechner, M. and Parson, W. (2001). Automation and high through-put for a DNA database laboratory: development of a laboratory information management system, *Croatian Medical Journal*, 42(3), 252-255. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11387633

Taylor, R. et al. (2009). Lean six sigma engineering for improved laboratory throughput and efficiency. Poster Session at the 20th International Symposium on Human Identification. Abstract retrieved from: https://www.promega.com/~/media/files/resources/conference%20proceedings/ishi%2020/poster%20abstracts/poster70.pdf?la=en

Thompson, E., Hong, M., Hill, C., & Scoville, S. (2012). *Implementation of a DNA triage and analysis system dedicated to increasing the throughput of high volume crimes in a forensic laboratory*. (Document No. 239170). Retrieved from: https://www.ncjrs.gov/pdffiles1/nij/grants/239170.pdf

U.S. Department of Justice. (2012). *Audit of the Federal Bureau of Investigation laboratory's forensic DNA case backlog.* Retrieved from http://www.justice.gov/oig/reports/2012/a1239.pdf

U.S. Department of Justice. (2008 January). *Increasing efficiency in crime laboratories.* Retrieved from the National Criminal Justice Resource Service https://www.ncjrs.gov/pdffiles1/nij/220336.pdf

Varlaro, J. and Duceman, B. (2002). Dealing with increasing casework demands for DNA analysis, *Profiles in DNA*, 5(2), 3-6. Retrieved from http://www.promega.com/~/media/files/resources/profiles%20in%20dna/502/dealing%20with%20increasing%20casework%20demands%20for%20dna%20analysis.pdf?la=en

Verwijs, C. (2012, July 24). *Agile Teams: Don't use happiness metrics, measure Team Morale*. Retrieved from http://www.christiaanverwijs.nl/post/2012/07/24/Agile-Teams-Dont-use-happiness-metrics-measure-Team-Morale.aspx

Appendix A - Lean Laboratory Team-Based DNA Processing Model Biology Unit Staff-Interview

INTRODUCTION

Laboratory management has the responsibility of creating a work environment that fosters camaraderie, provides positive reinforcement and professional development, while supporting a healthy work-life balance and open communication. Staff should look forward to coming to work, be supported and given the tools and resources needed to perform their job and flourish professionally. Working together to create a positive work environment while improving the efficiency and effectiveness within the laboratory is an ongoing challenge.

As members of the Biology Unit, you have been part of a lean laboratory team-based DNA productivity model that was launched in March 2013. As active participants, you were directed to work together as a team to maximize efficiency by batching DNA samples on instrument runs. When possible, samples from multiple cases assigned to different analysts were to be processed together at specific steps in the DNA process. These steps include quantitation, amplification and electrophoresis.

In addition to team-based batching, a lean laboratory approach was used to identify inefficiency and redundancy in administrative activities associated with sample management, work flow, worksheets, case documentation, technical/administrative review, and report generation. Elements of these administrative processes were evaluated and streamlined in an effort to produce a more effective and efficient work flow process.

As Biology Unit staff, you have performed work both before and after the implementation of this modified approach to sample processing. Each of you is a valuable member of the Biology/DNA team, and I would like to ask your opinion about your experience working within this lean laboratory team-based model. I am inviting you to participate in a brief interview. The purpose of this interview is to determine if the team-based approach to DNA processing generated an increased level of job satisfaction, and I'd like to get your perspective on this topic.

I am completing a master's degree in public administration at Golden Gate University, and this subject has been the focus on my research study. Your interview should take approximately 20 minutes, and answers will be kept confidential and anonymous. I will not publicly release your responses or other information about you. Your answers will provide guidance to help evaluate and enhance this team-based model, and will also be used for the purpose of completing my degree. Your input is very important, and I look forward to your participation. Thank you in advance for helping me to complete this research study.

1. Do you feel that sufficient effort was made by your supervisor to get your opinions and ideas related to adopting a team-based sample batching practice?

2. Do you feel that the work assignments associated with the batching of samples were distributed fairly?

3. How confident are you with the work produced by your team members?

4. Do you feel your team members are held accountable for the decisions they make?

5. Do you feel supported by your team members?

6. In what ways, if any, has adopting this team-based sample processing model allowed you greater flexibility in managing your time during sample processing?

7. Overall, how satisfied are you with the teamwork within the Biology/DNA Unit?

Appendix B - Lean Laboratory Team-Based DNA Processing Model Biology Unit Staff - Survey

INTRODUCTION

As members of the Biology Unit, you have been part of a lean laboratory team-based DNA productivity model that was launched in March 2013. As active participants, you were directed to work together as a team to maximize efficiency by batching DNA samples on instrument runs. When possible, samples from multiple cases assigned to different analysts were to be processed together at specific steps in the DNA process. These steps include quantitation, amplification and electrophoresis.

In addition to team-based batching, a lean laboratory approach was used to identify inefficiency and redundancy in administrative activities associated with sample management, work flow, worksheets, case documentation, technical/administrative review, and report generation. Elements of these administrative processes were evaluated and streamlined in an effort to produce a more effective and efficient work flow process.

As Biology Unit staff, you have performed work both before and after the implementation of this modified approach to sample processing. I would like to ask your opinion about your experience working within this lean laboratory team-based model, so I am inviting you to participate in a brief survey. The purpose of this survey is to determine if the team-based approach to DNA processing generated an increased level of job satisfaction, and I'd like to get your perspective on this topic.

I am completing a master's degree in public administration at Golden Gate University, and this subject has been the focus on my research study. Your survey should take approximately 10 minutes, and answers will be kept confidential and anonymous. Neither your name nor employee number is required to complete this survey.

You can access the survey at: http://fluidsurveys.com/surveys/debbie-mckillop/efficiency-improvement-team-morale/

Your responses will be considered finished only when you press the "submit" button. I will not publicly release your responses or other information about you. Your answers will provide guidance to help evaluate and enhance this team-based model, and will also be used for the purpose of completing my degree. Your input is very important, and I look forward to your participation. My hope is that you complete the survey by April 4, 2014. If you have questions or difficulty completing the survey, email me at dmcki@so.cccounty.us. Thank you in advance for helping me to complete this research study.

Appendix C - Screenshot of Survey on Fluidsurvey.com

Efficiency Improvement Team Morale

As members of the Biology/DNA Unit, you have been part of a lean laboratory team-based DNA productivity model that was launched in March 2013. As active participants, you were directed to work together as a team to maximize efficiency by batching DNA samples on instrument runs. When possible, samples from multiple cases assigned to different analysts were to be processed together at specific steps in the DNA process. These steps include quantitation, amplification and electrophoresis. In addition to team-based batching, a lean laboratory approach was used to identify inefficiency and redundancy in administrative activities associated with sample management, work flow, worksheets, case documentation, technical/administrative review, and report generation. Elements of these administrative processes were evaluated and streamlined in an effort to produce a more effective and efficient work flow process. Each survey participant has performed work in the Biology/DNA Unit both before and after the implementation of this modified approach to DNA processing. As a valuable member of the Biology/DNA team, I would like to ask your opinion about your experience working within this lean laboratory team-based model. Your answers will provide guidance to help evaluate and enhancing this team-based DNA processing model.

Question 1

I am enthusiastic about the work that I do for my team.

Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree	Strongly Disagree
○	○	○	○	○	○	○

Question 2

I find the work that I do for my team has meaning and purpose.

Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree	Strongly Disagree
○	○	○	○	○	○	○

Question 3

I am proud of the work that I do for my team.

Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree	Strongly Disagree
○	○	○	○	○	○	○

Question 4

To me, the work that I do for my team is challenging.

Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree	Strongly Disagree
○	○	○	○	○	○	○

Question 5

In my team, I feel energized.

Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree	Strongly Disagree
○	○	○	○	○	○	○

Question 6

In my team, I feel secure and capable.

Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree	Strongly Disagree
○	○	○	○	○	○	○

Question 7

In my team, I quickly recover from setbacks.

Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree	Strongly Disagree
○	○	○	○	○	○	○

Question 8

In my team, I can maintain stamina.

Strongly Agree	Agree	Somewhat Agree	Neutral	Somewhat Disagree	Disagree	Strongly Disagree
○	○	○	○	○	○	○