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Financial Management of Forensic Science Laboratories: Lessons from Project FORESIGHT 2011-2012

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ABSTRACT Critical to the decision-making within an individual forensic science laboratory is an understanding of their efficiency and effectiveness. The NIJ-funded project, FORESIGHT, applies financial management techniques to avowed public sector goals and offers a common starting point for the comparison of individual forensic laboratories to the established standards in the industry through a review of financial ratios. Such ratios adjust for size differences and allow insight into several aspects of the operation including evaluation of efficiency, quality, risk, market nuances, and return on investment. This study offers insight into the financial performance, productivity, efficiency, and effectiveness of forensic science laboratories. Using data from the National Institute of Justice's Project FORESIGHT for 2011-2012, a variety of benchmark performance data is presented with analytical insight into the nature of that performance. The tabular and graphic presentations offer some insight into the current status of the forensic science industry in general and provide a basis by which individual laboratories may begin to assess their own performance with respect to both analytical efficiency and cost effectiveness.

KEYWORDS financial management, forensic laboratory, efficiency, cost effectiveness

INTRODUCTION

Critical to the decision making within an individual forensic science laboratory is an understanding of the efficiency and effectiveness of the laboratory. Financial management analysis in the for-profit world offers a variety of techniques to evaluate such performance, but those techniques must be adapted to the public sector. A common starting point is a comparison of the individual operation to the established standards in the industry through a review of financial ratios. Such ratios adjust for size differences and allow insight into several aspects of the operation including evaluation of efficiency, quality, risk, market nuances, and return on investment. Once an individual operation has found its comparative place among the industry, evaluation of performance over time

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may be tracked with the same metrics as managers begin to ascertain the effectiveness of changes for increased efficiency, quality, and return on investment.

This study offers some insight into the financial performance, productivity, efficiency, and effectiveness of forensic science laboratories. Using data from the National Institute of Justice's Project FORESIGHT[1] for 2011–2012, a variety of benchmark performance data is presented in the material to follow with some analytical insight into the nature of that performance. The tabular and graphic presentations offer some insight into the current status of the forensic science industry in general and provide a basis by which individual laboratories may begin to assess their own performance with respect to both analytical efficiency and cost effectiveness.

Project FORESIGHT (Houck et al. 2009) is a cooperative effort among laboratories worldwide to connect financial and strategic management techniques to the performance of forensic laboratories. Using the individual missions of laboratories as the guidepost, project laboratories have defined a common language and common counting methods for the development of consistent metrics to measure the performance of individual laboratories and the industry as a whole for performance comparison and analysis. (Appendix A includes relevant excerpts from the FORESIGHT glossary and Appendix B contains the descriptions of the FORESIGHT Areas of Investigation.) For consistency in measurement of casework data, the data collection tool, LabRAT, offers examples to guide a laboratory's submission.[2]

Project FORESIGHT data comes from voluntary participation and as such, does not represent a random sample from all laboratories. For the 2011-2012 reporting period, 81 laboratories submitted data on casework, expenditures, and personnel. All laboratories met industry quality standards via ASCLD/LAB accreditation or have been independently verified as having met ISO 17025 standards. Participating laboratories represent six continents (with all expenditure data converted to U.S. dollars), but a majority of the reporting laboratories represent U.S. jurisdictions. The laboratories represent municipal, regional, provincial, national jurisdictions as well as private laboratories.

The reported metrics represent a subset of the possible business metrics introduced in Speaker (2009a). The following section provides a univariate review by areas of investigation. These summary statistics offer a benchmark for comparison, including the detail for a disaggregation of the data (Speaker 2009b). After the summary statistics, the following section offers a bivariate view of the data with attention to economies of scale. Included in the graphical display of efficiency and cost-effectiveness are the estimated efficient relationships from which laboratories may make a finer comparison of their performance.

Concluding remarks follow the presentation of the data and stress the importance to place a holistic view when reviewing data (Houck et al. 2012). That closing section includes a brief overview of some of the other avenues of exploration and discovery that have come from the data.

Foresight Summary Statistics

The benchmark data for the 2011–2012 performance period includes laboratory submissions for several different fiscal year definitions. However, all submissions have December 31, 2011, as part of their fiscal year accounting. The majority of submissions follow a July 1, 2011, through June 30, 2012, convention. Others follow a year that begins as early as April 1, 2011, (ending March 31, 2012) while the other extreme includes laboratories with a fiscal year originating October 1, 2011, and ending September 30, 2012.

Return on Investment Metrics

Consider the summary statistics for several of the key performance indicators. The first sets of metrics offer a direct measure of a laboratory's ability to meet its mandate. The typical public sector laboratory adopts a mission statement that professes the laboratory's objective to process as much evidence as its budget allows, while following accepted scientific procedures under high standards for quality control. To convert avowed mission into a workable measure, several metrics have been proposed (Speaker 2009a), including cases processed relative to total expenditures, items examined relative to total expenditures, samples processed relative to total expenditures, and tests performed relative to total expenditures. The higher is each of these ratios for given quality, then the higher is the return on the investment from the forensic laboratory for a particular area of investigation. However, other than a comparison of one laboratory to another, the metric itself holds little common interpretation. On the other hand,

TABLE 1 **Cost per Case and Cost per Item by Investigative Area**

Investigative Area	Cost per Case			Cost per Item		
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.
Blood Alcohol	$271	$121	$360	$218	$104	$274
Crime Scene Investigation	$4,433	$5,409	$3,441	$12,878	$5,620	$18,469
Digital evidence - Audio & Video	$4,527	$4,824	$1,011	$3,767	$3,424	$1,449
DNA Casework	$1,902	$1,746	$641	$766	$689	$218
DNA Database	$71	$54	$54	$984	$52	$2,479
Document Examination	$3,965	$3,899	$2,071	$1,501	$1,219	$1,236
Drugs - Controlled Substances	$229	$187	$105	$127	$106	$87
Evidence Screening & Processing	$520	$525	$121	$260	$97	$288
Explosives	$8,542	$5,205	$6,949	$4,408	$2,801	$3,749
Fingerprints	$416	$326	$348	$191	$133	$183
Fire analysis	$2,088	$956	$1,957	$738	$444	$825
Firearms and Ballistics	$1,331	$820	$1,402	$436	$338	$321
Forensic Pathology	$3,115	$3,291	$644	$3,115	$3,291	$644
Gun Shot Residue (GSR)	$2,168	$1,215	$1,852	$1,197	$732	$1,007
Marks and Impressions	$4,349	$3,989	$3,078	$1,421	$1,086	$813
Serology/Biology	$690	$591	$370	$193	$139	$120
Toxicology ante mortem (excluding BAC)	$694	$607	$561	$486	$446	$392
Toxicology post mortem (excluding BAC)	$715	$637	$412	$373	$333	$210
Trace Evidence	$5,679	$2,843	$7,201	$3,025	$1,629	$3,581

the inverse of these metrics: Cost/Case, Cost/Item, Cost/Sample, and Cost/Test, respectively, have convenient interpretations. Since the maximization of the former is equivalent to the minimization of the latter measures, then the reports to follow show the more interpretable average cost metrics.

For each metric, two estimates of central tendency, mean, and median, are reported. Because of outliers in several of the investigative areas, the most meaningful comparisons might best be made with respect to median as a representation of "typical" laboratory performance.

Consider the first of the metrics, Cost/Case (defined as Total Expenditures/Cases Processed). Table 1 highlights the summary statistics for each of the areas of investigation. The **cost** includes allocations for capital, wages and salary, benefits, overtime and temporary hires, chemicals, reagents, consumables, gases, travel, quality assurance and accreditation, subcontracting, service of instruments, advertisements, non-instrument repairs and maintenance, equipment leasing, utilities, telecommunications, overhead, and other expenses. A **case** in an investigative area refers to a request from a crime laboratory customer that includes forensic investigation in that investigative area. Note that a customer request may lead to a case in multiple investigative areas.

The latter columns in Table 1 also highlight the summary statistics for the ratio Cost/Item (defined as Total Expenditures/Items processed internally). An **item** is a single object for examination submitted to the laboratory. Note that one item may be investigated and counted in several investigation areas. For the reported metrics, items only include those items that were examined internally.

For either metric, note that several areas of investigation have noticeable differences between mean and median, suggesting some severe skewness in the distribution of performances. Likewise, many of standard deviations may appear to be quite high. In particular, blood alcohol, firearms and ballistics, and trace evidence all have a coefficient of variation (standard deviation/mean) that is greater than one. The multivariate analysis in the latter part of this study provides an explanation for these extreme values.

For some laboratories, alternative measures may hold more meaning. Table 2 offers the summary statistics for Cost/Sample (defined as Total Expenditures/Samples processed) and Cost/Test (defined as Total Expenditures/Tests Performed). A **sample** is defined as an item of evidence or a portion of an item of evidence that generates a reportable result. A **test** is an analytical process, including but not limited to visual examination, instrumental analysis, presumptive evaluations, enhancement techniques, extractions, quantifications, microscopic techniques, and comparative examinations.

TABLE 2 **Cost per Sample and Cost per Test by Investigative Area**

Investigative Area	Cost per Sample			Cost per Test		
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.
Blood Alcohol	$160	$85	$175	$85	$45	$87
Crime Scene Investigation	$13,737	$940	$22,979	$7,374	$1,984	$11,094
Digital evidence - Audio & Video	$2,174	$870	$2,469	$85	$79	$28
DNA Casework	$514	$481	$222	$294	$137	$546
DNA Database	$984	$52	$2,479	$269	$45	$610
Document Examination	$1,637	$1,247	$1,481	$567	$222	$835
Drugs - Controlled Substances	$110	$81	$87	$41	$36	$25
Evidence Screening & Processing	$161	$110	$99	$46	$39	$24
Explosives	$2,821	$2,914	$485	$804	$840	$404
Fingerprints	$166	$129	$132	$62	$61	$31
Fire analysis	$743	$396	$922	$306	$191	$234
Firearms and Ballistics	$355	$277	$258	$158	$151	$131
Forensic Pathology	$2,954	$2,986	$683	$1,166	$698	$946
Gun Shot Residue (GSR)	$702	$324	$1,060	$377	$175	$384
Marks and Impressions	$1,421	$1,042	$1,203	$433	$401	$306
Serology/Biology	$127	$110	$92	$39	$29	$21
Toxicology ante mortem (excluding BAC)	$327	$332	$204	$88	$82	$53
Toxicology post mortem (excluding BAC)	$311	$333	$225	$79	$60	$54
Trace Evidence	$2,926	$1,308	$4,050	$627	$378	$554

This does not include technical or administrative reviews.

As with the previous average cost metrics, the summary statistics suggest significant variation and skewness that begs explanation. This explanation will be more apparent with the decomposition of the data and the subsequent multivariate review of the data.

An interpretation of the four metrics offered in Tables 1 and 2 comes from a technique known as a DuPont expansion. This technique relates the ratio metrics to the key issues for the laboratory. This includes questions regarding productivity, market conditions, analytical process, and quality. The various unit cost metrics may be interpreted using the technique highlighted in Speaker (2009b, 2010a, 2010b).

Consider the Cost/Case metric that may be decomposed (Speaker 2009b) into:

$$\frac{Cost}{Case} = \frac{Average\ Compensation \times Testsper\ Case}{Testsper\ FTE \times Personnel\ Expense\ Ratio} \quad (1)$$

From the decomposition expression for the Cost/Case, an increase in the numerator components, Average Compensation or Testing (or Sampling) Intensity, will increase the cost per case. Similarly, a decrease in denominator component will increase the cost per case. This may occur from either a drop in productivity, as measured by cases processed per FTE, or from an increase in capital investment for future productivity but financed via a drop in personnel expenses relative to total expenses.

A similar decomposition may be made for the remaining four metrics. In particular,

$$\frac{Cost}{Item} = \frac{Average\ Compensation\ \times\ Tests\ per\ Item}{Tests\ per\ FTE\ \times\ Personnel\ Expense\ Ratio} \quad (2)$$

$$\frac{Cost}{Sample} = \frac{Average\ Compensation\ \times\ Tests\ per\ Sample\ Samples\ perF}{TE\ \times\ Personnel\ Expense\ Ratio} \quad (3)$$

$$\frac{Cost}{Test} = \frac{Average\ Compensation}{Tests\ per\ FTE\ \times\ Personnel\ Expense\ Ratio} \quad (4)$$

Local Market Conditions Metric

Table 3 provides the summary statistics for the average compensation portion of these equations. As a numerator metric, then the higher is the average compensation, then the greater with be the corresponding average cost metric. Average compensation is a market

TABLE 3 **Average Compensation by Investigative Area**

Investigative Area	Average Compensation Mean	Median	Std. Dev.
Blood Alcohol	$74,241	$76,292	$19,653
Crime Scene Investigation	$88,082	$91,150	$16,881
Digital evidence - Audio & Video	$82,709	$78,321	$10,813
DNA Casework	$95,804	$87,242	$41,919
DNA Database	$60,354	$66,988	$18,431
Document Examination	$78,142	$74,439	$19,364
Drugs - Controlled Substances	$77,120	$71,772	$16,264
Evidence Screening & Processing	$73,357	$60,732	$38,644
Explosives	$79,893	$81,758	$34,260
Fingerprints	$75,901	$72,517	$16,092
Fire analysis	$88,241	$76,038	$40,314
Firearms and Ballistics	$87,344	$82,689	$23,627
Forensic Pathology	$103,604	$102,783	$5,804
Gun Shot Residue (GSR)	$74,646	$69,843	$19,968
Marks and Impressions	$71,747	$70,943	$27,460
Serology/Biology	$74,165	$67,487	$27,022
Toxicology ante mortem (excluding BAC)	$75,675	$62,374	$25,312
Toxicology post mortem (excluding BAC)	$75,821	$66,211	$26,589
Trace Evidence	$100,599	$90,490	$62,848

measure that captures the need for the laboratory to adhere to the local conditions for personnel talent and corresponding benefits. To see the effect of market forces, a substitution of the summary statistic measures of central tendency (mean or median) offers insight into the effect of local conditions towards return on investment.

Average compensation is the total of all personnel expenditures divided by FTE, where **personnel expenditures** represent the sum of direct salaries, social expenses (employer contribution to FICA, Medicare, workers compensation, and unemployment compensation), retirement (employer contribution only towards pensions, 401K plans, etc.), personnel development and training (internal or external delivery, including travel), and occupational health service expenses (employer contribution only). A **full-time equivalent (FTE)** is the work input of a full-time employee working for one full year.

Quality/Risk Metrics

From the beginning of Project FORESIGHT, laboratory directors have emphasized the need to account for quality when it comes to laboratory comparisons. As noted above, one level of quality control is captured by limiting the reported laboratories to those laboratories that have met industry quality standards via ASCLD/LAB accreditation or have been independently verified as having met ISO 17025 standards. Given this baseline, differences in laboratories with respect to quality or risk management may be perceived via the depth of the analysis before issuing a report.

Table 4 presents two metrics on sampling intensity at the case level. A higher sampling intensity indicates that a greater amount of resources are devoted to a typical case. While this may lower the uncertainty regarding the outcome of the evidence, a higher sampling intensity increases the cost of the typical case and increases the backlog percentage. The items per case metric appears in the first set of columns and samples per case appear in the last three columns. Notice that crime scene investigation, fingerprint identification, toxicology ante mortem, and toxicology post mortem all have a high degree of variability in sampling intensity across laboratories.[3]

Table 5 extends this sampling intensity to individual testing with respect to the case level and sample level and offers some suggestions regarding internal process. In Tests/Case, document examination, fingerprint identification, firearms and ballistics, and marks and impressions all demonstrate high variability. In Tests/

TABLE 4 Items per Case and Samples per Case by Investigative Area

Investigative Area	Items per Case			Samples per Case		
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.
Blood Alcohol	1.26	1.03	0.38	1.69	1.51	0.80
Crime Scene Investigation	31.96	1.00	62.43	44.17	7.60	69.82
Digital evidence - Audio & Video	1.25	1.35	0.22	4.00	5.40	2.54
DNA Casework	2.63	2.35	1.00	4.08	3.98	1.52
DNA Database	0.89	1.00	0.41	0.89	1.00	0.41
Document Examination	4.35	3.46	3.28	5.08	2.66	4.59
Drugs - Controlled Substances	2.46	2.03	1.59	3.06	2.21	2.93
Evidence Screening & Processing	4.03	4.07	3.13	3.92	4.07	1.94
Explosives	2.03	1.75	0.85	4.00	3.89	2.56
Fingerprints	2.74	2.25	1.54	3.63	2.40	4.03
Fire analysis	2.99	2.54	1.41	4.09	2.88	2.90
Firearms and Ballistics	3.76	2.47	3.66	5.12	3.97	4.19
Forensic Pathology	1.00	1.00	0.00	1.00	1.00	
Gun Shot Residue (GSR)	1.96	2.22	0.76	5.15	4.58	2.85
Marks and Impressions	3.10	3.31	1.39	3.93	3.50	3.16
Serology/Biology	4.93	3.95	3.26	6.30	7.82	2.60
Toxicology ante mortem (excluding BAC)	1.71	1.35	1.19	3.16	1.65	3.55
Toxicology post mortem (excluding BAC)	2.76	2.09	2.48	4.81	2.08	6.16
Trace Evidence	2.06	2.13	0.47	3.41	2.13	3.33

Sample digital evidence, document examination, firearms and ballistics and gunshot residue all have high relative variability suggesting areas for individual laboratory review of process and procedure.

Productivity Metrics

A series of metrics on productivity by area of investigation is particularly useful, as they can be

TABLE 5 Tests per Case and Tests per Samples by Investigative Area

Investigative Area	Tests per Case			Tests per Sample		
	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.
Blood Alcohol	2.98	2.19	1.73	1.80	2.00	0.44
Crime Scene Investigation*						
Digital evidence - Audio & Video	57.52	43.20	26.32	32.62	8.00	43.11
DNA Casework	15.30	10.94	12.47	3.70	3.74	2.51
DNA Database	1.35	1.06	1.24	1.89	1.10	1.44
Document Examination	30.99	11.64	43.16	21.40	3.44	45.67
Drugs - Controlled Substances	7.02	5.28	4.30	2.64	2.63	1.17
Evidence Screening & Processing	13.60	10.18	8.61	3.45	3.79	0.83
Explosives	14.07	15.31	5.90	4.31	4.02	2.14
Fingerprints	9.39	6.24	12.76	3.14	2.19	2.80
Fire analysis	7.87	6.00	3.87	2.33	2.00	1.09
Firearms and Ballistics	27.20	7.43	50.87	4.53	2.87	6.53
Forensic Pathology	3.89	5.19	2.51	3.89	5.19	2.51
Gun Shot Residue (GSR)	9.08	6.49	8.86	2.34	1.00	2.72
Marks and Impressions	16.02	10.75	16.61	3.85	3.07	2.59
Serology/Biology	20.82	21.90	10.44	3.39	2.98	1.20
Toxicology ante mortem (excluding BAC)	7.70	8.07	3.76	3.54	2.90	3.15
Toxicology post mortem (excluding BAC)	11.49	11.98	5.80	2.68	2.62	1.48
Trace Evidence	11.60	10.60	6.23	4.44	3.70	2.49

*Sample size too small to determine reliable summary statistics.

TABLE 6 **Cases per FTE and Items per FTE by Investigative Area**

Investigative Area	Cases per FTE Mean	Cases per FTE Median	Cases per FTE Std. Dev.	Items per FTE Mean	Items per FTE Median	Items per FTE Std. Dev.
Blood Alcohol	857.02	830.66	580.10	1,007.75	965.78	626.81
Crime Scene Investigation	54.41	21.60	64.92	2,735.18	19.20	5,442.52
Digital evidence - Audio & Video	22.94	18.02	8.56	29.22	25.33	13.57
DNA Casework	81.96	82.46	27.77	209.84	171.17	103.00
DNA Database	2,604.33	2,523.06	493.48	2,470.79	2,395.05	1,303.69
Document Examination	32.98	26.47	25.11	197.29	79.32	371.05
Drugs - Controlled Substances	544.78	467.65	239.23	1,597.00	870.14	1,902.83
Evidence Screening & Processing	193.92	161.51	85.29	613.56	657.60	336.02
Explosives	31.90	28.15	24.19	57.35	49.63	39.95
Fingerprints	367.41	309.77	249.99	899.84	655.30	603.87
Fire analysis	102.71	98.87	68.04	273.17	265.98	161.62
Firearms and Ballistics	135.78	119.49	93.10	383.47	295.60	276.80
Forensic Pathology	46.48	43.72	6.89	46.48	43.72	6.89
Gun Shot Residue (GSR)	85.28	73.51	61.81	139.62	149.59	79.95
Marks and Impressions	33.41	24.08	26.87	83.85	81.87	43.71
Serology/Biology	167.20	164.57	77.35	644.42	559.29	329.81
Toxicology ante mortem (excluding BAC)	244.56	192.95	147.34	487.36	251.60	661.90
Toxicology post mortem (excluding BAC)	216.52	195.43	134.90	799.26	300.00	1,458.72
Trace Evidence	45.51	40.41	27.26	83.87	75.10	46.14

considered laboratory-wide as well as used at the individual level. Tables 6, 7, and 8 offer a glimpse at several productivity metrics. For individual laboratories, one or more of these metrics may have greater meaning depending upon historical measures of importance to the laboratory. Table 6 provides productivity summary statistics at the case and item level relative to FTE. A **full-time equivalent (FTE)**

TABLE 7 **Samples per FTE and Tests per FTE by Investigative Area**

Investigative Area	Samples per FTE Mean	Samples per FTE Median	Samples per FTE Std. Dev.	Tests per FTE Mean	Tests per FTE Median	Tests per FTE Std. Dev.
Blood Alcohol	1,277.49	1,080.82	914.04	2,113.45	1,863.16	1,268.91
Crime Scene Investigation*	3,687.63	239.88	6,177.64			
Digital evidence - Audio & Video	98.72	99.68	79.02	1,249.12	1,418.07	444.26
DNA Casework	326.92	320.13	143.21	1,229.09	904.48	1,119.52
DNA Database	2,470.79	2,395.05	1,303.69	3,536.52	2,634.55	2,739.60
Document Examination	267.00	79.32	464.11	987.95	580.28	1,181.92
Drugs - Controlled Substances	1,822.25	1,276.01	2,394.99	3,839.15	2,748.76	3,217.22
Evidence Screening & Processing	653.64	657.60	97.32	2,258.47	2,100.00	707.15
Explosives	48.03	47.48	8.21	212.25	166.49	132.23
Fingerprints	1,080.38	655.67	981.70	2,291.67	1,935.17	2,353.78
Fire analysis	341.35	410.28	207.31	588.73	576.38	342.44
Firearms and Ballistics	421.08	334.68	227.66	1,903.75	827.58	2,813.81
Forensic Pathology	47.02	42.57	8.33	168.99	217.09	97.64
Gun Shot Residue (GSR)	382.72	385.12	254.94	1,044.03	504.35	1,873.22
Marks and Impressions	103.30	86.51	77.65	382.26	224.15	390.17
Serology/Biology	891.60	868.80	315.99	2,870.25	2,854.83	1,067.63
Toxicology ante mortem (excluding BAC)	882.99	386.17	1,670.15	2,049.38	1,377.95	1,771.77
Toxicology post mortem (excluding BAC)	1,600.40	379.54	3,489.75	3,209.77	2,223.02	3,846.30
Trace Evidence	117.92	87.03	87.97	384.75	410.63	203.41

*Sample size too small to determine reliable summary statistics.

TABLE 8 Reports per FTE by Investigative Area

Investigative Area	Reports per FTE		
	Mean	Median	Std. Dev.
Blood Alcohol	879.56	826.30	580.40
Crime Scene Investigation	62.00	21.60	82.61
Digital evidence - Audio & Video	24.77	23.70	4.33
DNA Casework	99.07	81.15	66.97
DNA Database	5,409.93	2,496.98	7,601.16
Document Examination	36.42	24.89	28.33
Drugs - Controlled Substances	609.61	510.19	228.23
Evidence Screening & Processing	157.02	157.02	27.87
Explosives	30.05	31.72	18.91
Fingerprints	395.40	342.52	264.78
Fire analysis	110.53	91.19	81.71
Firearms and Ballistics	148.83	129.81	114.78
Forensic Pathology	47.25	43.96	7.57
Gun Shot Residue (GSR)	102.99	108.24	70.79
Marks and Impressions	33.66	23.79	35.93
Serology/Biology	184.46	162.94	111.49
Toxicology ante mortem (excluding BAC)	267.04	208.10	176.55
Toxicology post mortem (excluding BAC)	209.18	137.13	145.71
Trace Evidence	45.68	35.92	32.45

is the work input of a full-time employee working for one full year.

Both Cases/FTE and Items/FTE reveal some interesting trends. There appears to be a low relative variability for cases per FTE across investigative areas. For several areas of investigation, including digital evidence, DNA casework, DNA database, evidence screening and processing, forensic pathology, serology/biology and trace evidence, the coefficient of variation is relatively low. Only crime scene investigation has a standard deviation of cases per FTE that is higher than the corresponding mean. Items per FTE, on the other hand, shows much higher relative dispersion. Crime scene investigation, document examination, drugs-controlled substances, toxicology ante mortem, and toxicology post mortem all have a standard deviation that exceeds the mean. Thus, while there is some consistency with the amount of casework handled by individuals across laboratories, there is a noticeable difference in the detail of that analysis.

When those productivity metrics are driven down to the sample and test level, that level of variability continues to be present. Table 7 presents the summary statistics for Samples/FTE and Tests/FTE and offer results consistent with items in Table 6.

However, when the productivity metrics turn to reporting, the results are similar to the case level productivity. For this metric a **report** is defined as a formal statement of the results of an investigation, or of any matter on which definite information is required, made by some person or body instructed or required to do so. The summary statistics in Table 8 for Reports/FTE are similar to the Table 6 outcomes for Cases/FTE.

Analytical Process Metrics

The last ratio in the decompositions are related to the choice of analytical process. In any production process, inputs can be categorized into several different categories, including capital, consumables, personnel, and overhead. We are most interested in the choice in analytical process as they become more capital-intensive versus process choices that are more labor-intensive. We would expect to see greater investment in capital as an indication of longer term investment in which only a portion of the returns would be realized in the present period. Therefore, a higher percentage of capital expenditures, while having a long-term benefit, would also show a short-term cost with higher Cost/Case, Cost/Item, Cost/Sample, and Cost/Test in the present period. However, that would not be viewed negatively when the benefits from the investment suggest greater long-term benefits.

TABLE 9 **Personnel Expenditures/Total Expenditures & Capital Expenditures/Total Expenditures by Investigative Area**

	Personnel Expenditures/ Total Expenditures			Capital Expenditures/ Total Expenditures		
Investigative Area	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.
Blood Alcohol	75.31%	79.17%	15.74%	5.89%	4.83%	5.15%
Crime Scene Investigation	76.62%	78.72%	15.11%	3.00%	2.52%	3.19%
Digital evidence - Audio & Video	84.16%	85.11%	2.68%	8.88%	8.24%	2.52%
DNA Casework	64.74%	65.75%	12.01%	11.10%	11.09%	4.12%
DNA Database	45.80%	54.89%	25.36%	6.93%	6.05%	5.77%
Document Examination	79.82%	82.22%	8.28%	2.62%	1.58%	2.26%
Drugs - Controlled Substances	72.66%	73.07%	8.44%	10.96%	10.49%	6.79%
Evidence Screening & Processing	83.87%	84.19%	13.44%	3.88%	4.36%	3.03%
Explosives	60.97%	63.49%	19.82%	18.46%	9.18%	18.53%
Fingerprints	79.47%	77.64%	8.96%	6.72%	5.53%	7.73%
Fire analysis	74.61%	77.49%	13.81%	5.39%	3.99%	3.77%
Firearms and Ballistics	77.43%	78.62%	9.51%	9.00%	5.48%	8.56%
Forensic Pathology	73.66%	74.44%	8.33%	5.12%	6.26%	3.30%
Gun Shot Residue (GSR)	69.98%	73.22%	12.54%	13.41%	8.14%	11.57%
Marks and Impressions	78.74%	84.91%	14.71%	4.77%	4.34%	4.29%
Serology/Biology	76.28%	76.80%	8.18%	5.63%	6.34%	3.81%
Toxicology ante mortem (excluding BAC)	63.18%	64.16%	11.40%	12.97%	9.95%	8.61%
Toxicology post mortem (excluding BAC)	62.93%	63.99%	13.21%	11.39%	10.73%	7.38%
Trace Evidence	67.75%	72.34%	16.06%	17.55%	11.41%	16.03%

Personnel expenditures represent the sum of direct salaries, social expenses (employer contribution to FICA, Medicare, Workers Compensation, and Unemployment Compensation), retirement (employer contribution only towards pensions, 401K plans, etc.), personnel development and training (internal or external delivery, including travel), and occupational health service expenses (employer contribution only). **Capital expenditure**s include purchases of equipment, instruments, etc. with a lifetime longer than a year. These expenditures include newly purchased items as well as investments to improve the useful life of existing capital equipment. Expenses to maintain an asset at its current condition are not capitalized.

Table 9 highlights the summary statistics for the percentage of total expenditures in the form of personnel expenditures for the first three data columns and the percentage of capital expenditures for the latter three data columns. For Personnel Expenditures/Total Expenditures, a laboratory with a higher percentage will see this as an average cost reducing activity. Essentially, such a laboratory has borrowed from the future by not investing in capital, instead opting to process more cases today and thus lowering average cost.[4] The warning is that the demands for future investment will grow and the lowering of average cost is a temporary phenomenon.

The percentage of personnel expenditures are relatively stable across laboratories. Capital expenditure, on the other hand, show a great deal more variability. Some of this variability is tied to grant funding success.

Table 10 highlights the percentage of expenditures for consumables. This category includes all expenditures for chemicals, reagents, gases, and any other laboratory consumables.

Capacity Utilization Metrics

The aforementioned metrics are all related to a direct interpretation of mission. Maximizing quality output for a given budget, and the corresponding decomposition, offer some insight into the ability of the laboratory to offer a return on investment for its constituency. In addition to maximizing output or correspondingly minimizing average cost, the justice system also expresses a keen interest in backlog and turnaround time, both issues related to capacity utilization.

Table 11 offers two measurements of turnaround time. The first measure counts turnaround time from

TABLE 10 **Consumables Expenditures/Total Expenditures by Investigative Area**

Investigative Area	Consumables Expenditures/Total Expenditures Mean	Median	Std. Dev.
Blood Alcohol	8.85%	6.62%	7.87%
Crime Scene Investigation*			
Digital evidence - Audio & Video*			
DNA Casework	13.72%	11.48%	9.19%
DNA Database	13.42%	11.06%	11.26%
Document Examination	2.32%	1.42%	2.81%
Drugs - Controlled Substances	6.70%	6.21%	3.79%
Evidence Screening & Processing	3.89%	4.44%	2.09%
Explosives	5.12%	4.37%	3.41%
Fingerprints	3.54%	1.32%	4.37%
Fire analysis	4.68%	5.02%	2.19%
Firearms and Ballistics	2.61%	1.53%	2.49%
Forensic Pathology	3.31%	3.16%	0.69%
Gun Shot Residue (GSR)	4.04%	3.38%	3.27%
Marks and Impressions	4.76%	1.74%	4.90%
Serology/Biology	6.67%	7.50%	2.01%
Toxicology ante mortem (excluding BAC)	10.26%	10.46%	3.86%
Toxicology post mortem (excluding BAC)	8.81%	7.42%	2.35%
Trace Evidence	3.50%	2.64%	2.93%

*Sample size too small to determine reliable summary statistics.

TABLE 11 **Turnaround Time (TAT) by Investigative Area**

Investigative Area	TAT (measured from last submission)* Mean	Median	Std. Dev.	TAT (measured from first submission)** Mean	Median	Std. Dev.
Blood Alcohol	29	12	41	21	18	13
Crime Scene Investigation	39	29	36	35	27	32
Digital evidence - Audio & Video	48	48	6	76	64	40
DNA Casework	77	66	59	77	68	48
DNA Database	113	82	92	147	82	139
Document Examination	43	34	14	68	59	26
Drugs - Controlled Substances	45	38	24	49	44	32
Evidence Screening & Processing***	27	27	13			
Explosives	101	31	144	137	139	131
Fingerprints	34	35	17	44	45	18
Fire analysis	42	46	19	41	43	21
Firearms and Ballistics	52	39	57	79	62	67
Forensic Pathology***	57	57	41	28	28	
Gun Shot Residue (GSR)	44	34	39	36	34	28
Marks and Impressions	41	39	28	68	60	47
Serology/Biology	43	31	38	56	48	33
Toxicology ante mortem (excluding BAC)	33	24	27	44	36	25
Toxicology post mortem (excluding BAC)	28	24	14	42	33	22
Trace Evidence	75	68	37	86	93	35

*Turnaround time (days) with time measured from the first submission of evidence to a case.
**Turnaround time (days) with time measured from the last submission of evidence to a case.
***Sample size too small to determine reliable summary statistics.

the time of the last submission in a case until the issuance of a report. This metric follows a metric that appeared in a study of four European laboratories (European Network of Forensic Science Institutes 2003).

Since many laboratories employ a different measure of turnaround time, a second set of summary statistics appear in Table 11. For this metric, the turnaround time clock begins when the first evidence in an area of investigation is submitted to the laboratory and the time is counted until the issuance of a report. Only a few laboratories have been able to provide both metrics with approximately forty percent of the sample offering information on the first three data columns and over sixty percent offering input for the final three columns.

Examination of Table 11 reveals some seeming inconsistencies. By definition, TAT—measured from last submission is less than or equal to TAT—measured from first submission. Yet, for Blood Alcohol, Crime Scene Investigation, Fire Analysis, Gunshot Residue, and Forensic Pathology, the mean and/or median TAT relationship violates this ordinal relationship. However, these anomalies are easily explained. Since few laboratories report both TAT measures, and some laboratories are unable to report either TAT measure, the reduced sample size for each metric may suffer from being drawn from a small number of observations. This is certainly true for Crime Scene Investigation, Fire Analysis, Gunshot Residue, and Forensic Pathology. For Blood Alcohol, the relationship between the median TAT's appears as expected, but the median TAT's do not. The extraordinarily large standard deviation associated with TAT—measured from last submission is suggestive of some very large TAT submissions which have skewed the distribution and led to a higher mean.

The final table provides some detail on the percentage of cases older than thirty days. While thirty days is acknowledged to be a rather arbitrary measure of backlog, it does offer some measurement consistency across laboratories.

Table 12 offers the summary statistics for the number of cases over 30 days old as a percentage of the volume of casework for an entire year by each area of investigation. The backlog situation is heavily skewed in several areas of investigation, including DNA casework, document examination, firearms and ballistics, forensic pathology, marks and impressions, and trace evidence. In several areas of investigation the median is very low, suggesting a fairly efficient throughput in the typical laboratory.

Kobus et al (2011) and Newman et al. (2011) offer some lessons regarding the use of the above metrics into the strategic planning and corresponding change in the laboratory. Comparison of an individual

TABLE 12 **Backlogged Cases (30 days +) as a percentage of Total Caseload by Investigative Area**

	Backlog Cases/Total Cases		
Investigative Area	Mean	Median	Std. Dev.
Blood Alcohol	2.62%	0.50%	5.34%
Crime Scene Investigation	9.53%	0.27%	16.24%
Digital evidence - Audio & Video	9.55%	9.55%	0.64%
DNA Casework	18.99%	9.34%	22.41%
DNA Database	26.92%	25.76%	20.51%
Document Examination	40.19%	18.48%	57.79%
Drugs - Controlled Substances	6.84%	5.75%	5.45%
Evidence Screening & Processing	33.44%	33.44%	11.23%
Explosives	31.07%	20.00%	21.24%
Fingerprints	13.52%	5.74%	19.39%
Fire analysis	6.18%	7.50%	6.82%
Firearms and Ballistics	32.43%	16.46%	34.45%
Forensic Pathology	54.06%	39.38%	52.85%
Gun Shot Residue (GSR)	10.45%	4.32%	15.67%
Marks and Impressions	51.98%	43.75%	74.05%
Serology/Biology	6.71%	8.20%	4.21%
Toxicology ante mortem (excluding BAC)	6.74%	5.83%	4.96%
Toxicology post mortem (excluding BAC)	11.17%	9.74%	6.75%
Trace Evidence	53.19%	25.87%	91.74%

laboratory's metrics to the norms of the industry offer a notion of where to look for situations in which the laboratory excels and those areas in which it may be deficient. The resulting strategic changes should lead to a series of allocations across areas in the laboratory budget (Speaker and Fleming 2010).

FORESIGHT: MULTIVARIATE ANALYSIS

While the metrics highlighted in Tables 1–12 offer some insight into the comparative performance of individual laboratories, they are limited to a univariate viewpoint. Such a view is not as problematic in the for-profit world where the invisible hand of market forces guides organizations to the "right size" via competitive forces. Without such market forces for public institutions, a jurisdictional-based laboratory size retains some inefficiencies with respect to cost effectiveness (Maguire et al. 2012b). In particular, the Cost/Case ratio, and similar metrics, must be reconsidered with respect to the volume of activity in the jurisdiction.

This multivariate analysis was developed in response to inquiries into the best model for the delivery of forensic science. Bedford (2011) offers an argument into the value of the market forces in competitive markets and the efficiencies that arise from a profit motive. Maguire et al (2012b) following a study of Canada's provision of forensic science services (Maguire et al. 2012a), suggest that there is a natural sense of best that is less model-driven, and more size-driven by economies of scale. Following these developments, it may be the case that the success attributed to market forces in Bedford (2011) is shared with other economies (Speaker 2013).

This analysis follows from the law of diminishing marginal returns (LDMR) in economics that leads to the conclusion that there is an ideal size in every industry. The notion of "ideal size" is a reflection of perfect economies of scale or the level of output at which average costs are minimized. The corresponding depiction of average total cost is a U-shaped curve as average total cost is related to volume of production. For each of the areas of investigation, a second-degree polynomial regression was estimated where:

$$\frac{Cost}{Case} = \alpha + \beta_1 Cases + \beta_2 Cases^2 \qquad (5)$$

The results of those regressions using (5) are presented below in equations (6)–(20) for each area of investigation[5] and the figures that follow provide a depiction of the data and the estimated curve. For better comparison that the univariate summary statistics in Table 1, a laboratory may put its case level into the estimated equation and obtain the mean response for that level of casework as a comparison to their actual performance.

Blood Alcohol

The estimate of equation (5) for blood alcohol analysis is:

$$\begin{aligned} Average\ \mathrm{Cost}(Blood\ \mathrm{Alcohol}) &= 247.424 \\ &- 0.02573\,Cases + 0.0000011467\,Cases^2 \end{aligned} \qquad (6)$$

Figure 1 illustrates the data from the FORESIGHT submissions with the estimate in (6) drawn as a solid curve. At the minimum point on the curve is an estimate of perfect economies of scale and for blood alcohol analysis this occurs at approximately 11,218 cases. This area of investigation includes analysis of blood or breath samples to detect the presence of and quantify the amount of alcohol. The quadratic equation estimated in (6) offers a fairly simple relationship between casework and average cost. More sophisticated econometric techniques might offer more detail at the low casework levels to explain more of the variation, but above a 5,000 caseload, the estimated equation offers valuable comparative information for laboratories.

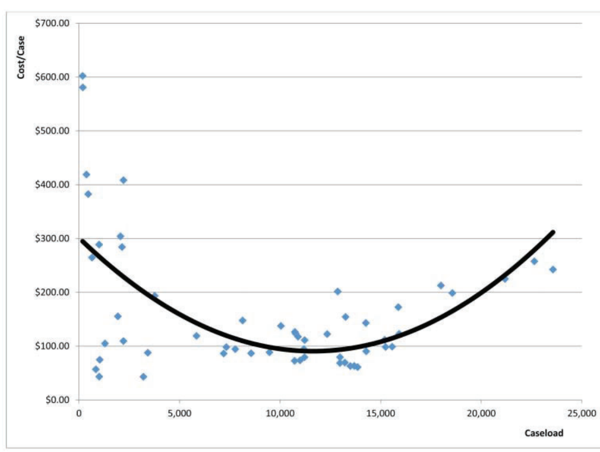

FIGURE 1 **Blood alcohol analysis economies of scale.**

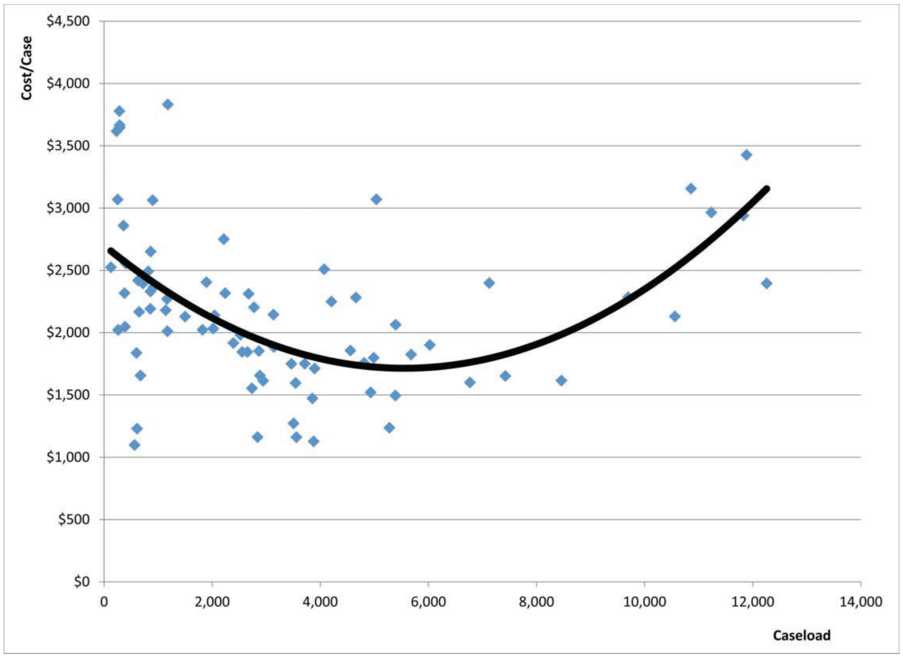

FIGURE 2 **DNA casework analysis economies of scale.**

DNA Casework

The estimate of equation (5) for DNA casework analysis is:

$$Average\ \mathrm{Cost}(DN\ Acasework) = 2,700.513 - 0.35531 Cases + 0.000032 Cases^2 \quad (7)$$

Figure 2 illustrates the data from the FORESIGHT submissions with the estimate in (7) drawn as a solid curve. At the minimum point on the curve is an estimate of perfect economies of scale and for DNA casework analysis this occurs at approximately 5,550 cases. The simple model estimated for DNA casework in (7) provides a fairly good fit to the data. More sophisticated econometric analysis may be found elsewhere (Maguire et al. 2012a), but the essence of the relationship is captured in the quadratic estimate in (7).

DNA Database

The estimate of equation (5) for DNA database analysis is:

$$Average\ \mathrm{Cost}(DN\ Adatabase) = 140.486 - 0.00544 Cases + 0.000000064326 Cases^2 \quad (8)$$

Figure 3 illustrates the data from the FORESIGHT submissions with the estimate in (8) drawn as a solid curve. At the minimum point on the curve is an estimate of perfect economies of scale and for DNA database this occurs at approximately 42,301 cases. As seen in Figure 3, the sample of laboratories analyzing and entering DNA results into the database is a smaller subset of the submitting laboratories and very few laboratories are operating at a level large enough to take advantage of economies of scale. As more laboratories provide data in the future, a better comparative picture should emerge on the relationship between average cost and caseload.

Document Examination

The estimate of equation (5) for document examination is:

$$Average\ \mathrm{Cost}(documen\ texamination) = 5,399.327 - 21.4757 Cases \quad (9)$$

Figure 4 illustrates the data from the FORESIGHT submissions with the estimate in (9) drawn as a solid curve. At the minimum point on the curve is an estimate of perfect economies of scale and for document examination this occurs at approximately 283 cases. Document examination includes the analysis of legal, counterfeit, and questioned documents, including handwriting analysis.

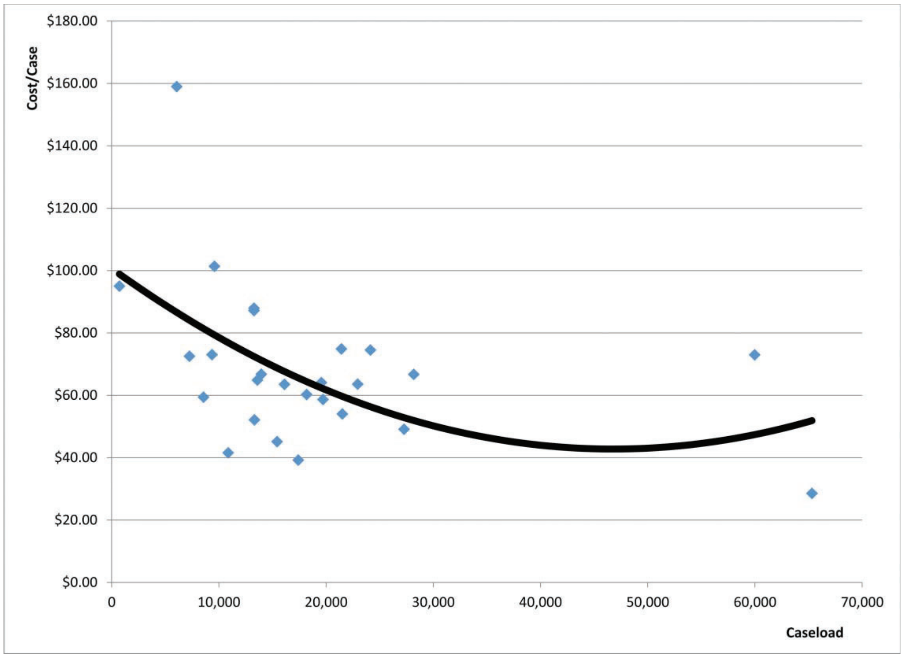

FIGURE 3 DNA database analysis economies of scale.

Drugs—Controlled Substances

The estimate of equation (5) for drugs—controlled substances is:

$$\begin{aligned} \textit{Average Cost}(\textit{Drugs}) = 380.95 - 0.01725\textit{Cases} \\ + 0.000000366\textit{Cases}^2 \end{aligned} \quad (10)$$

Figure 5 illustrates the data from the FORESIGHT submissions with the estimate in (10) drawn as a solid curve. At the minimum point on the curve is an estimate of perfect economies of scale and for drugs/controlled substance analysis this occurs in approximately 23,547 cases. Drugs/controlled substances include analysis of solid dosage licit and illicit drugs, including precursor materials.

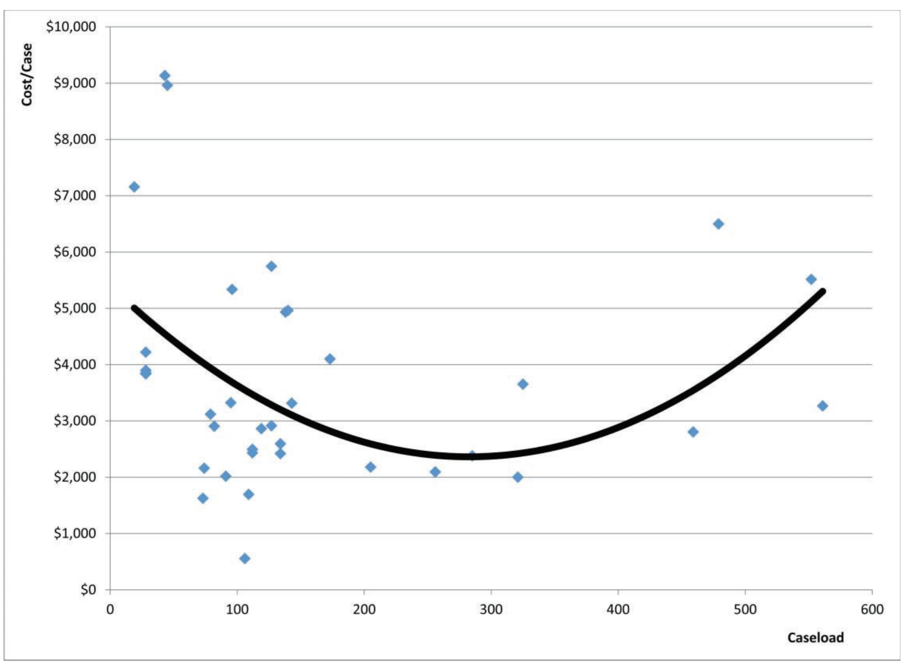

FIGURE 4 Document examination (including handwriting) analysis economies of scale.

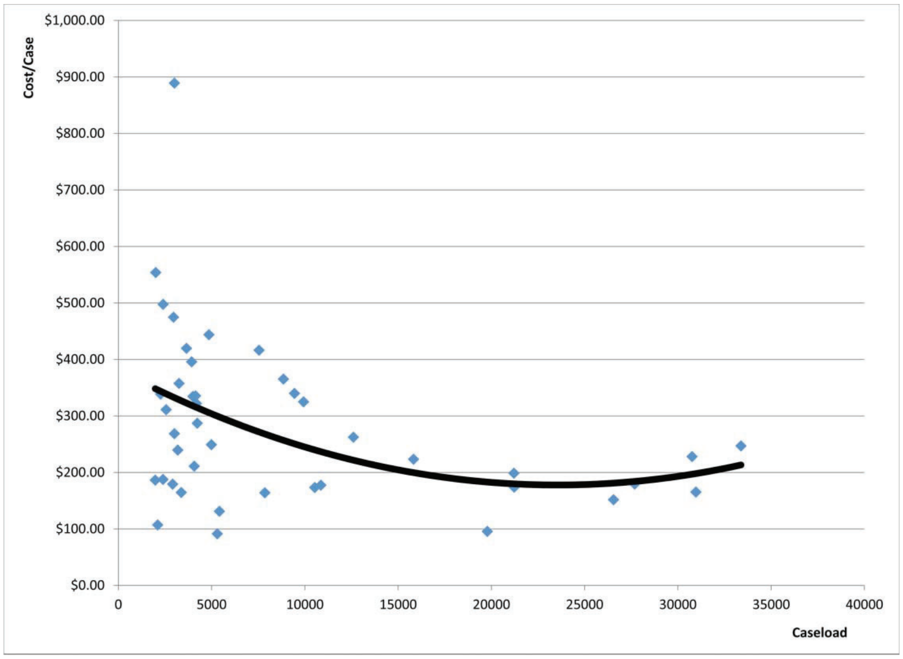

FIGURE 5 **Drugs-controlled substance analysis economies of scale.**

Explosives

The estimate of equation (5) for explosives is:

$$Average\ \mathrm{Cost} = 11,714.063 - 161.2313 Cases + 0.99573 Cases^2 \quad (11)$$

Figure 6 illustrates the data from the FORESIGHT submissions with the estimate in (11) drawn as a solid curve. At the minimum point on the curve is an estimate of perfect economies of scale and for explosives analysis; this occurs at approximately 81 cases. The explosives area of investigation includes analysis of energetic materials in pre- and post-blast incidents.

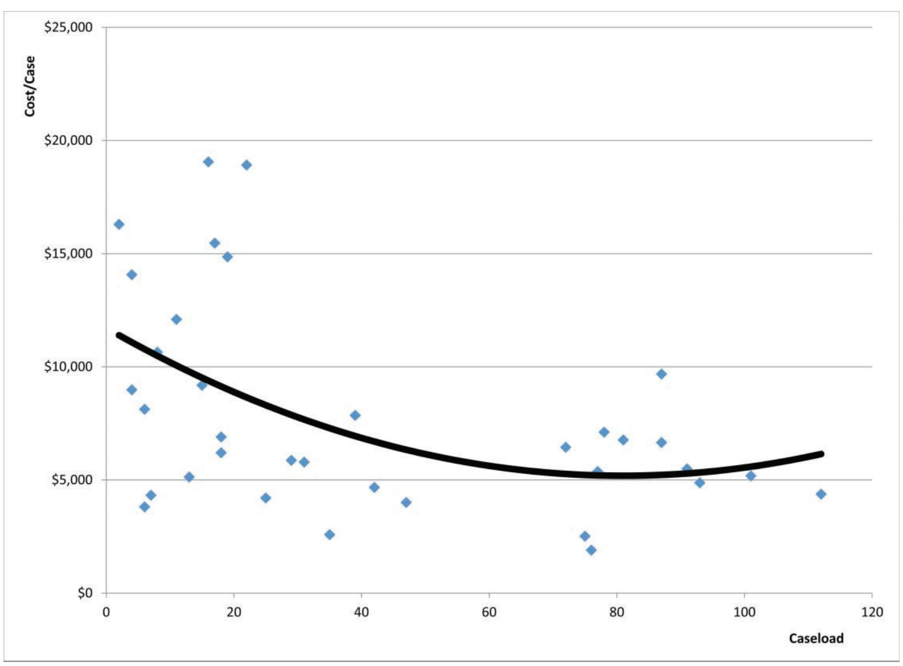

FIGURE 6 **Explosives analysis economies of scale.**

Fingerprint Identification

The estimate of equation (5) for fingerprint identification is:

$$Average\ \text{Cost} = 690.727 - 0.1548 Cases + 0.000011 Cases^2 \quad (12)$$

Fingerprint identification involves the development and analysis of friction ridge patterns. Figure 7 illustrates the data from the FORESIGHT submissions with the estimate in (12) drawn as a solid curve. At the minimum point on the curve is an estimate of perfect economies of scale and for fingerprint identification; this occurs at approximately 7,006 cases.

Fire Analysis

The estimate of equation (5) for fire analysis is:

$$Average\ \text{Cost} = 4,184.652 - 19.9925 Cases + 0.028006 Cases^2 \quad (13)$$

This area of investigation involves the analysis of materials from suspicious fires to include ignitable liquid residue analysis. Figure 8 illustrates the data from the FORESIGHT submissions with the estimate in (13) drawn as a solid curve. At the minimum point on the curve is an estimate of perfect economies of scale at 357 cases.

Firearms and Ballistics

The estimate of equation (5) for firearms and ballistics analysis is:

$$Average\ \text{Cost} = 2,067.331 - 0.958 Cases + 0.00013 Cases^2 \quad (14)$$

Firearms and ballistics involves the analysis of firearms and ammunition, to include distance determinations, shooting reconstructions, integrated ballistics identification system (IBIS), and tool marks. Figure 9 illustrates the data from the FORESIGHT submissions with the estimate in (14) drawn as a solid curve. At the minimum point on the curve is an estimate of perfect economies of scale at 3,680 cases per year.

Gun Shot Residue

The estimate of equation (5) for the analysis of gunshot residue is:

$$Average\ \text{Cost} = 3,804.241 - 17.420 Cases + 0.02165 Cases^2 \quad (15)$$

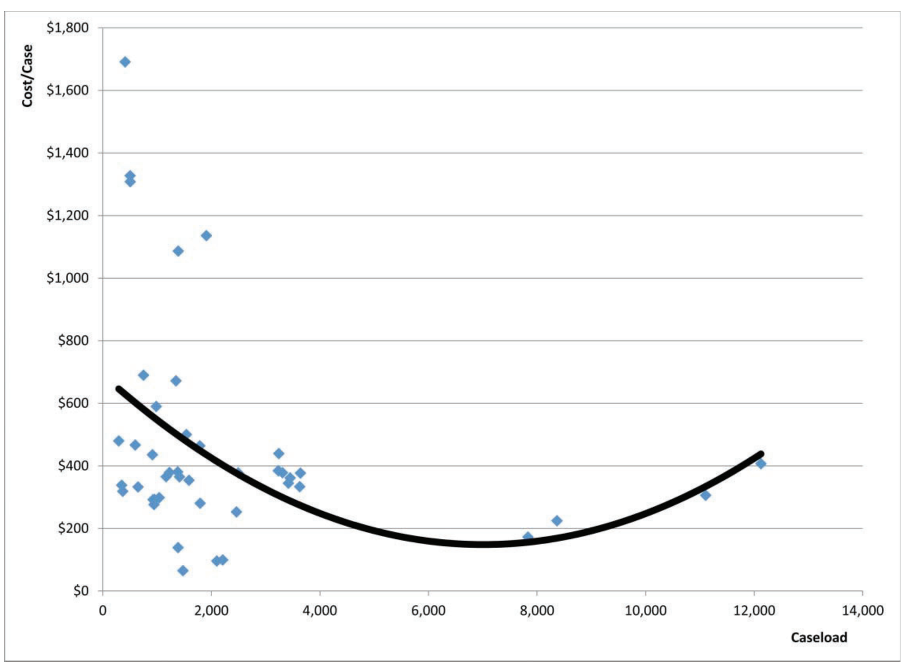

FIGURE 7 **Fingerprint identification analysis economies of scale.**

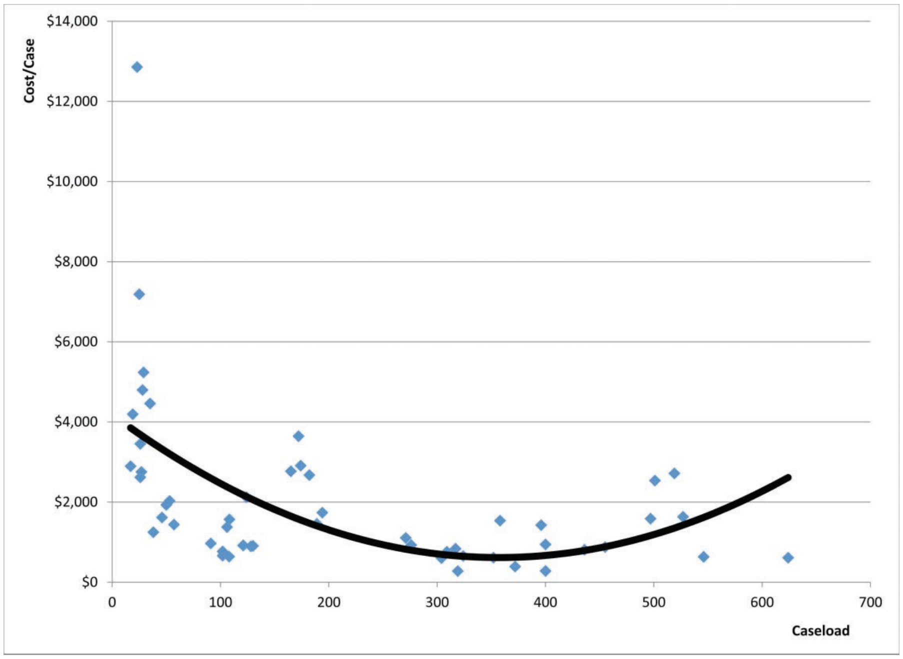

FIGURE 8 Fire analysis economies of scale.

Gun shot residue (GSR) is the analysis of primer residues from discharged firearms (not distance determinations). Figure 10 illustrates the data from the FORESIGHT submission with the estimate illustrated in equation (15) drawn as a solid curve. The estimation suggests that perfect economies of scale are realized at an estimate of 402 cases annually.

Marks and Impressions

The estimate of equation (5) for the analysis of marks and impressions was not evaluated as specified, given the relationship observed between the average cost per case and the caseload. Visual inspection of the data in Figure 11 suggests that the expected U-shaped

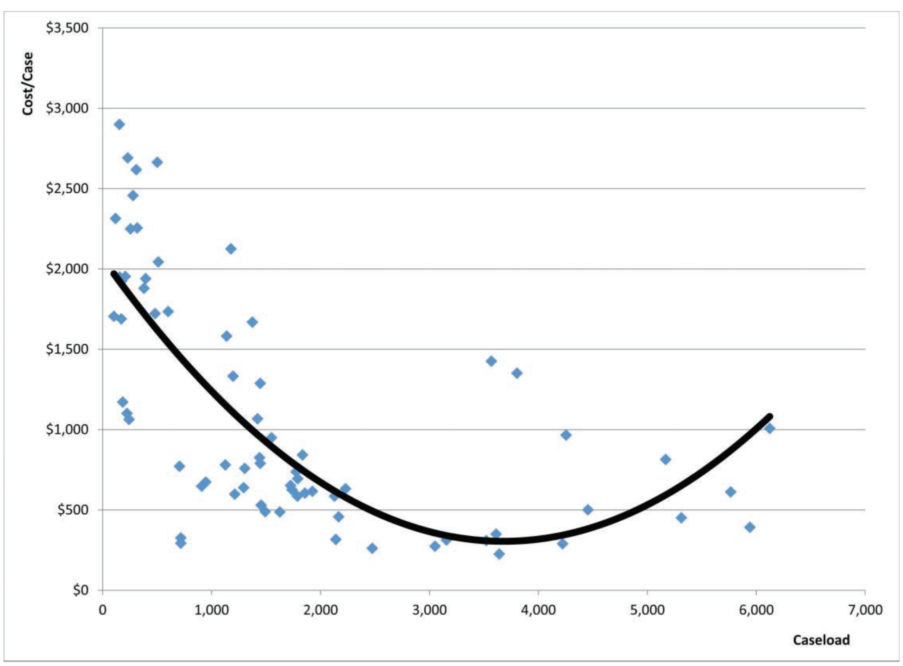

FIGURE 9 Firearms & ballistics analysis economies of scale.

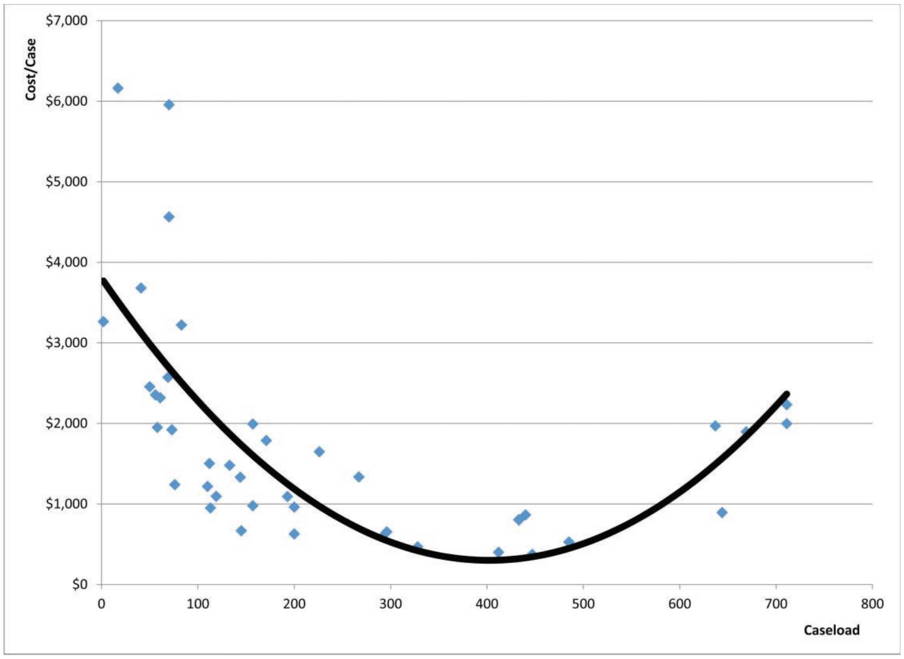

FIGURE 10 Gun shot residue analysis economies of scale.

curve is not fully revealed. Rather the relationship appears to only reveal part of the downward-sloped portion of that expected U-shaped curve. To account for this, a power function is estimated:

$$Average\ \mathrm{Cost} = 10.063\,Cases^{-0.57679} \tag{16}$$

Marks and impressions is the analysis of physical patterns received and retained through the interaction of objects of various hardness, including shoeprints and tire tracks. As illustrated in Figure 11, perfect economies of scale are undefined since the caseload does not appear to have reached the minimum for the laboratories examined.

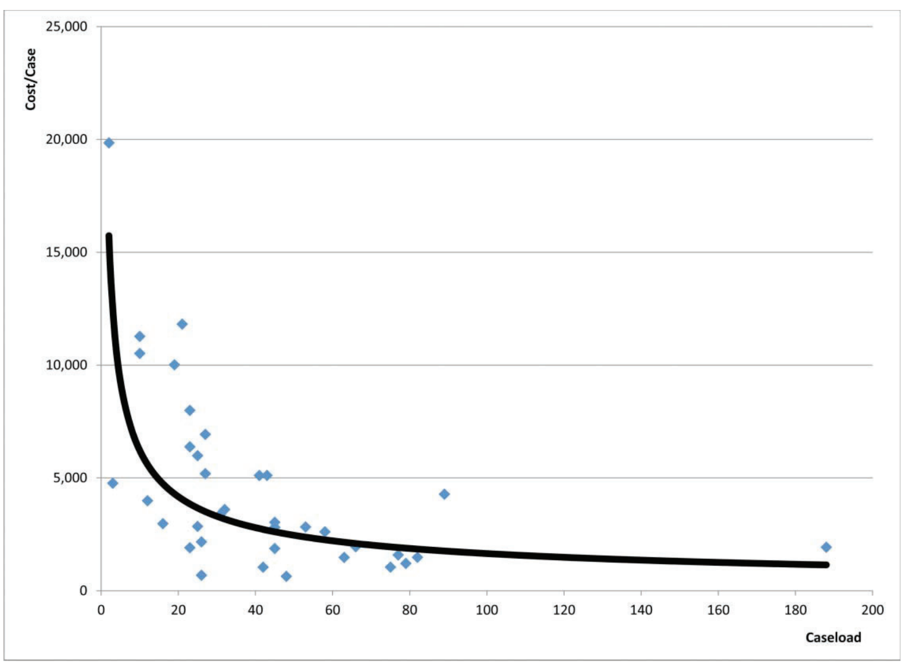

FIGURE 11 Marks and& impressions analysis economies of scale.

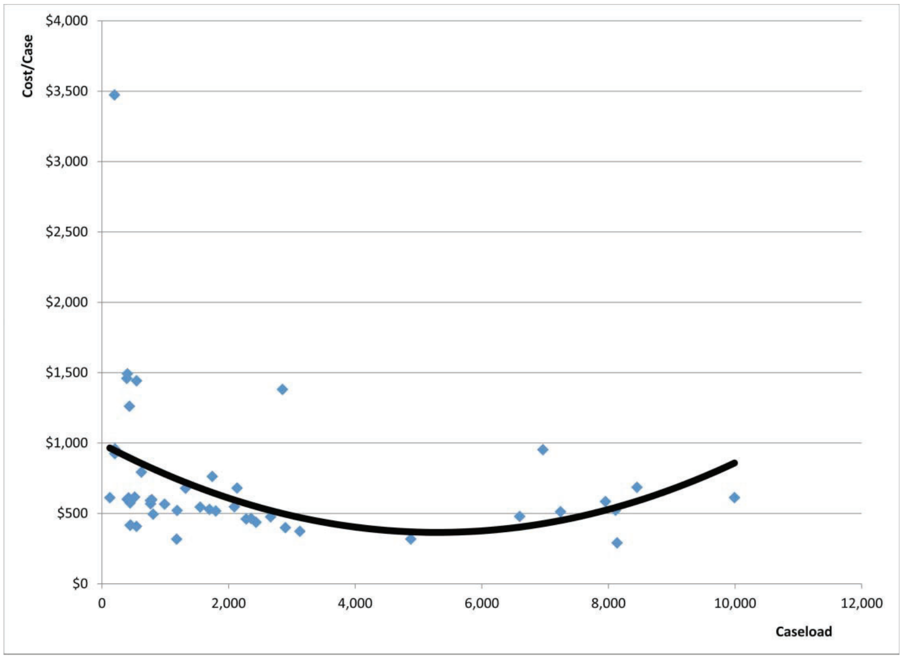

FIGURE 12 Serology and& biology analysis economies of scale.

Serology/Biology

The estimate of equation (5) for serology and biology analysis is:

$$Average\ Cost = 993.986 - 0.23738 Cases + 0.0000224 Cases^2 \quad (17)$$

Biology/serology includes the detection, collection, and non-DNA analysis of biological fluids. Figure 12 illustrates the data from the FORESIGHT submissions with the estimate in (17) drawn as a solid curve. At the minimum point on the curve is an estimate of perfect economies of scale at 5,300 cases per year.

Toxicology Ante Mortem

The estimate of equation (5) for the analysis of toxicology ante mortem is:

$$Average\ Cost = 1,288.9914 - 0.37679 Cases + 0.00003487 Cases^2 \quad (18)$$

Toxicology ante mortem involves the chemical analysis of body fluids and tissues to determine if a drug or poison is present in a living individual, to include blood alcohol analysis (BAC). Toxicologists are then able to determine if a drug (including alcohol) or poison is present in a living individual and at what concentration. Figure 13 illustrates the data from the FORESIGHT submissions with the estimate in (18) drawn as a solid curve. At the minimum point on the curve is an estimate of perfect economies of scale estimate at 5,402 cases per year.

Toxicology Post Mortem

The estimate of equation (5) for the analysis of toxicology post mortem is:

$$Average\ Cost = 1,451.3074 - 0.47299 Cases + 0.00004815 Cases^2 \quad (19)$$

Toxicology post mortem involves the chemical analysis of body fluids and tissues to determine if a drug or poison is present in a deceased individual. Toxicologists are then able to determine if a drug (including alcohol) or poison is present in a deceased individual and at what concentration. Figure 14 illustrates the data from the FORESIGHT submissions with the estimate in (19) drawn as a solid curve. At the minimum point on the curve is an estimate of perfect economies of scale estimate at 4,912 cases per year.

Trace Evidence

The estimate of equation (5) for the analysis of trace evidence is:

$$Average\ Cost = 7,949.999 - 18.9443 Cases + 0.012983 Cases^2 \quad (20)$$

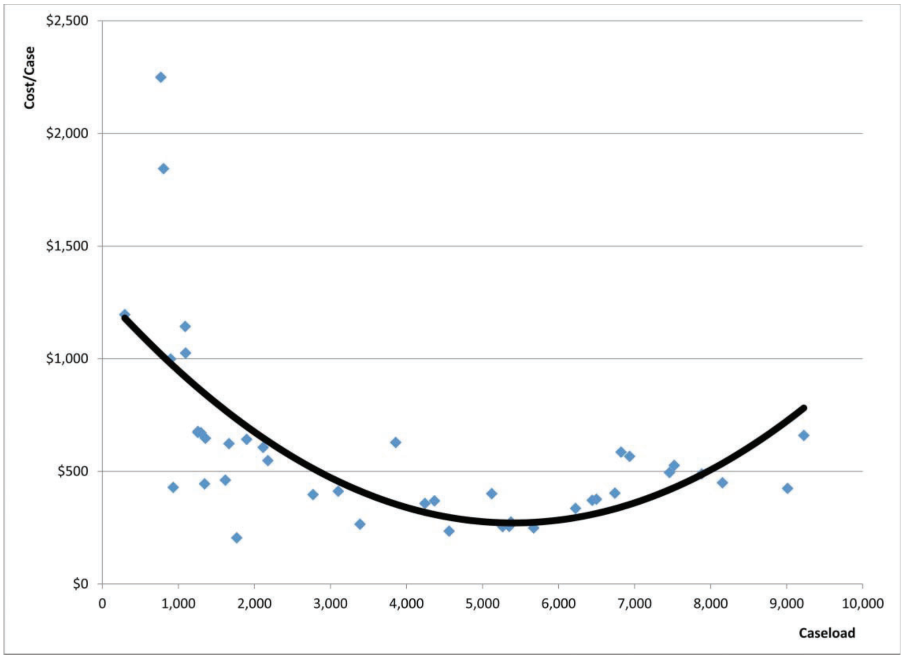

FIGURE 13 Toxicology ante mortemante-mortem analysis economies of scale.

Trace evidence includes the analysis of materials that, because of their size or texture, transfer from one location to another and persist there for some period of time. Microscopy, either directly or as an adjunct to another instrument, is involved. Includes analysis of hairs and fibers and paint and glass. Figure 15 illustrates the data from the FORESIGHT submissions with the estimate in (20) drawn as a solid curve. At the minimum point on the curve is an estimate of perfect economies of scale estimate at 730 cases per year.

CONCLUDING REMARKS

Project FORESIGHT offers a detailed glimpse into the operation of forensic science laboratories. The project has analysed data annually from the 2005–2006 fiscal years to the present and will continue into the

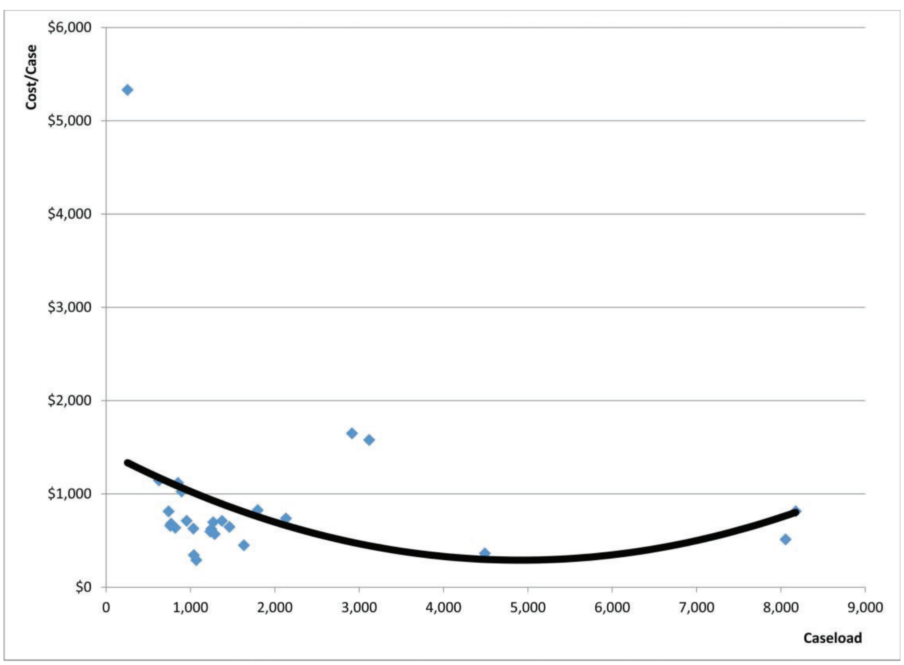

FIGURE 14 Toxicology post- mortem analysis economies of scale.

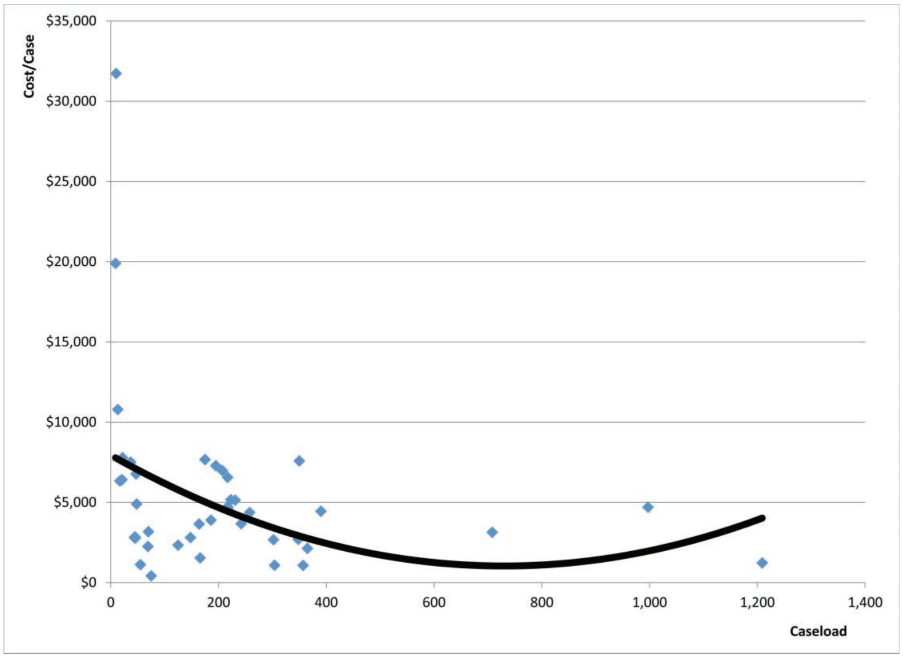

FIGURE 15 Trace evidence (including paint & glass and hairs & fibers) analysis economies of scale.

foreseeable future. While data submissions started small, they have grown in the recent years and the 2011–2012 reporting period offers some large sample properties from the data submissions. It is these insights that have been highlighted in the previous sections. We remind the reader that Project FORESIGHT data comes from voluntary participation and as such, does not represent a random sample from all laboratories. For the 2011–2012 reporting period, 81 laboratories submitted data on casework, expenditures, and personnel. As noted, all laboratories met industry quality standards and the participating laboratories represent six continents with a majority of the reporting laboratories representing U.S. jurisdictions. The laboratories represent municipal, regional, provincial, national jurisdictions as well as private laboratories. It is anticipated for the 2013–2014 reporting period that the number of laboratories submitting data will far exceed one hundred laboratories.

The summary statistics offer a good starting point for any laboratory to analyze their internal operations. Such a self-study can be easily accomplished using the tables, equations, and figures above. Note, however, that any laboratory may choose to participate in Project FORESIGHT by submitting data using the LabRAT tool (available at http://www.be.wvu.edu/forensic/foresight.htm). Following submission, participating laboratories receive immediate access to industry comparables and time series analysis of performance to match against strategic initiatives.

Beyond the positioning of an individual laboratory using the analysis above, Houck et al. (2012) highlights how the financial management is only a part of the performance analysis, but an integral part. Expanding analysis into a balanced scorecard model enables a continual cycle of continuous improvement. Newman et al. (2011) provide a best practices approach to strategic improvement with the FORESIGHT data helping to guide the direction for the laboratory. McAndrew and Speaker (2012) extend the analysis to industry trends that may expand the laboratory's ability to meet its mission. Combining FORESIGHT results with independent evaluations of the external return on investment offers direction for future work. That pathway has been illuminated with the impact from DNA Database CITATION Dol13 /l 1033 (Doleac, 2013) and applied by Lodhi et al. (2014). As more laboratories participate, so will the knowledge shared with all laboratories.

NOTES

1 NIJ award #1004801AR (West Virginia University Forensic Science Initiative 2014).

2 The LabRAT data collection tool is available via http://www.be.wvu.edu/forensic/foresight.htm.

3 As one reviewer noted, the large variability in Crime Scene Investigation can be affected by rate-limiting process steps at the laboratory level. FORESIGHT does not track such restrictions and comparison across laboratories may be difficult. As noted in Houck et al. (2012), a balanced scorecard approach to the evaluation of any metrics is important for a contextual understanding of the measures.
4 Across areas of investigation there are considerable differences in the median percentages allocated for personnel. Comparisons across areas of investigation are difficult to make and are not suggested. Some areas are naturally capital-intensive and others are naturally personnel-intensive. As such, comparisons should generally be limited to other laboratories with an area of investigation or of the laboratory over time in a particular area of investigation.
5 In a few areas of investigation there was insufficient data to provide a reliable estimate and those areas have been omitted.

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APPENDIX A—FORESIGHT GLOSSARY

Assistant/Analyst: An individual carrying out general casework examinations or analytical tests under the instruction of a reporting scientist or reporting analyst and who is able to provide information to assist with the interpretation of the tests.
Backlog: Open cases that are older than 30 days.
Capital Expenditure: Purchases of equipment, instruments, etc. with a lifetime longer than a year. These expenditures include newly purchased items as well as investments to improve the useful life of existing capital equipment. Expenses to maintain an asset at is current condition is not capitalized.
Case—institute case: A request from a crime lab "customer" that includes forensic investigations in one or more investigative areas.
Case—area case: A request for examination in one forensic investigation area. An area case is a subset of an institute case.
Case (as reported in the LabRat form): Cases reported in LabRat are "area cases."
Casework: All laboratory activities involved in examination of cases.
Casework time: Total FTE's for operational personnel in an investigation area (in hours) subtracted by the hours of research and development, education and training, and support and service given to external partners.
Floor area: Total of all floor area including office, laboratory, and other.
Full-time equivalent (FTE): The work input of a full-time employee working for one full year.
Investigation area: Area limited by item type and methods as they are listed in the definitions of investigative areas tab.
Item: A single object for examination submitted to the laboratory. Note: one item may be investigated and counted in several investigation areas.
Laboratory area: Floor area used for forensic investigation, including sample and consumable storage rooms.
Non-reporting manager: An individual whose primary responsibilities are in managing and administering a laboratory or a unit thereof and who is not taking part in casework.
Office area: Floor area of offices (square feet).
Operational personnel: Personnel in operational units providing casework, research and development (R and D), education and training (E and T) and external support services. Non-reporting unit heads are included.
Other floor area: Floor area of space not belonging to laboratories or offices, i.e. corridors, lunch corners, meeting rooms, etc. (square feet).
Personnel expense: Sum of direct salaries, social expenses (employer contribution to FICA, Medicare, workers comp, and unemployment comp), retirement (employer contribution only towards pensions, 401K plans, etc.), personnel development and training (internal or external delivery, including travel), and occupational health service expenses (employer contribution only).

Report: A formal statement of the results of an investigation, or of any matter on which definite information is required, made by some person or body instructed or required to do so.
Sample: An item of evidence or a portion of an item of evidence that generates a reportable result.
Support personnel: Forensic laboratory staff providing various internal support services. Management and administration personnel not belonging to the operational units are included.
Test: An analytical process, including but not limited to visual examination, instrumental analysis, presumptive evaluations, enhancement techniques, extractions, quantifications, microscopic techniques, and comparative examinations. This does not include technical or administrative reviews.
Turn-around time (TAT): The number of days from a request for examination in an investigative area until issuance of a report. (Note that an area case may have multiple requests and each new request has a separate turn-around time.)
Workload: Total time spent on all work related to job, including overtime.

APPENDIX B—FORESIGHT AREAS OF INVESTIGATION

Biology/Serology: The detection, collection, and non-DNA analysis of biological fluids.
Blood Alcohol: The analysis of blood or breath samples to detect the presence of and quantify the amount of alcohol.
Crime Scene Investigation: The collection, analysis, and processing of locations for evidence relating to a criminal incident.
Digital evidence—Computer, Audio and Video: The analysis of multimedia audio, video, and still image materials, such as surveillance recordings and video enhancement. Includes the analysis of computers, computerized consumer goods, and associated hardware for data retrieval and sourcing.
DNA Casework: Analysis of biological evidence for DNA in criminal cases.
DNA Database: Analysis and entry of DNA samples from individuals for database purposes.
Document Examination: The analysis of legal, counterfeit, and questioned documents, including handwriting analysis.
Drugs—Controlled Substances: The analysis of solid dosage licit and illicit drugs, including pre-cursor materials.
Evidence Screening and Processing: The detection, collection, and processing of physical evidence in the laboratory for potential additional analysis.
Explosives: The analysis of energetic materials in pre- and post-blast incidents.
Fingerprint Identification: The development and analysis of friction ridge patterns.
Fire analysis: The analysis of materials from suspicious fires to include ignitable liquid residue analysis.
Firearms and Ballistics: The analysis of firearms and ammunition, to include distance determinations, shooting reconstructions, NIBIN, and tool marks.
Forensic Pathology: Forensic pathology is a branch of medicine that deals with the determination of the cause and manner of death in cases in which death occurred under suspicious or unknown circumstances.
Gun Shot Residue (GSR): The analysis of primer residues from discharged firearms (not distance determinations).
Marks and Impressions: The analysis of physical patterns received and retained through the interaction of objects of various hardness, including shoeprints and tire tracks.
Toxicology, ante-mortem: Toxicology involves the chemical analysis of body fluids and tissues to determine if a drug or poison is present in a living individual, to include blood alcohol analysis (BAC). Toxicologists are then able to determine how much and what effect, if any, the substance might have had on the person.
Toxicology, post-mortem: Toxicology involves the chemical analysis of body fluids and tissues to determine if a drug or poison is present in a deceased individual. Toxicologists are then able to determine how much and what effect, if any, the substance might have had on the person.
Trace Evidence: The analysis of materials that, because of their size or texture, transfer from one location to another and persist there for some period of time. Microscopy, either directly or as an adjunct to another instrument, is involved. Includes analysis of hairs and fibers and paint and glass.