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Project FORESIGHT and Return on Investment: Forensic Science Laboratories and Public Health Laboratories

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ABSTRACT
Forensic laboratories have experienced a growing demand for services that has far outpaced the resources allocated for the investigation of forensic evidence. European and North American projects have led to the development of managerial tools for optimizing efficiency and the cost effective delivery of forensic science services. These developments have attracted the attention of other public sector operations, including public health laboratories. The public health laboratories share many of the characteristics of the forensic science laboratory. Both sectors are dominated by the work of scientists with many of the laboratory applications using similar techniques. Observing the Project FORESIGHT developments with forensic science laboratories, the Association of Public Health Laboratories introduced a project to create data collection tools for their membership, and to offer a foundation for research into the issues and challenges facing these laboratories. We outline the progression of events where the forensic science laboratory experience has been extended to the public health laboratories. The public health laboratory project has, in turn, developed some metrics that may prove valuable to the future research of forensic science laboratories. The public health laboratory project went beyond the internal inspection of the business experience and connected the internal efficiencies to the public outcomes via the development of return on investment metrics. Careful observation of the public health laboratory project provides some future direction for extension of the use of business metrics for forensic science laboratories.

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Introduction

The emergence of the European QUADRUPOL project (European Network of Forensic Science Institutes 2003) and the subsequent Project FORESIGHT (Houck et al. 2009) were the response to the forensic science's need for the development of business tools for forensic laboratory managers. Forensic laboratories experienced a growing demand for services that had far outpaced the resources allocated. These projects have led to the development of managerial tools for optimizing efficiency and the cost-effective delivery of forensic science services (Kobus et al. 2011).

These developments have attracted the attention of other public sector operations. Following guidelines for independence of the crime laboratory from policing agencies as highlighted in the 2009 National Research Council of the National Academies of Science Report (NAS 2009), the district government of Washington, DC created the Consolidated Forensic Laboratory (CFL) that included the Forensic Science Laboratory, Crime Scene Sciences, and the Public Health Laboratory (PHL). The CFL Management's adoption of Project FORESIGHT metrics as an integral decision-making tool for the forensic science laboratory sparked the interest of managers in the PHL portion of the operations.[1] The CFL leadership invited the Association of Public Health Laboratories (APHL) to join in the discussion of business metrics for the PHL, which led to a multi-year project to develop similar metrics for public health laboratories across the U.S.

The PHLs share many of the characteristics of the forensic science laboratory making the conversion of the Project FORESIGHT data collection easier than it might have been with other public sector activities. Both sectors are dominated by the work of scientists with many of the applications of similar techniques

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from toxicological examination to applications of DNA technologies. Similar to the forensic sciences, public health laboratorians work in a culture that requires standard operating procedures. The accompanying data collection tool for the PHLs needed to be easy to complete while capturing essential information, yet providing immediate feedback. The data collection tool's immediate feedback would include output to demonstrate PHL value to decision makers, and be presented in the language of those decision makers; that is, using some standard business metrics that were familiar to those decision makers.

Project FORESIGHT data has enabled research into several areas for forensic laboratories. From the development of basic business ratios (Speaker 2009a) to managerial interpretation of those ratios (Speaker 2009b) and subsequent strategic change (Newman et al. 2011), the gains in efficiency can be dramatic (van Asten 2014), but are predictable (Maguire et al. 2012). The reaction to the widening gap between available resources has prompted questions regarding the optimal model for the delivery of forensic laboratory services (Bedford 2011; Tjin-A-Tsoi 2013). The availability of industry level data from QUADRUPOL and FORESIGHT enables such questions to be examined from a data-driven basis (Speaker 2013).

Observing these developments with forensic science laboratories, APHL introduced a project to create data collection tools for their membership, and to offer a foundation for research into the issues and challenges facing these laboratories. In the sections to follow, we outline the progression of events where the forensic science laboratory experience has been extended to the PHLs. The PHL project has, in turn, developed some metrics that may prove valuable to the forensic laboratory. The PHL project went beyond the internal inspection of the business experience of the laboratories and connected the internal efficiencies to the public outcomes via the development of return on investment (ROI) metrics. Careful observation of the PHL project provides some future direction for extension of the use of business metrics for forensic science laboratories.

The measurement of a return on investment may come in different forms. In a financial realm, the return on investment is a measurement of the net gain in dollars relative to the dollars invested. For the PHLs, the measurement of the net gain is a representation of the avoidance of treatment expenses for the dollars expended or a measure of lives saved or improvement in the quality of life from avoidance of illness or disease. Extending such measures for the forensic laboratory, the measures could represent savings to society from faster detection and the savings from additional crimes avoided or lives saved or improved.

While the development of managerial tools for forensic science laboratories has progressed vigorously over the past decade, the contribution of forensic sciences to the justice system has been difficult to measure (Peterson et al. 2010). The lessons from the PHLs offer a direction for forensic laboratory future research to demonstrate the return to the public welfare that results from laboratory contributions to the justice system. The PHL project demonstrates that the generalities of the overall societal gains from PHL testing can be connected to the internal efficiencies of individual laboratories to show the return on investment from each laboratory. Following this direction should enable forensic science laboratories to connect the justice system societal gains to the contributions by individual laboratories and use that connection to serve as the basis for public funding to be expanded to meet the growing demands for forensic laboratory services.

The public health laboratory metrics project

Project FORESIGHT began with a series of sessions where laboratory representatives across North America outlined their biggest management issues, which led business faculty to link those issues to relevant data for participants to collect regarding casework, budgets, and personnel allocation. To frame the direction for the project, the FORESIGHT team had to first link laboratory missions with a common language to permit industry-wide measurement. It took nearly two years of discussion before any data could be collected. The PHL metrics project was able to proceed at a much more rapid pace than the forensic science laboratories experienced, largely due to two factors: the existence of a data collection repository through the APHL; and the documented experience via Project FORESIGHT and other developments in the business of forensics (Houck et al. 2015).

Initial data review

Before devising a data collection tool to survey PHLs on their laboratory, personnel, and expenditure data, a review of existing APHL data collection was undertaken. APHL had previously conducted a survey of its membership with information regarding testing, expenditures, and personnel levels. Using the APHL *Core 2011* survey data, base level metrics were developed along the lines of the metrics used in Project FORESIGHT (Speaker 2015). Key among those measures was the construction of an output metric showing the average total cost of testing which allowed laboratories to make a comparison of their average total cost of testing to other laboratories with a similar number of tests performed. With forensic science laboratories, the data showed substantial economies of scale, where the average cost of testing fell until an optimal level of testing was performed. A first look at the PHL data revealed a similar sense of economies of scale with a dramatic fit of the data to the theoretical relationship between the average total cost of testing as it relates to the volume of testing. Figure 1 highlights the data by plotting average total cost per test against the test level for each reporting laboratory. A glance at the data appears to demonstrate the expected relationship as theorized in economics; namely, when average total cost is mapped against the scale of operations, a U-shaped curve emerges. Economies of scale are realized as the level of testing is increased. While we would normally expect that at some point diseconomies of scale may be realized (i.e., the rising portion of the U-shaped average total cost curve), it does not appear that the testing level has been reached where diseconomies have been experienced by the laboratories in the APHL's *Core 2011* survey.

The reference to efficiency and cost effectiveness, can be seen through the U-shaped average total cost curve. Efficiency is a reference to the lowest cost production for a given level of output. All points along the U-shaped average total cost curve represent a point of efficiency. If a laboratory operates at a point above the average total cost curve, it is inefficient. That is, the laboratory should be able to produce that same level of output for a lower average cost. Cost effectiveness, on the other hand, is a reference to a specific point on that average total cost curve where perfect economies of scale have been achieved. The laboratory is efficient and operates at the lowest average cost for any level of output.

As had been done with the forensic science laboratory data, the relationship between the average total cost and the level of testing was estimated using a non-linear regression technique. From an examination of Figure 1, it does not appear that any of the laboratories had achieved a level of testing beyond the minimum average cost. The data suggest an image that is reminiscent of the downward sloped portion of the expected U-shaped curve. The functional form of a power function offers a potential nonlinear relationship between the average total cost and the level of testing that may be estimated. That is,

$$Cost/Test = \alpha \; Tests^{\beta}$$

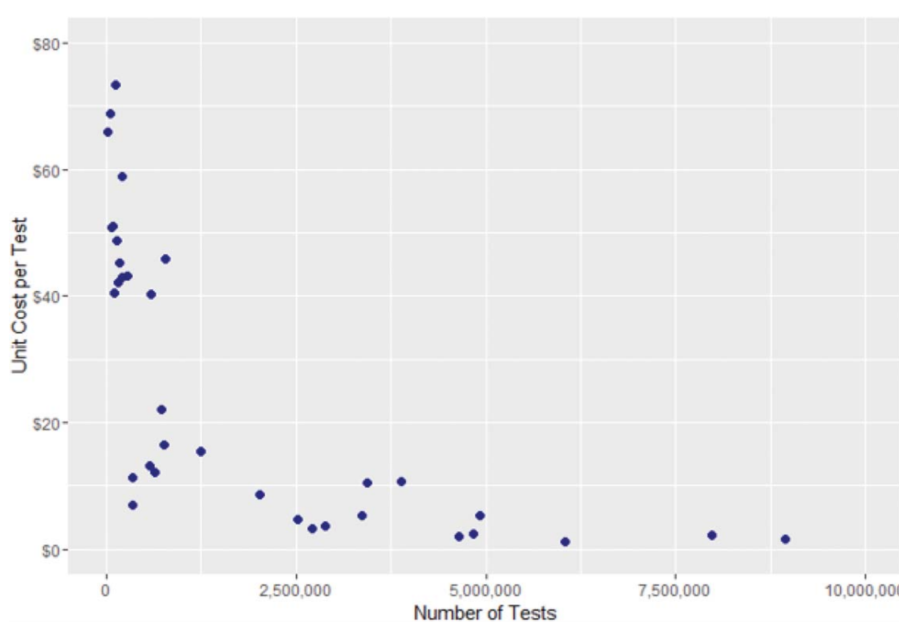

Figure 1. Cost per test vs. test volume.

Plotting histograms of the number of Tests and the Cost/Test, there is a right skewness in each of the variables; after a log transformation of each variable, when each histogram is replotted, the resulting distribution is much closer to a normal distribution. This observation is strengthened after calculating p-values using the Shapiro-Wilk test for each log transformed variable, Cost/Test and Tests, with p-values of 0.6727 and 0.0904, respectively, which suggests that we cannot reject the null hypothesis that these samples are taken from a normal population. Given this information, a log-log regression model is estimated to preserve the properties of a linear model, while providing an interpretation of the non-linear relationship between the Cost/Test and Tests.

Taking natural logarithms of each side we run the regression:

$$LN(Cost/Test) = LN(\alpha) + \beta \times LN(Tests).$$

Figure 2 illustrates the selected log-log model with corresponding 95% confidence interval of the plotted regression line:

$$LN(Cost/Test) = 12.04660 - 0.69797 \text{ x } LN(Tests)$$
$$(0.7475)^{***} \ (-0.0546)^{***}$$

***significant at the 0.01 level;
adjusted R-squared = 0.8187

Transforming these estimates of the log-log transformation back to the original relationship between Costs/Test and Tests yields:

$$Cost/Test = 170,519 \times Tests^{-0.6979}.$$

The strength of this initial relationship was encouraging in that PHLs appear to provide a very good fit to the expected relationship formed by economic theory. This early finding was used to support the recruiting of laboratories to participate in the initial development of data collection tools. A few existing PHL committees were tapped for initial participation in the metrics workgroup; the Laboratory Systems & Standards committee offered a systems perspective and the Knowledge Management committee provided both state and local laboratory perspectives. This newly formed metrics workgroup followed a similar path to that forged by the original Project FORESIGHT members. However, the guidance permitted from the earlier project permitted a much faster pace for the PHL workgroup and within the first nine months, the workgroup had reached general consensus on language with the adoption of several key definitions (Appendix A) and test counting conventions.

As with the forensic science laboratories, the connection between mission and metrics had to be addressed. To develop appropriate business metrics for the PHLs, an examination of the mission of each laboratory had to be considered and the results synthesized to establish a common optimization problem

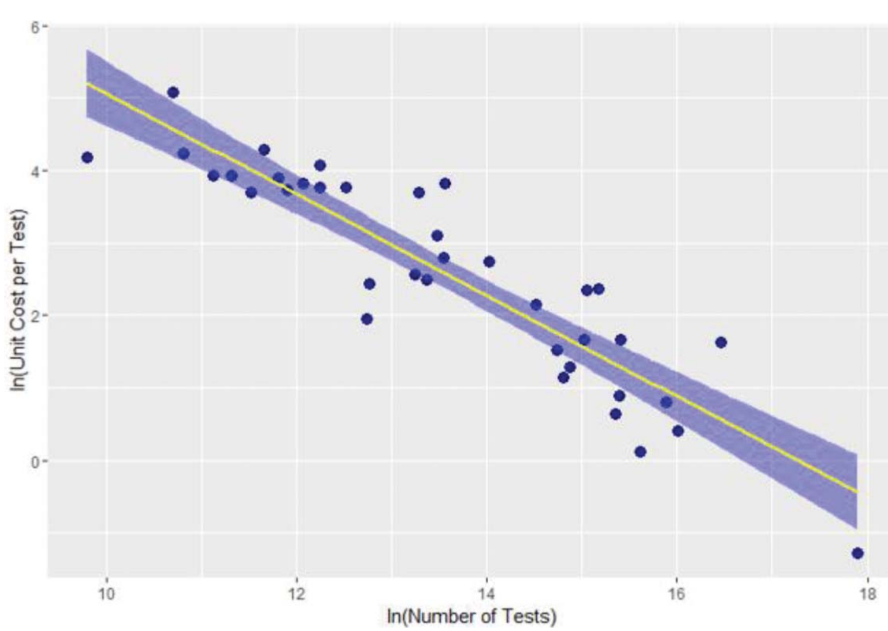

Figure 2. Natural log of cost per test vs. Natural log of test volume.

faced by each laboratory. Fortunately, such an examination had already been performed through the APHL and the common missions inherent in a listing of core activities.

Public health laboratory core activities

In the Project FORESIGHT review of the mission and mandates of forensic science laboratories, most mission statements centered on casework activity with some missions also including a research function. However, the breakdown of activity for forensic science laboratories left little time beyond casework and casework related activities. Data collected for each year of Project FORESIGHT revealed a very small percentage of forensic laboratory time devoted to research or other non-casework activity. For the PHLs, however, the range of activities is much broader with time allocated across a list of core functions (see Appendix B for a detailed description of each core function) with testing comprising an average of approximately 70% of laboratory activity.

PHL core functions

1. Disease Prevention, Control, and Surveillance
2. Environmental Health and Protection
3. Public Health Preparedness and Response
4. Integrated Data Management
5. Reference and Specialized Testing
6. Food Safety
7. Laboratory Improvement and Regulation
8. Policy Development
9. Public Health Related Research
10. Training and Education
11. Partnerships and Communication

To isolate the expenditures attributable to each activity of the laboratory, the project design required each laboratory to provide a breakdown of effort across the laboratory to meet each of these core functions. From these breakdowns of activity, laboratory expenditures could then be allocated accordingly.

Pilot testing

While recognizing the breadth of PHL mandates, the PHL workgroup decided to concentrate trial efforts in a few areas of hot button issues and easily recognizable efforts of the laboratories. These included program level testing for the areas of foodborne illness, influenza, newborn screening, safe drinking water, and tuberculosis. These program areas have a national impact and are common to most PHLs, and had a direct public interest with a great deal of relevant scientific literature on impact. Meeting on the heels of some critical public health crises (Ebola outbreak and Zika virus), PHLs effort towards emergency preparedness was also included in the data collection. During the course of the 2015–2016 fiscal year, the pilot study participants began to collect the data, refine definitions and counting techniques, and submitted data that permitted individual output standards to be connected to the body of literature on the benefits received from each area of testing. As had occurred with forensic science laboratories, multiple meetings were held to provide details for categories with examples, glossary definitions, updates, consistent test measurement, and collection methodology. These clarifications were discussed and revisited on multiple occasions.

As with the forensic science laboratories, the collected data concentrated on the information needed to directly address the consensus missions across laboratories. For testing activity, this led to metrics that would permit evaluation of a mandate to provide high quality testing for the budgets allocated to meet this mission. The data collection tool was designed to include revenue levels and sources (national, state, and local funding; federal and state grants; and for-fee services), and to separate expenditures into personnel, capital, consumables, and other expenditure categories. Additional data captured the distribution of c3. ore activities, full-time equivalent personnel distribution, and testing volumes across various laboratory activities.

Output

The forensic science data collection tool, LabRAT, included data entry pages for casework and laboratory financials which were linked to an output page for immediate feedback. That feedback page provided immediately usable metrics that followed the analysis highlighted in the literature (Houck et al. 2015). The project team directed the PHL data collection tool to offer some of the same immediate feedback, including output with average total cost metrics as well as the introduction of return on investment metrics.

Many PHL programs are designed for early detection of potential public health problems. The medical and health economics literature offer a large number of studies that measure the direct individual and indirect social costs from adverse medical conditions. From these studies, health economics calculate cost-benefit comparisons that connect the benefits to society from preventive and early detection via costs avoided when preventive care is able to eliminate or reduce the need for health care treatments of medical conditions.

Unfortunately, the project design in the medical and health economics literature was not created for interpretation for the specific cost structure of an individual laboratory. Because their service areas are generally associated with some political jurisdiction, PHLs, as with forensic science laboratories, operate at different average total costs, often reflecting an under-achievement of economies of scale. As a result, these different average cost structures do not permit a generalized return on investment that is directly applicable to each individual laboratory. The estimation of the ROI for each individual laboratory requires conversion from the average total cost in published studies to the individual laboratory's experience as reflected in the individual laboratory's cost structure.

The output sections of the data collection tool included indications of the average total cost for the laboratory and the conversion to the corresponding return on investment in each program evaluated. The nature of the returns were presented in multiple forms, a dollar return per dollar invested, a health economics metric marking the improved lifestyle (termed a Quality Adjusted Life Year (QALY)), and a combined metric noting dollar treatment expenditures avoided plus QALY gains.

Quality adjusted life years

A Quality Adjusted Life Year (QALY) is a measure widely used in matters of health economics. It is a metric that is frequently adopted as a means to quantify cost-benefit decisions in healthcare. QALY's are the product of life expectancy and a quality metric associated with any health condition and these are compared to the average quality of a person without the associated condition. The value of a particular treatment as measured in QALY's is the difference between the quality of an average person's life and the expected QALY associated with the condition in question.

A person in perfect health would have a QALY valued at 1.00. For severe conditions, the QALY may be negative. Note that the average person has a QALY of 0.87 for a typical year (Scharff et al. 2015). The common use of the QALY is to then value the QALY expected gain at \$50,000, \$100,000, or up to \$200,000 for the benefit comparison to the cost of treating the condition, or making a capital expenditure, etc.

Measuring social benefit

Fortunately, there is an extensive literature that provides detail regarding the likelihood of the adverse events tested in public health laboratories, as well as the distribution of costs incurred for treatment and the loss of function associated with the adverse condition. A measurement of the social benefit from detection and/or treatment relies upon the estimated value of costs avoided, pain and suffering, and any associated deterioration in the quality of life from the adverse condition. Several medical and other scientific studies were reviewed for detail on cost of treatment, value of statistical life, QALYs, etc. In particular, the benefit measurement included a review of economic studies, particularly in health economics, for use of detailed cost-benefit analyses. Thus,

$$Social\ Benefit = Tests \times p(positive\ test) \times E(cost\ of\ treatment\ avoided),$$

where the probability of a test subject yielding a definitive positive indication of the adverse condition, *p(positive test)* and the expected cost of treatment, *E(cost of treatment avoided)* are each taken from medical/health/economic studies. In addition to the costs avoided, other social benefits may include values for the pain and suffering avoided, both directly to the person with the diagnosed condition and indirectly to others, such as the anguish to parents from a previously undiagnosed condition. Those direct pain and suffering effects are generally measured in QALYs and provided a dollar value per QALY that ranges from \$50,000 to as much as \$200,000.

While many health care professionals have a claim that they have provided a contribution to the benefit or costs avoided (e.g., laboratory, physician, hospitals, over-the-counter treatment, environmental engineers), at the margin, many may rightly take credit for the public benefits. The benefits claimed by the individual contributors do not sum to the total social benefit, but at the margin, all may claim the social benefits. That is, the ROI is claimed by many who each make critical contributions for the social benefit. The size of the ROI across laboratories differs according to the internal productivity, processes, and market conditions in which they operate.

Return on investment methodology

From the medical and health economics literature, details were extracted on costs of treatment, QALYs lost, and statistical analysis of incidence. The total social benefits were then approximated from these prior studies for use in the determination of part of the numerator of ROI. As for the denominator, the total costs for testing were collected from the same studies and then amended from the detail collected for the pilot laboratories. These measures of the total cost also affect the numerator, where the term represents the net benefit to society; that is, net of the costs.

The individual laboratory's total cost determination for a particular activity is the key contribution of the pilot study. Consider the average cost of a test for a particular laboratory compared to the volume of testing in that laboratory. To illustrate the conversion from published studies to a determination of the return on investment to an individual laboratory i (ROI_i), assume that the average benefit per test is independent of the laboratory doing the testing. That is, if ATB_L represents the average social benefit per test across all laboratories, we assume that $ATB_i = ATB_L$. The average return on investment across all laboratories relates the total social benefit, TB, to the total expenditures for testing, TC:

$$ROI_L = (TB - TC)/TC.$$

Divide numerator and denominator by the total number of tests N by all laboratories yields:

$$ROI_L = \left(\frac{TB}{N} - \frac{TC}{N}\right) / \left(\frac{TC}{N}\right) = {}^{(ATB_L - ATC_L)}\Big/_{ATC_L},$$

where ATC_L is the average total cost across all laboratories.

Solving for the average total benefit, ATB_L, we obtain

$$ATB_L = ATC_L \times (1 + ROI_L).$$

For laboratory i:

$$ROI_i = {}^{(ATB_i - ATC_i)}\Big/_{ATC_i} = {}^{(ATB_L - ATC_i)}\Big/_{ATC_i},$$

where ATC_i is the average total cost for laboratory i. Substituting for ATB_L from above, we obtain

$$ROI_i = {}^{(ATC_L \times (1 + ROI_L) - ATC_i)}\Big/_{ATC_i} = \left({}^{ATC_L}\Big/_{ATC_i}\right) \times (1 + ROI_L) - 1.$$

Several of the health economics studies have attempted to capture the cost of particular testing by counting hours devoted to a single test and measuring materials cost employed in the test. While such a micro level examination offers some information, it does not capture the full cost to the laboratory, including capital requirements, overhead, and incidental expenditures. Taking a macro view of the laboratory and breaking down the fully-loaded costs, including facilities, infrastructure, training and development, education, preparedness, etc., then a more complete picture of the costs may be determined. The use of the core functions breakdown to help allocate the infrastructure costs is an explicit recognition of the complex mission of the public health laboratory.

Return on investment

In a for-profit environment, ROI represents the dollar returns minus the total expenditures, relative to the total expenditures. While typically presented as a percentage, it may also be presented as a dollar of benefit per dollar spent. To put this magnitude into perspective, consider the ROI for the thirty firms in the Dow Jones Industrial Average, where published ROIs range from near zero to a high of 28.23% (Google.com 2016). A comparison of the returns to these leading companies offers some perspective to the public health laboratories and their societal returns.

Extending the concept of return on investment to the public sector, the ROI numerator, net benefits, may be measured in dollars saved, quality adjusted life years (QALY), or some combination that accounts for costs avoided for treatment as well as pain and suffering. The alternative measures may be extracted from the existing health, medical, and health economics literature and then applied to the detailed expenditure structure of the PHL's.

ROI example

Consider the role of the PHLs with respect to food safety. The Centers for Disease Control and Prevention (CDC) program, PulseNet USA, provides a nationwide network to speed up the identification and subsequent intervention regarding foodborne illness.

> "PulseNet is a national laboratory network that connects foodborne illness cases to detect outbreaks. PulseNet uses DNA fingerprinting, or patterns of bacteria making people sick, to detect thousands of local and multistate outbreaks. Since the network began in 1996, PulseNet has improved our food safety systems through identifying outbreaks early. This allows investigators to find the source, alert the public sooner, and identify gaps in our food safety systems that would not otherwise be recognized." (Centers for Disease Control and Prevention 2016)

The Individual laboratory ROI was suggested by the following details in the medical and health economics literature (Scharff 2012). Total national net benefit from PulseNet was evaluated using data from 1994–2009 (Scharff et al. 2015). Those benefits represent costs avoided because of early detection. Multiple models were employed to measure the social benefits including direct benefits from product recall and the indirect effects from averted harm. The measurement of these benefits ranged from $491–654 million, with the lower bound capturing the benefits from costs avoided and the upper bound reflects the inclusion of both costs avoided and QALYs which were valued at $100,000 per QALY.

The determination of the ROI also requires measurement of the total costs of the investment. For the PulseNet project, the nationwide costs of the program totaled $7.3 million. For the total program, the Return on Investment in terms of cost avoided exceeds 6,600% or stated in terms of dollar returns per dollar invested, the PulseNet program returns $67.26 per dollar invested. And when the returns capture both costs avoided and quality of life from early detection, the ROI exceeds 8,850%, a return of $89.59 per dollar invested in the program.

While those program totals for social benefits and total program costs provide a sense of the ROI for the entire program, the localized laboratory returns required adjustment for laboratory productivity and associated economies of scale. The economies of scale adjusted returns can be quite dramatic. As a laboratory increases its testing level towards the optimum sized testing facility, average total costs decline, while social benefits per test remain constant.

To estimate the per laboratory performance, we examined each pilot laboratory's level of effort with the Core Function "Food Safety," which includes the laboratory effort in PulseNet. Total laboratory expenditures were allocated to the food safety category according to its corresponding level of effort. That expenditure was then divided by the number of reported PulseNet tests as a proxy for the average cost of testing. The overall PulseNet project ROI was reallocated to the individual laboratory as described in the ROI methodology section. The result was a range of individual laboratory ROI.

Figure 3 demonstrates the relationship between the program wide average return on investment and the return on investment to the individual laboratories. The humped shaped curve in the upper graph is the result of a quadratic regression of the data points relating the individual laboratory return on investment (the ROI_i) measured on the vertical axis to the level of testing on the horizontal axis. The flat line in the center of the upper graph illustrates the average ROI (ROI_L). Directly below in Figure 4 are the associated average total costs per laboratory (ATC_i), which are also fitted with a quadratic regression to represent the U-shaped curve showing economies of scale. Again, the mean average total cost (ATC_L) is plotted as a flat line for the overall program across all laboratories.

While the APHL pilot study results only offer a first pass look at the relationship between the individual laboratory performance and the resulting societal outcomes, the study offers valuable direction as the project moves forward. Certainly, a more detailed breakdown of activity is needed to more accurately account for expenditures and future data collections will offer that detail. Those future data collections include more detail on the assignment of full-time equivalent employees, a complete allocation of testing activity across all programs within the laboratory, and continued improvement in the description of processes for consistent measurement across all participants. However, the current proxy measures also provide direction for research into the contributions of other entities, including forensic science laboratories. The direction of the PHL study to connect operational and financial efficiency to the

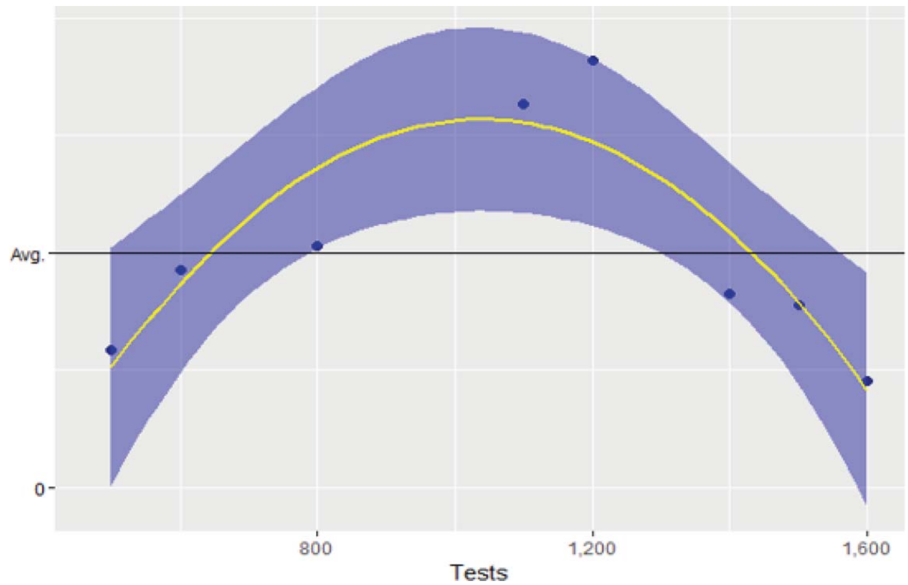

Figure 3. Return on investment vs. test volume.

resultant gains to society should be a direction followed in other public sector studies.

Concluding observations

Moving forward, the direction of the PHL project offers suggestions for continued business research for forensic laboratories, especially the determination of ROI for forensic laboratories. For the 19 areas of investigation in Project FORESIGHT, can the associated literature provide some connections to the benefits from casework testing? If so, this offers a leap forward for the justice system and for managers of forensic science laboratories. For the system as a whole, a societal return on investment from various efforts can help to guide the allocation of public funds towards optimizing the social benefits. That optimization of fund allocation cuts across all public sectors. It permits a more informed discussion of what can be expected for each dollar invested.

A move toward measures of the contribution of forensic science laboratories to the justice system has

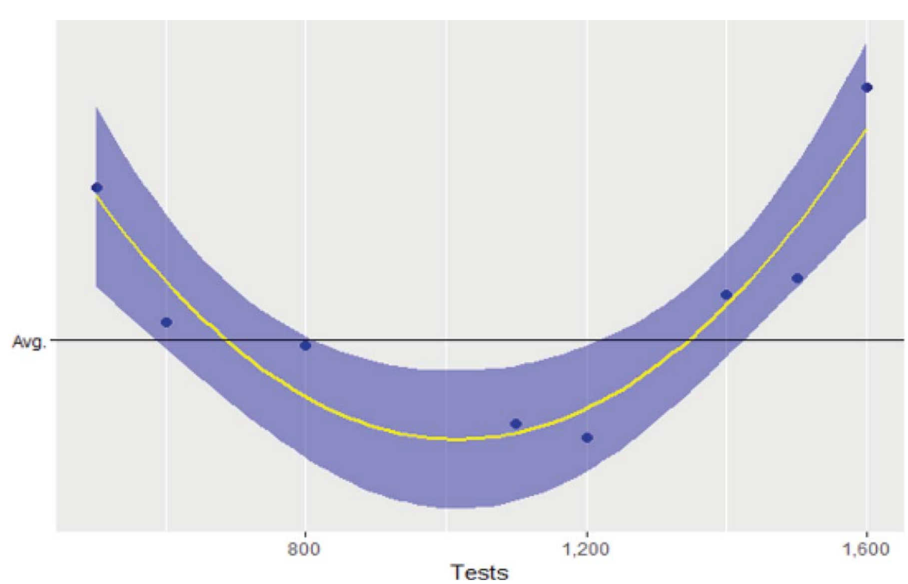

Figure 4. Average total cost vs. test volume.

not been a simple process. However, the expansion of the FORESIGHT database enables the measurement of the fully loaded costs of forensic science services down to the individual investigative areas. When coupled with economic, social, and criminology studies on outcomes, the return on investment in selected forensic areas of investigation may be developed. While it is not expected that all areas of investigation will be easily addressed, other areas should yield some quickly obtained, useful measures of the societal returns from forensic laboratories.

For laboratory managers, a greater sense of the societal return on investment allows more informed decision-making with the allocation of resources within the laboratory. While developments to-date from QUADRUPOL and FORESIGHT offer insight into the cost structure towards efficiency and cost effectiveness, a move to connect the societal benefits would offer a more complete picture to influence the allocation of scarce resources. Armed with the returns information, laboratory leadership can better address funding bodies to inform of the societal contribution of areas of investigation in support of mounting requests for services.

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Notes

1. The CFL declined participation in Project FORESIGHT after the 2015 fiscal year.

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Appendix A: Key definitions

	Glossary
Administrative & Support Staff	Administration includes the laboratory director, associate directors and other key personnel whose primary job function is related to executive leadership and organizational decision-making. Support staff includes laboratory personnel whose primary job functions are not directly related to performing the test and whose salary is contributed to overhead. Examples of job functions include central services, accessioning/sample receiving, specimen transport, finance/billing, customer service, outreach, education/training, facilities, safety, emergency preparedness, HR, public relations, quality assurance, and IT.
Capital Expenditure	Purchases of equipment, instruments, etc., over $1,000 with a lifetime longer than one year.
Consumables	Chemicals, reagents, gases, and other laboratory supplies.
Employee Benefits	Employer contribution to FICA, Medicare, Workers Comp, and Unemployment Comp, retirement (employer contribution only towards pensions, 403B or 401K plans, etc.), and occupational health service expenses (employer contribution only).
Equipment Leasing	Payments for rent or lease contracts for capital equipment, instruments, etc. with a lifetime longer than one year (the lease contract may include maintenance as part of the annual payment).
Fee-for-Service (FFS)	Payment of public health laboratory services are based on unit price such as test fees. Includes FFS contracts and direct invoicing.
Grants/Contracts	Includes all federal, in-state and out-of-state, and local grants and contracts. Includes federal pass-through funding, cooperative agreements, and memorandums and understanding. Budgets are itemized by such categories as personnel, equipment, and supplies. Does not include any contracts that are for Fee-For-Service.
Internal TAT	The time measured from the point of receipt of a sample or specimen within the laboratory until the generation of a final result.
Other Expenses	Includes any laboratory expenditure not included in the other subcategories.
Other Revenue	Includes any revenue source not included in State Appropriations, Grants/Contracts, or Fee-for-Service.
Program	Includes all tests specific to any organized public health action or activity. Defined by specific criteria or legislation and partially or fully supported through federal, state, or local funding.
Service of Instruments	Includes maintenance contracts for upkeep of capital equipment and unplanned expenditures for equipment/instrument repair.
State Appropriations	Funding dedicated by the state legislature for the purposes of public health laboratory services.
Technical Staff	Excludes any support personnel including those who perform sample accessioning, kit preparation, client services, facilities, safety, quality assurance, administrative functions, education/outreach, information technology, billing and finances, and grants/contracts.
Test	A standard laboratory procedure or method
Transport Time	The time measured from the point of collection of a sample or specimen until received by the laboratory.
Wages & Salaries	Includes personnel expenditures paid directly to the employee including overtime and temporary.

Appendix B: Core functions of public health laboratories

Core Function

Disease Prevention, Control, and Surveillance

Provide accurate and precise analytical data in a timely manner in support of the:

- Prevention and control of infectious, communicable, genetic and chronic diseases, and environmental exposure. This may include testing for emerging and re-emerging microbial agents, immune status, antibiotic resistance, screening for inherited neonatal metabolic disorders, environmental toxins, and heavy metals such as blood lead.
- Recognition of outbreaks and other events of public health significance, by the identification and characterization of the causative agents of disease and their origin.
- Population-based surveillance for conditions of public health importance and to guide programmatic decisions.
- Early detection of congenital disorders in newborns leading to timely diagnosis and treatment.
- Monitoring of low incidence and/or high risk diseases, such as antibiotic-resistant tuberculosis, influenza, botulism, and rabies.
- Investigation and control of communicable or environmental diseases when testing is not available in the private sector.

Environmental Health and Protection

Collaborate with partners to coordinate and ensure scientific analysis of environmental and human samples to identify, quantify, and monitor potential threats to health by:

- Testing for toxic chemical, radiological, and microbiological contaminants in air, water, soil, and hazardous waste.
- Conducting biomonitoring of human specimens in the assessment of toxic chemical exposure.
- Testing of environmental samples in support of federal and state regulations, aiding in the compliance with those regulations.
- Industrial hygiene/occupational health testing to assist in efforts to protect indoor air quality and worker health, such as routine analysis of asbestos, lead, pesticides, and radon.
- Participating in the Chemical Laboratory Response Network (LRN-C) and the Environmental Response Laboratory Network (ERLN).

Public Health Preparedness and Response

Fulfill a key partnership role in local, state and national disaster preparedness and response by:

- Functioning as a Laboratory Response Network (LRN) Reference laboratory for biological agents and as an LRN Chemical Laboratory at a level designated by CDC.
- Assuring the triaging of environmental samples for the rapid identification of threat agents (chemical, biological, radiological and nuclear – CBRN); and food samples as a part of the Food Emergency Response Network (FERN).
- Planning for and ensuring that surge capacity is available during a public health emergency.
- Having a Continuity of Operations Plan in the event of a disruption of laboratory services.
- Participating in the Environmental Response Laboratory Network (ERLN).

(*continued*)

(*Continued*)

Core Function

Integrated Data Management

Serve as the conduit for scientific data and information in support of public health programs through the:

- Capturing of laboratory data essential for public health analysis and decision making, including detecting trends and sentinel events.
- Use of standardized data formats.
- Influencing public health policy.
- Linkage with CDC and other national and international surveillance databases.
- Collaboration with state and national laboratory systems.
- Continuous improvement of laboratory data systems

Reference and Specialized Testing

Serve as centers of excellence using their expertise, reference and resources in the areas of biological, chemical and radiologic issues of public health importance to:

- Support the diagnosis of and surveillance for unusual and emerging pathogens.
- Confirm atypical laboratory test results.
- Verify results of other laboratories' tests.
- Provide reference services to laboratories that may not have the capability to fully identify disease agents of public health importance.
- Provide diagnostic testing for diseases of public health importance directly to providers when testing is not readily available.
- Test for diseases of public health importance that are too rare and unusual for other laboratories to maintain capacity

Food Safety

Collaborate in the detection, monitoring and response to food safety issues by:

- Testing samples from persons, food and beverages implicated in food-borne illness outbreaks to detect and identify potential food-borne pathogens.
- Characterizing isolates and participating in national strain characterization databases, such as PulseNet, to inform epidemiologic investigations.
- Analyzing food specimens to detect, identify and quantify toxic contaminants such as pesticide residues, heavy metals and volatile organic compounds.
- Monitoring for radioactive contamination.
- Participating in the Food Emergency Response Network (FERN).

Laboratory Improvement and Regulation

Provide leadership for laboratory improvement in areas of public health importance by:

- Promoting quality improvement programs for partner laboratories through activities such as training, consultation and proficiency testing.
- Developing and overseeing statewide laboratory improvement programs to ensure the reliability of laboratory data used for environmental monitoring and communicable disease surveillance and control.
- Promoting safe laboratory practice through education, training and consultation.
- Assessing and improving the State Public Health Laboratory System by implementing the Laboratory System Improvement Program (L-SIP).
- Guiding the creation of and supporting enforcement of regulations and laws that contribute to laboratory improvement.

Policy Development

Play a role in the development of state and federal health policy by:

- Generating scientific evidence that informs public health practice and law.
- Monitoring the impact of public health laboratory practice on health outcomes.
- Serving as centers of expertise, reference and resources in the areas of biological, chemical and radiologic issues of public health importance.
- Participating in the development and evaluation of standards related to the operation and performance of laboratories involved in public health testing.
- Advocating for the use of sound reasoning in the application of laboratory science and system infrastructure sustainment.
- Engaging in strategic planning at local, state and national levels.

Public Health Related Research

Engage in research to improve and expand the scientific and policy bases of public health laboratory practice and assure their optimal application in support of the public health system by:

- Developing, evaluating and implementing new technologies and methodologies.
- Partnering with other public health disciplines.
- Collaborating with academic institutions to carry out clinical and translational science.
- Conducting public health systems and service research.
- Working with the private sector to foster scientific innovation.

Training and Education

Facilitate access to training and education by:

- Sponsoring training opportunities to improve scientific and technical skills within the public health laboratory system.
- Supporting management and leadership development opportunities.
- Participating in the training of both domestic and international scientists.
- Partnering with academia to provide experiential learning opportunities.
- Providing continuing education in the area of laboratory practice.

Partnerships and Communication

Support their respective state public health laboratory systems by:

- Highlighting the importance of laboratory contributions in support of public health.
- Maintaining a strong communication plan that links all system partners.
- Utilizing information technology for robust connectivity;
- Engaging traditional and non-traditional partners.
- Coordinating activities through the use of a laboratory program advisor, (i.e., laboratory system coordinator).
- Linking the SPH Laboratory System to appropriate national surveillance networks.

Source: (Association of Public Health Laboratories, 2014)